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Two Worlds of Innovation

Japan is a nation where early stage innovation, that is the discovery and early stage refinement of new products and processes, occurs primarily in large established companies. In contrast, early stage innovation in the USA is relatively evenly divided between established companies, new companies, and universities. The reasons for this difference, its persistence despite policies to improve the environment for ventures in Japan, and its implications for economic and technical progress in both countries, are the central issues of this book.

But to begin, what evidence supports this basic assertion? Others have described the challenges facing Japanese ventures.[1] However, there have been few studies that trace the development history of new products in different countries to show whether they originated in large companies, universities, ventures or other small companies. I have done this in the case of pharmaceuticals and thus I know the assertion to be true in the case of this industry. But to my knowledge, third generation mobile telecommunications technology is the only other field in which such an analysis has been conducted (see chapter 7 and note 313.) One of the recurrent issues in this book is the degree to which innovation in biomedical industries differs from that in other industries.

Simply looking at available data on the number of new companies in high technology industries does not give a clear picture of sources of innovation. The rate of new company formation in Japan has been among the lowest among industrialized countries.[2] But since 1998 the numbers of Japanese university startups[3] and biomedical ventures have been increasing rapidly. Indeed on a per population basis, or comparing the numbers of Japanese startups with those in the USA *an equivalent number of years* after enactment of the laws facilitating startup formation, the Japanese numbers are quite respectable. Also, the numbers of established Japanese small and medium size enterprises (SMEs) engaged in manufacturing and even new product development are considerable.

This book addresses these inconsistencies later. But for the purpose of this introduction, a comparison of what types of organizations are obtaining US patents in a small selection of high technology fields provides preliminary

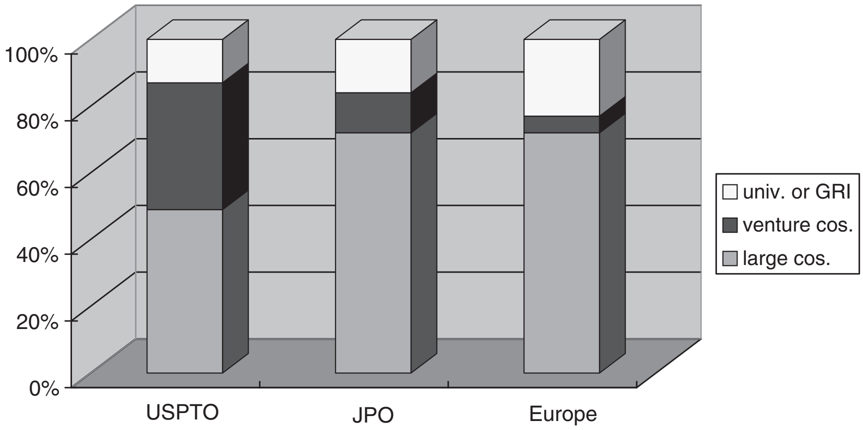

Figure 1.1. Patent applications in genomics, proteomics, and related applications (1990–97, percentages only)

Source: JPO 2002.

support for the basic assertion. Patents are not ideal indicators of innovation. Nevertheless, issued patents at least represent a subset of new discoveries that, for the applicants, merited the expenditure of funds to obtain the right to exclude others from using those discoveries.[4]

To my knowledge, the only comparative survey of the origins of patents within an entire industry[5] was conducted by the Japan Patent Office (JPO). It covered genomics, proteomics, and related patent applications in the USA, Japan, and major European countries.[6] As shown in Figure 1.1, while venture companies accounted for nearly 40 percent of US applications, they accounted for only 12 and 6 percent respectively of applications in Japan and Europe.[7] Conversely, large companies accounted for only about 50 percent of US applications but 72 percent of applications in both Japan and Europe.

Lacking similar information for other industries, I selected the International Patent Classification (IPC) codes covering six narrow nonpharmaceutical technologies that draw on new scientific or engineering knowledge.[8]

- Hip and knee prostheses,
- Video cryptography,
- Rewritable electromagnetic recordable devices,
- Tomography and planar medical radiography,
- Irradiation devices, especially for X- or gamma ray lithography, and
- Ion beam tubes and ion sources.

