

## 7

## Innovation Across Time and Space: Advantage New Companies

### INTRODUCTION

This book began with the assertion that innovation in Japan depends primarily on large companies, while, in the USA, universities, venture companies, and established companies all play major roles in the discovery and early improvement of technologies with commercial potential. The most striking difference between the two countries is the role of venture companies. The middle chapters described the challenges and opportunities facing ventures in Japan.

Now we come face to face with the issue of which innovation system is better, mindful that innovation systems are part of larger social and institutional systems and that effectiveness depends on the specific technology and industry at issue.

This in turn raises the question of the extent to which these differences have influenced the changing fortunes of high technology industries in Japan, the USA, and other countries over the last decades of the twentieth century and the initial years of the twenty-first century. What were the roots of Japan's economic miracle from the 1960s to 1980s? Why did many US and European industries seem to lag behind Japanese counterparts in terms of innovation capabilities, and why did Japan seem to falter and the USA recover beginning around 1990? Finally, what are prospects for the future, and the lessons various countries can learn from this experience? These are complex issues which this book can only address in part.

To lay my cards on the table, I think one of the key factors concerns the vitality of high technology venture companies. This vitality is based on their ability to draw liberally on and to develop quickly university discoveries, to provide a professional rebirth for scientists and engineers whose ideas are not being developed in large companies, and to find receptive customers and development partners among established large companies. In Chapters 2–6, I have tried to show how Japan's innovation system has problems with respect to all these factors. These problems, juxtaposed against the more nourishing US environment for ventures, probably explain to a significant degree the varying

fortunes of the high technology industries in Japan and the USA over the past half century.

However, because of deeply rooted social factors, the environment for ventures in Japan and many countries of Continental Europe is unlikely to become similarly supportive in the foreseeable future. Thus, these countries will continue to rely on their large companies for innovation, while the USA will rely to a large extent on new companies to be innovation leaders.

Whether one agrees with these assessments (or thinks their obviousness precludes the need for further analysis), because the role of ventures in US and Japanese high technology industries differs so markedly, these two countries provide a natural experiment shedding light on the types of environments ventures need to flourish, the strengths of shortcomings of the two types of innovation systems, and how government policies, university–industry relations, and social factors, influence the balance between ventures and established companies as innovation leaders.

Part I compares the innovative capabilities of ventures and established companies. The work of others suggests that in a fairly large number of UK and US industries, independent venture companies can be superior early stage innovators. The data presented at the end of Part 1 show, in the case of pharmaceuticals, that on a world wide basis venture companies are generally better innovators than established pharmaceutical companies, and that America's innovation leadership is due to its venture companies. Part II discusses whether these findings are likely to be applicable to other industries. Whether strong intellectual property (IP) rights can protect ventures in fields other than pharmaceuticals from encroachment by competitors is a related issue. The conclusion is that ventures can be innovation leaders in many fields besides pharmaceuticals, and that IP is vital for them, too.

Parts III and IV explore the sustainability of an innovation system based on venture companies. Part III explores whether venture companies undercut the innovation capabilities of large companies, particularly by poaching employees. The conclusion is that, while losing employees does hurt companies, probably the advantages of labor mobility outweigh the disadvantages. Part IV discusses whether ventures are capable of sustained innovation even though many companies are narrowly focused and lack broad integrated learning and organizational capabilities. The conclusion is that in an entrepreneurial region such as Silicon Valley, integrated learning and organizational capabilities that foster continued innovation are built into the disaggregated yet networked system of independent companies. However, there are questions whether the Silicon Valley model can be replicated in other regions. There are also questions whether ventures need a large supply of skilled, young researchers and whether US demographics and immigration policies can meet this need.

Applying these perspectives to Japan, Part V suggests that Japan's dearth of venture companies probably is hurting its innovation capabilities in a number of fields. Nevertheless, Japan's manufacturing industry has unique strengths that contributed to Japan's economic miracle and to its continuing strength in some industries. Part VI analyzes some of these strengths: the behind-the-scenes role of small companies and personal management policies based on a system of lifetime employment, as well as the purported benefits of government-organized R&D consortia. Some of these factors are also sources of weakness for Japanese ventures. Part VII examines whether the system of lifetime employment, autarkic innovation in large companies, and preemption of university research is likely to change in the near future, and concludes that the likelihood is low. In part this is because these factors underlie the strength of large companies, and in part because of deeply rooted social factors, including Japan's system of education. However, another reason is the new strategy of large Japanese companies to cooperate more closely with universities—to rely on them for basic research and potentially valuable early stage discoveries—which will leave ventures with even less space to grow.