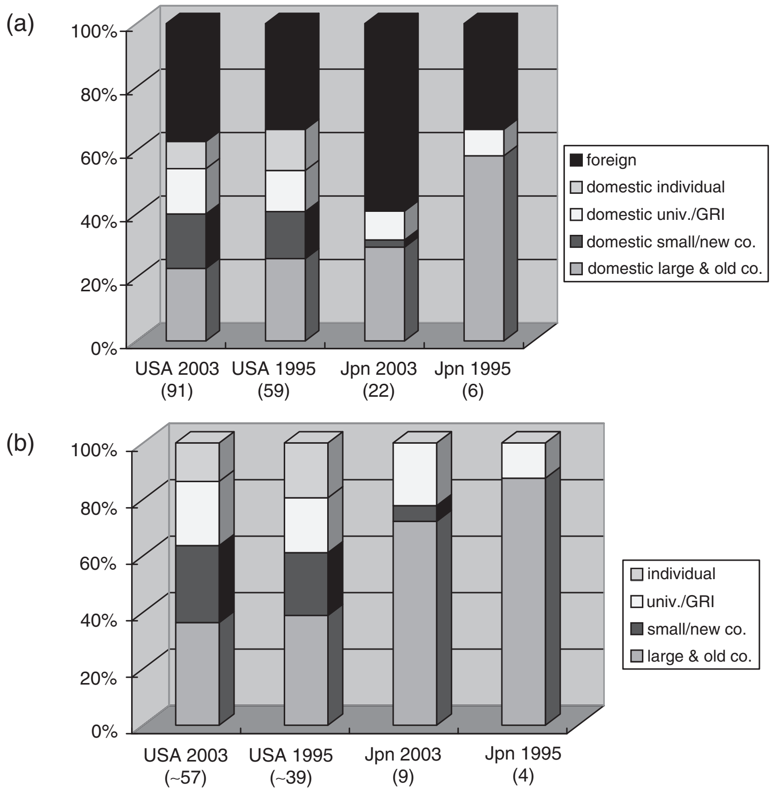

Figure 1.2. Issued patents covering hip and knee prostheses: (a) all applicants and (b) domestic applicants only

Sampling the US and Japanese patents issued in 1995 and 2003 in each of these categories and classifying the applicants according to nationality and whether they were

- individuals,
- universities or government research institutes (GRIs),
- SMEs (under 500 employees) or new companies (formed 1975 or later), or
- large companies (at least 500 employees and incorporated before 1975),

enabled me to make the following graphs (Figures 1.2–1.7). (The numbers in parentheses below each bar indicate the total number of patents for each category.)

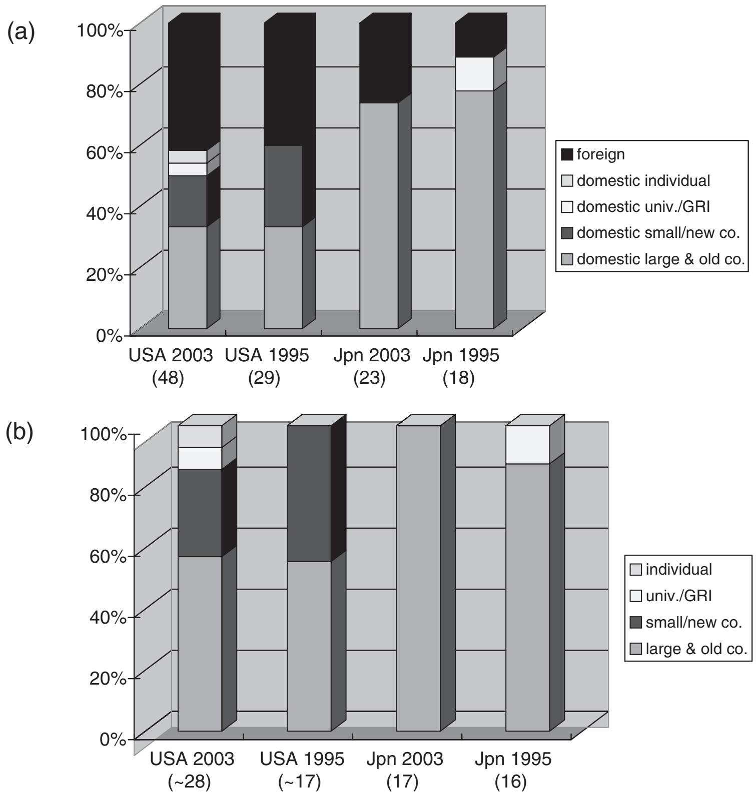

Figure 1.3. Issued patents covering video cryptography: (a) all applicants and (b) domestic applicants only

The principal difference between the US and Japanese applicants is that universities and new companies account for significant proportions of domestically originating patents in the USA, but much smaller proportions of domestically originating patents in Japan. With just a few exceptions, small or new Japanese companies do not appear as innovators in these fields, and when they do, they are usually old small companies.[9]

Of course, there is variation among technical fields. In medical tomography and radiography, innovation appears to occur almost exclusively in large companies such as General Electric. In rewritable electromagnetic recording devices such as DVDs, innovation seems confined to large foreign (mainly Japanese) companies. But in hip and knee prostheses (which often incorporate advances in materials science), video cryptography (which involves software and electrical engineering), high energy lithography (especially for integrated

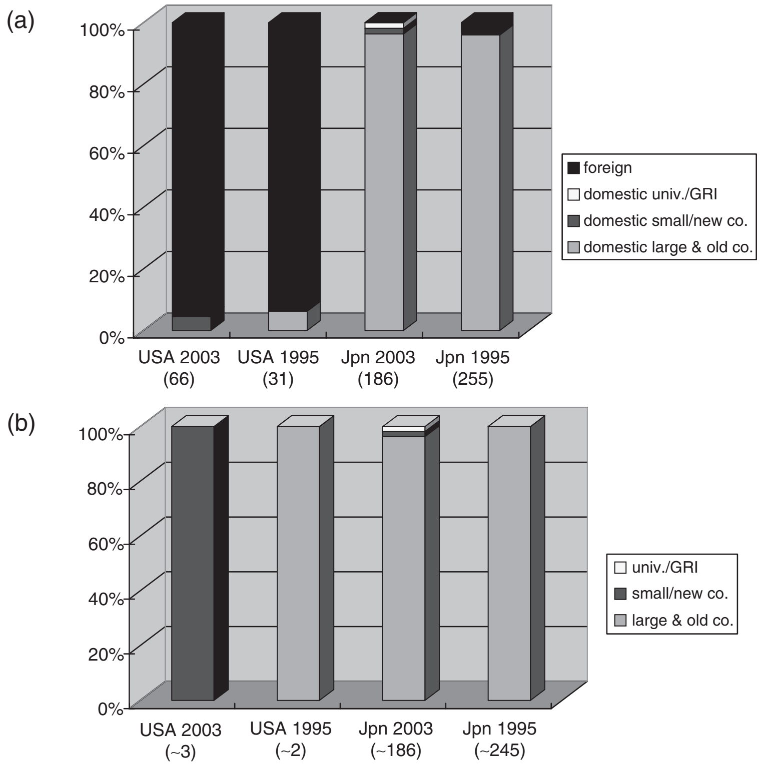

Figure 1.4. Issued patents covering rewritable electromagnetic recording devices: (a) all applicants and (b) domestic applicants only

circuit design and manufacture), and ion implantation devices (for doping various materials to improve the performance of semiconductors, e.g.), US venture companies account for a significant proportion of innovative activity, but Japanese ventures very little.

Moreover, this analysis suggests that the relative contribution to innovation of US small or new companies is not diminishing. In Japan, there is no indication that this proportion is increasing. However, the share of universities and GRIs may have increased slightly between 1995 and 2003 in both countries.

This evidence is not conclusive proof of the assertion at the beginning of this chapter. There are hundreds of IPC codes and I analyzed the patents under only six. I cannot claim that these are representative of all nonbiomedical industries. Nevertheless, they do suggest differences between the two countries that may be consistent across a range of rapidly evolving scientific and engineering fields. If this is indeed the case, then there are probably many

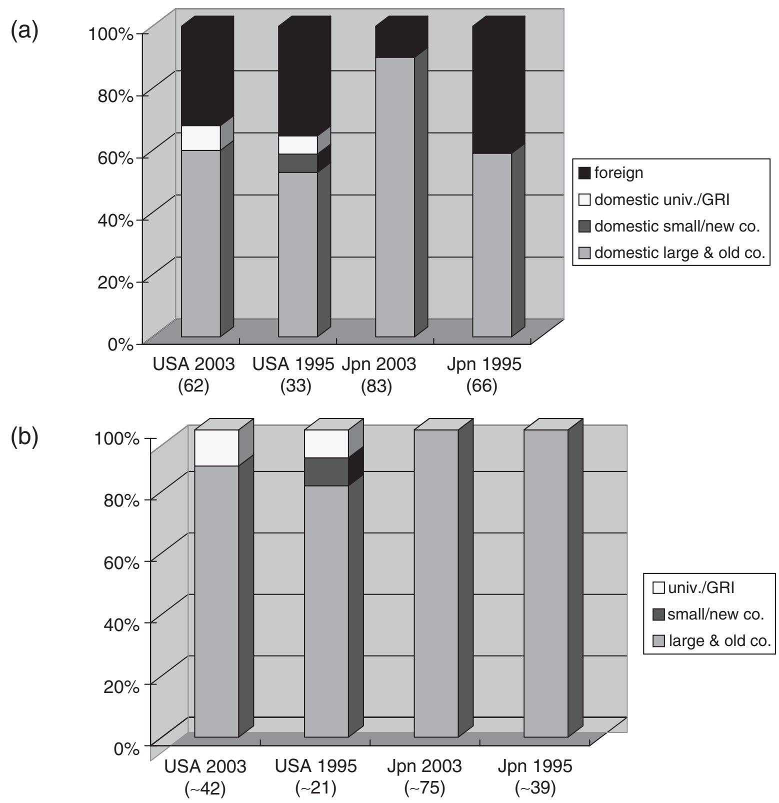

Figure 1.5. Issued patents covering tomography and planar medical radiography: (a) all applicants and (b) domestic applicants only

high technology industries in which small or new US companies are leading innovators, but few industries in which new or small Japanese companies are leading innovators.

I approached this issue in a different way by sampling the first pages of all US and Japanese patents issued in 2003 and 1995 that contained ‘micromachine’[10] or ‘nano’[11] as a title word or as a fragment of a title word. The inventions reflect a variety of applications of micromachine (including micro-electrical mechanical systems (MEMS)) and nanodevice or nanoparticle technologies (Figures 1.8 and 1.9). The pattern is even starker than when selecting patents according to specific IPC codes.

While both micromachines and nano patents have increased sharply since 1995, the share of small or new US companies has increased and that of large

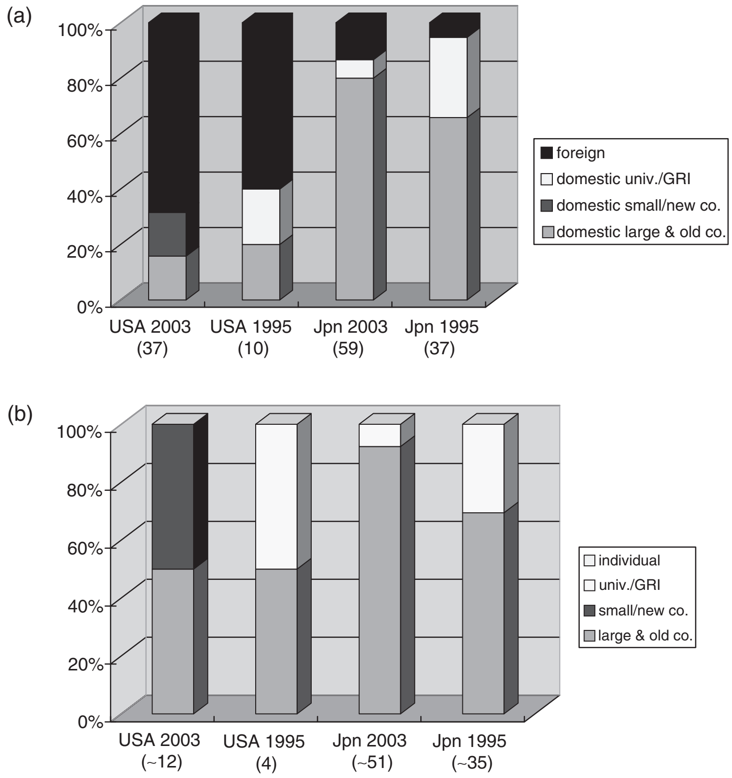

Figure 1.6. Issued patents covering irradiation devices, especially for X- or gamma ray lithography: (a) all applicants and (b) domestic applicants only

and established companies has decreased. In contrast, Japanese new or small companies are playing a negligible role.[12]

Two specific points relate to the main conclusions of this book. The first concerns patents to individual inventors. About 10 percent of the US patents issued to US applicants list no assignee. In other words, the inventors applied for the patents on their own. About one-quarter were university faculty, about 30 percent were entrepreneurs who had founded viable businesses in the field of their patents.[13] Some are prolific inventors.[14] In contrast, only one of the Japanese patents issued to Japanese applicants was unassigned, and in this case, the inventors turned out to have been University of Tokyo faculty at the time of the invention. In other words, compared to Americans, Japanese inventors rarely apply for patents on their own. Affiliation

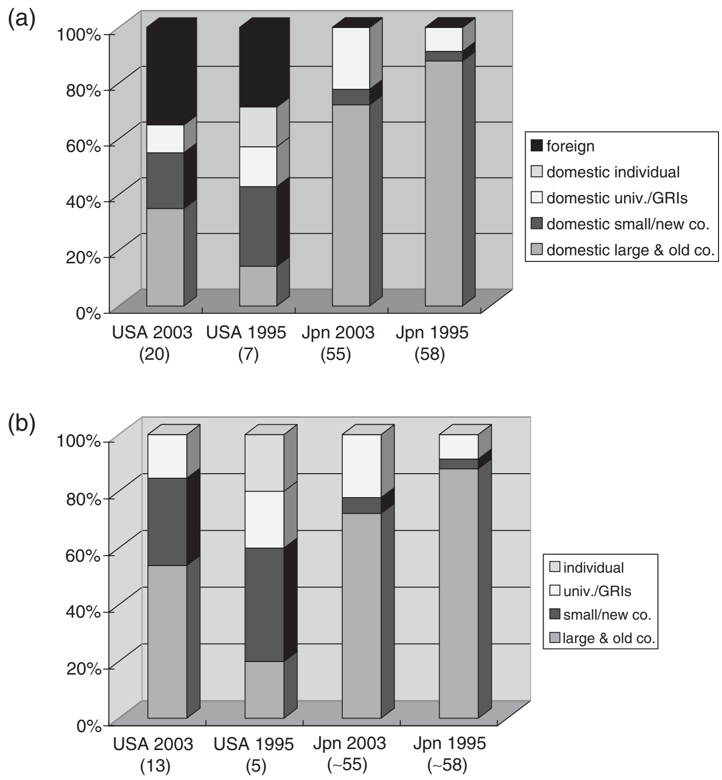

Figure 1.7. Issued patents covering ion beam tubes and ion sources: (a) all applicants and (b) domestic applicants only

with a large company seems to be necessary for inventive Japanese to realize the patenting and commercialization of their discoveries in many fields of technology.[15]

The other point concerns patenting by universities and GRIs. Overall about 13 percent of the Japanese-origin Japanese patents I surveyed were attributable, at least in part, to research in Japanese universities or GRIs, that is, they had had at least one university or GRI inventor. Over half of these patents arose under collaborative research with a Japanese company—in over 90 percent of such cases with a large, established company. In other words, these data suggest that Japanese universities and GRIs do play an important and increasing role in innovation, although probably not as great as their US counterparts, which accounted for 22 percent of the US-origin US patents in my survey.[16] University and GRI innovation frequently occurs in collaboration with large,

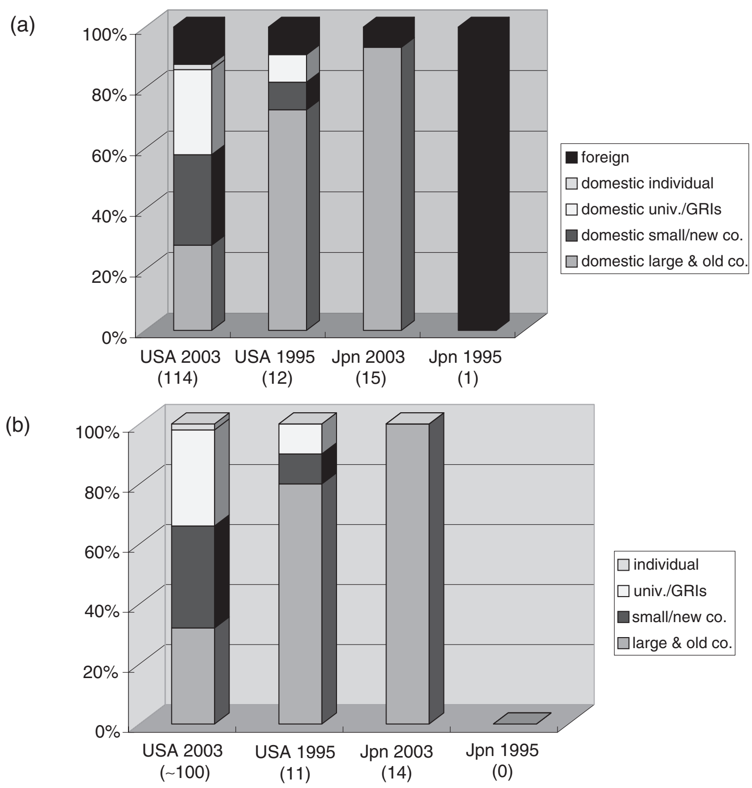

Figure 1.8. Issued patents containing 'micromachine' in the title: (a) all applicants and (b) domestic applicants only

established companies, but rarely in collaboration with small companies, and even more rarely in collaboration with new companies—at least outside of biomedicine.[17] Later chapters show that university–industry collaboration in Japan is indeed biased in favor of large companies.

New companies once flourished in Japan. The immediate postwar years saw the formation of Sony (1946), Sanyo (1947), Honda (1948), and Kyocera (1959). Sony pioneered innovations in transistor technology and their applications first to radios then to a range of other electronic products. Kyocera (short for Kyoto Ceramics) became a leader in the application of materials science to electronics and other products. Also during the 1950s and 1960s, Hayakawa Electric transformed itself from a struggling medium-size maker of radios and televisions to the world's leading pioneer of liquid crystal and plasma displays and the company we know today as Sharp.

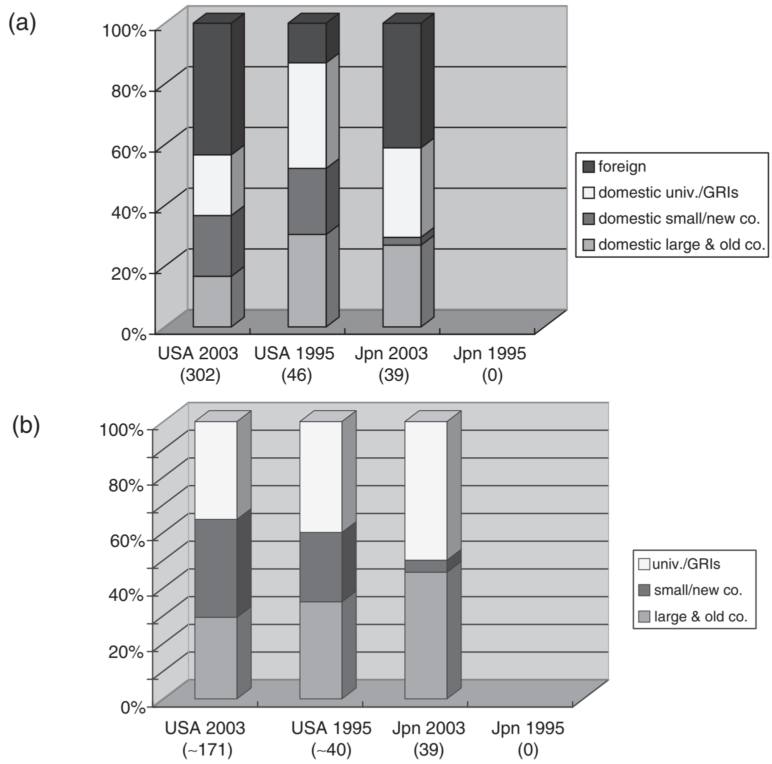

Figure 1.9. Issued patents containing 'nano' in the title: (a) all applicants and (b) domestic applicants only

SMEs still contribute significantly to the Japanese economy. In 2000, SMEs accounted for about 89 percent of employment and 57 percent of value added in Japanese manufacturing, higher levels than in 1970.[18] However, at least until recently, a majority of manufacturing SMEs probably relied on subcontracting work for most of their business, and approximately one-third relied on subcontracting from a single customer.[19] As discussed in Chapter 6, this may have limited innovation and growth opportunities for many. Recently some established high technology SMEs have been trying to diversify their customer base and to develop new products, but some remain focused on meeting the needs of a few large customers.[20] Some large companies maintain traditional relations with the SMEs that depend on them for most of their sales. Their contracts with the SMEs contain generous profit margins and they provide the SMEs with technical information so that the SMEs can manufacture state-of-the-art components. But if one of these SMEs tries to recruit other customers, orders from the large company will be cut immediately.[21] In any event, the patent analysis above suggests that as of 2003, SMEs had still not become a major force in early stage innovation in new or rapidly evolving, science-based technology fields. But my limited analysis may have missed fields in which they are leading innovators,[22] or else, their contributions may yet result in new patents.

However, the focus of this book is not SMEs, in general, but rather new independent high technology companies. Chapter 4 examines the present status of these companies in Japan and the opportunities and challenges they face. It includes twenty case studies of ventures in biomedical and nonbiomedical fields. But in Japan, it has been more common for new technical opportunities to be exploited by established companies moving into new fields, and Chapter 6 examines this phenomenon and tries to explain the factors on which the success or failure of such efforts have depended. Finally, Chapter 7 addresses the larger issue of whether small/new or large/established companies are better at early stage innovation taking into account the importance of intellectual property, mobility of people, and other factors. Then, noting the current reliance of Japan on large companies and the USA to a great extent on new companies for innovation, it examines prospects for change and offers some suggestions how the environment for innovation can be improved in both countries and in countries with similar innovation systems.

But to understand the environment for ventures and the challenges they face, it is necessary first to understand the role that large companies and universities[23] have played in Japan's innovation system and the degree to which they have been willing to cooperate with venture companies. Chapter 2 explores the tendency of large established Japanese companies to innovate autarkicly, that is, to rely on their own in-house R&D laboratories for new prototype products and to try to maintain control over the upstream components of a vertically integrated value chain. Chapter 3 examines the role Japanese universities have played in Japan's innovation system. It also shows how, despite policies that have improved the environment for university startups, large companies maintain preferential access to university discoveries and barriers remain to the growth of strong university startups.

For venture companies to flourish in Japan, large companies will have to come to view independent smaller companies as long-term sources of new ideas and technologies that depend on the smaller companies' ability to grow rapidly. Large companies must become less autarkic and more networked with other independent organizations, in terms of both product discovery and the flow of personnel.

However, at least with respect to building bridges between large and small companies, this process will not be easy because it will be seen as undermining the fundamental strength of Japanese manufacturing based on lifetime employment and integrated control over all steps of the process from R&D to manufacturing and marketing. Instead, large Japanese companies are cooperating more actively with universities in order to access more early stage discoveries, but they are ceding little commercial R&D to small companies. A few large manufacturing companies actively seek alliances with independent domestic small or new companies. But this low level of engagement probably will not enable new high technology companies to become engines of innovation for Japan's industry. Furthermore, lifetime employment in large companies may always be more attractive than work in small, new companies, absent the low levels of job security in the USA. In other words, despite important changes in Japanese government policies and even some changes in corporate practices that have improved the environment for startups, Japan's innovation strength may continue for many years to rest with its large established companies, while at least for the near future that of the USA will rest to a large extent on new companies. Whether one of these distinct systems will prove to be superior to the other is one of the main themes of Chapter 7, but ultimately time will provide the answer.

APPENDIX: METHODOLOGY FOR ANALYSIS OF PATENTS ACCORDING TO TECHNOLOGY FIELD AND TYPE OF APPLICANT

Although I used the International Patent Classification (IPC) codes to select Japanese and US patents in equivalent technology fields, I actually used the US PTO classification to select the particular technologies I would investigate.

The IPC codes are 8 character alphanumeric codes published by the World Intellectual Property Organization. They tend to be based largely on constituent materials or components, or underlying scientific processes, rather than on industrial use (at least this was the case with the seventh version codes, the latest available when I did this analysis in early 2004). Therefore, for this analysis, they are not ideal. But because US, Japanese, and most European patents are classified according to IPC codes, they can be used to compare patenting activity between countries.

The US PTO has its own unique classification system based more on the end use or overall function of an invention. US patents are classified according to both systems, but the US PTO classification cannot be used for international comparisons. (In other words, I can search Japanese patents using IPC codes but not US PTO codes.) However, I used the US classification list available at http://www.uspto.gov/

web/patents/classification/selectnumwithtitle.htm to select twenty-one three-digit classifications of possible interest, because they represented a spectrum of technologies that are rapidly evolving and, to a large extent, depend on scientific or engineering progress in several countries in a number of research centers. (In other words, I avoided fields that where progress depends on R&D in a small number of countries or laboratories, e.g. automobiles, aircraft, pulp and paper, and nuclear power.) Then I used the US PTO's concordance system at http://www.uspto.gov/web/patents/classification/ to find equivalent IPC classifications. After reviewing the concordant IPC classifications for about half the twenty-one candidate US PTO classifications, I selected the six categories presented in this chapter, largely on the following criteria: (*a*) they would represent different types of technologies and (*b*) a small number of IPC codes would encompass a conceptually distinct and meaningful class of technologies.

Thus, I obtained lists of all US and Japanese patents issued (registered) in 1995[24] and 2003 for inventions classified under the following IPC codes:

A61F 2/32, 2/34, 2/36 & 2/38: *hip and knee (and some abdominal area) prostheses*;
H04N 7/167: *video cryptography*;
G11B 11/00: *rewritable electromagnetic recording devices*;
A61B 06/02 & 06/03: *tomography and planar medical radiography*;
G21K 05/00: *irradiation devices, especially for X or gamma ray lithography* and
H01J 27/00 & 27/02: *ion beam tubes and ion sources (for IC chip manufacturing etc.)*.

I randomly sampled among each of these sets of patents to obtain about twenty patents for each year-country-IPC code category of patents. Thus, when my sample was less than the total number of patents, my numbers in parentheses represent an *estimate* of the number of *domestic applicants only* patents based on the proportion of such patents in my sample frame. (If there were fewer than twenty patents, in a category, I selected them all.) Altogether there were 1,890 patents in the 32 sampling frames (8 technology categories (including micromachine* and nano* mentioned below), two national patent offices, two years) and out of these I sampled 673 (36%).

Then I printed out at least the first page of each patent application which identifies the names and addresses of the inventors and the patent applicant(s). I assigned national origin according to the addresses of the inventors. (A few patents had coinventors from several countries and I attributed these inventions to the nationality of the majority of the inventors.)

As for the type of institution where the inventions occurred, I relied on the identity of the applicant in the case of US patents. This is reasonable because US universities and SMEs generally insist on applying for inventions by their employees, as described in subsequent chapters. However, this is not the case for Japanese universities prior to 2004. Moreover, in Japan but not the USA coinventorship involving universities/GRI and corporate researchers is common. *However, Japanese patents usually list the inventors' work addresses.* Among the small number of Japanese inventors whose affiliations were not clear from their addresses, I was able to find affiliations for almost all from public sources.

In the case of companies, I determined from public sources their years of incorporation and numbers of employees.

The vast majority of inventions were assigned by their inventors to their employers. Among those with no assignee, however, I used various public sources to determine their principal affiliation.

NOTES

1. e.g., Rowen and Toyoda (2002), Ibata-Arens (2000), Kneller (2003*a*), Maeda (2004), Nakagawa (1999), and Suzuki (1999).
2. JSBRI (2003).
3. Throughout this book, I use the term *startup* to refer to a new, independent company whose core technology is based on university or GRI discoveries. A nearly synonymous term (more common in Japan) is university venture. As noted in the glossary at the end of this book, I distinguish startups from *spin-offs*, in that the latter are formed from technologies or personnel from existing companies.
4. Sometimes patent applications will be filed with little intention of prosecuting the application to obtain a patent. For example, in most countries, patent applications are published after eighteen months and such publication prevents rivals from patenting these discoveries. In other words, the application alone and subsequent publication can prevent patenting by rivals working in the same area. Also at least in Japan, numbers of patent applications are commonly used by employers in promotion decisions and by government agencies to evaluate the 'success' of applied research that they fund. Thus any comparative international analysis of innovation should use *issued* patents rather than patent *applications* whenever possible. Since the USA is the world's largest consumer market covered by a single, unified patent system, in many cases inventors and companies who think they have commercially valuable discoveries will try to obtain US patents. Thus issued US patents probably are appropriate to use for international comparisons of innovation. Yet these assumptions may not always hold true, especially in the case of non-US inventors and non-US companies thinking only of their domestic markets.

   However, even some issued US patents cover discoveries that the patent holders do not plan to develop. Rather, they were obtained to block competitors or to serve as ammunition or bargaining chips in case of patent disputes with other companies. Finally, even in the case of patents that are intended to protect the patent holder's discoveries related to its core businesses, it is difficult for nonspecialists to determine which patents have significant commercial value or represent significant technical achievements.

Nevertheless, prosecution of a US patent application to issuance requires on the order of US$ 10,000. If translation fees and local attorney fees are included in the case of applications covering countries such as Japan, China, or Continental Europe, costs are substantially higher. To obtain patent protection in the world's major markets requires on the order of US$ 100,000 per patent. Thus, issued US patents represent a nontrivial investment, especially in the case of foreign applicants. Thus the discoveries they cover probably have nontrivial value for the applicants.

5. Aside from my survey of pharmaceutical patents and that of 3G mobile communication patents discussed in Chapter 7.
6. These applications were filed between 1991 and 1999 in the JPO, US PTO, and patent offices of major European countries as well as the European Patent Office. (Steps were taken to avoid duplicate counting in the case of the European applications.) Although I have just described the problems of using patent applications as a measure of innovation, I present these data here because they are the only readily available data on this subject. I hope that the analysis of pipeline drugs in Chapter 2 and the analysis of the sources of new FDA-approved drugs in the following and the last chapters will convince readers that biotechs do indeed play a major role in drug discovery in the USA but a small role in Japan and Continental Europe.
7. The JPO study used the following definition for venture company: R&D oriented, established no later than 1980, fewer than 300 employees, and less than 300 million yen invested capital (personal email communication from JPO May 17, 2006).
8. Please see the Appendix for details regarding methodology.
9. Among the small or new company US patents, over 90 percent were issued to companies incorporated in 1975 or later. In contrast, among the Japanese patents with a small or new company inventor, only about 20 percent of these inventors were from companies formed no earlier than 1975.
10. マイクロマシン in Japanese.
11. ナノ in Japanese.
12. Of the thirty-nine Japanese 2003 nano patents, one was issued to a small chemical company formed in 1951 and one was issued jointly to AIST, METI's flagship GRI, and a small Japanese pharmaceutical company established in 1955. Korean venture companies formed after 1995 accounted for five of the nano Japanese patents. None of the fifteen Japanese 2003 micromachine patents was issued to an SME or a venture company.
13. Of the 22 unassigned US patents in my sample, 7 were issued to inventors who had founded viable businesses related to the patented technology (such as Lanny Johnson, mentioned in the following note or Rameshwar Bhargava, founder of Nanocrystals Technology), 5.5 were issued to persons whose main employer was a university, and 9.5 were issued to inventors (*a*) whose affiliation I could not determine or (*b*) whose inventions seemed to be ancillary to their main

work responsibilities, i.e., two of the joint prostheses inventors are orthopedic surgeons, and one of the video cryptography inventors is a patent attorney. (The fractions are due to a patent, one of whose inventors is a university professor and the other whose affiliation I could not determine.)

14. The 22 unassigned US patents mentioned in the previous note represented the inventions of 20 inventors (2 inventors appeared twice in the patents I sampled). Ten of these had been issued at least five US patents as of May 2006, seven had been issued over ten. Some such as Lanny Johnson, the CEO of Instrument Makar and the inventor of 40 inventions, mostly related to instruments for arthroscopic surgery, are famous in their fields. A few Japanese inventors, who are not employees of companies, appear frequently as co-owners of patents, but none of the 'independent' prolific inventors in my sample (who happened all to be university faculty) was ever the sole applicant. In other words, there were always coinventors from a company collaborating with the prolific inventor. In the vast majority of such cases, these collaborators are large companies (see the following note).
15. The one exception in my sample is Professor Nakayama Yoshikazu of Osaka University who is co-owner of about twenty nanotechnology-related US patents along with Daiken Chemical Co., a company founded in 1951 but with only eighty-five employees.
16. Of course, this statement is subject to the main limitation of this analysis; it cannot claim to be representative of all high technology industries. Also, I attributed Japanese patents with university and industry coinventors one-half to universities and one-half to industry (and in one case where an inventor was also from an SME, one-third each way). If I instead attributed these inventions 100 percent to universities (reasoning that they are the product of university–industry collaboration even though the university contribution may be only a fraction of the entire inventive input), then the percentage of patents attributed to US and Japanese universities/GRIs would be nearly the same. A counter argument might be that many US patents assigned solely to a company may have benefited from consultations or even joint research with university researchers, although they were not listed as inventors or they were listed but I had no way of knowing from the US patent applications that they were not company employees. Thus the attributions in my data to US universities may also be underestimated.
17. I surveyed 256 Japanese patents covering Japanese-origin inventions (i.e. the inventors had Japanese addresses). Twenty-one of these were 'pure' university or GRI inventions in that the listed inventors were only from GRIs or universities. (In fact, nineteen of these were issued to GRIs and had only GRI inventors, one was issued to a university, one (already noted above) was issued to individuals who turned out to be university inventors.) On the other hand, twenty-three were issued either (*a*) jointly to companies and universities/GRIs and had mixed inventors or (*b*) to companies alone but had one or more university (rarely GRI) inventors. Of these twenty-three, only three involved new/small companies

(only one of which was incorporated after 1975), and of these, one was issued to a large company but had coinventors from the large company, a small company and a university.

18. In 1970, they accounted for 83% of manufacturing employment and 47% of value added (JSBRI, 2003).
19. Whittaker (1997).
20. Compare, e.g., 'Corporate Japan Thrives as Subsidiaries Outshine Parents', *Nikkei Weekly*, January 17, 2005, 1 (this article describes progress by some subsidiaries to improve their technologies and to market to companies other than their parents; it could apply as well to independent SMEs that depend mainly on orders from one or two large customers) with Hotta, Takafumi, and Kame Manabu, 'Screw, Spring Makers Help Auto Industry Stay Ahead: Innovations by Basic Parts Suppliers Support Global Dominance of Carmakers', *Nikkei Weekly*, Feb. 13, 2006, 32 (describing KYB Corp. designing and manufacturing improved springs and shock absorbers for Toyota).
21. Personal communication in 2004 from the director of an SME manufacturing high quality electronic communication devices that are mostly sold to one of Japan's major telecommunications companies. The contracts with this large company are short-term which allows the company to cancel orders on short notice.
22. e.g. machine tools which I discuss in Chapter 7.
23. Henceforth, I often use the term *universities* to refer to both universities and GRIs. When necessary to distinguish between them, I refer to them separately.
24. Actually, for 1995 the JPO database contains only patents approved by JPO and then laid open for a three month of pre-grant opposition period during which other parties could challenge the patent. (Pre-grant oppositions ceased in 1996.) About 95% of laid open patents were ultimately approved (registered). Therefore, these patents are nearly equivalent to the US patents and the 2003 registered Japanese patents. By 2003, patents as actually registered were available in the JPO database.

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