In the concluding part, I suggest that this strategy probably will not allow established companies to remain in the forefront of early stage innovation. In other words, without vibrant new companies, Japan's prospects for long-term strength in new fields of technology are dim. On the other hand, some of the key factors that make the USA a fertile environment for ventures are also factors that undermine the innovative strength of its large companies, in particular labor mobility and its corollary, low job security. Thus, the USA has no choice but to rely on venture companies if it is to remain a leader in most new fields of technology. Moreover, although the US system is robust, the continued existence of all the various conditions required for its success cannot be taken for granted. Thus the USA and Japan are each locked into dependence on a different innovation system. The sources of each country's strength with respect to one system are the sources of its weakness with respect to the other. Yet the continued success of each country's system is not assured.

This phenomenon has parallels in previous comparisons of the institutional frameworks of innovation systems, in particular the contrast between liberal market economies, such as the USA and UK, and coordinated market economies, such as Japan and Germany. However, this chapter suggests that the different impact of various institutional systems are largely mediated by whether they create environments that favor early stage innovation by new companies or confine such innovation to established companies.

In order to distill the conclusions of this book into specific policies that can be the focus for productive debate, this chapter closes with suggested reforms

to improve the environment for high technology ventures in Japan, the USA, and developing countries.

#### PART I: ARE NEW-OR-SMALL OR ESTABLISHED-AND-LARGE COMPANIES BETTER INNOVATORS?

Of course the answer is, 'It depends'. The ability to realize advantages attributed to either large or small size (or longevity vs. youth)<sup>1</sup> often depends on the particular technology and industry, as well as the overall innovation system and social context. Nevertheless advantages attributed to new/small companies include the following:<sup>2</sup>

1. Many *people want to be their own boss*, and when they are, they generally are more satisfied with their work and with life in general.<sup>3</sup> Assuming job satisfaction and motivation translates into more productive effort on the part of the entrepreneur and other key employees than would be the case if they worked in large companies, then the productivity of these small businesses should be higher.
2. Small companies are *more able to focus and experiment on a new product or new class of products*—even though these products may seem incremental or risky and the market may seem small.
3. With a large number of small companies pursuing many different approaches, the chances of developing *optimal approaches* will be higher than if only a small number of large companies are involved.
4. *Vision and goals regarding the application of innovative ideas are less constrained in new companies* than they are in large organizations, where past successes and current customers may limit the applications of a new idea. An established company benefiting from steady relationships with other companies may be disinclined to push a new technology that might upset those relationships. Lacking such constraints, it might be easier for new companies to aim for a global market, which their new products might create.<sup>4</sup>
5. *Less bureaucracy*. Internal communication is better, decisions can be made quickly. Thus the young-or-small company can respond quickly to technical and market opportunities.
6. Young companies are more likely to *start out with people who are right for the job*, both in terms of management and technical experience, and their personalities and motivations. Moreover, a system that fosters the

formation of new companies and the movement of people between companies helps to *redeploy human resources to where they are most productive*.

7. *Motivation and morale can be very high*. The feeling that 'We are all in the same boat together', is widespread. Minimal hierarchy, good communication, shared goals, and shared expectation that all who contribute will be rewarded, all make it easier to sustain a high level of focused dedication from employees.<sup>5</sup>
8. Because of this well-fitting, focused grouping of personalities, and talents, the company's *ability to learn and grow quickly is great*, at least in its initial area of expertise.
9. Provided capital markets function well, promising new small companies may be able to raise funds more quickly than established companies (even large companies) that have to fund projects internally. *Venture capital may provide more funding to develop a new technology than internal funding which may face various internal budgetary constraints and bureaucratic hurdles*.<sup>6</sup>
10. Small companies focusing on developing new technologies *may be less vulnerable* than large companies, whose revenue is derived mainly from manufacturing or licensing of previously invented technologies, *to having their resource base undercut by lower-cost foreign competitors*.

Advantages attributed to large companies include the following:<sup>7</sup>

1. *Capital* to start and build a new operation, and to achieve economies of scale: Usually the single greatest hurdle new companies face is raising capital. The resources of a large company can be used to purchase capital equipment and hire skilled managers, scientists and engineers, and support personnel. A large company can fund the initial costs of a new operation with income from another.
2. *Complementary assets*: These include supplier, manufacturing and distribution networks; brand name and customer or supplier loyalty; as well as ability to tap into various sources of advice related to management and regulatory issues.
3. *Ability to invest in training* to increase know-how that is specific to the company and tailored to the company's goals.
4. *Ability to integrate* the products and services of many suppliers, which is especially helpful in the case of products requiring complementary technologies.

5. Ability to develop an *integrated learning base and integrated organizational capabilities*, enabling a company to build on previous experience and to tailor and integrate all the steps in the value creation process, from research to marketing, with appropriate feedback mechanisms—in other words, smart, responsive vertical integration.
6. Supplier and customer *brand recognition and trust*.
7. *Ability to appropriate returns* from its investment in innovation: Because of the need to disclose their technology to attract investment, human resources and suppliers, and the need to outsource manufacturing and distribution, it is harder for new companies to prevent their technology from becoming known to potential competitors, particularly larger companies that could pursue rapid development once a new company has developed its technology to proof of concept stage. These power imbalances can be exacerbated if small firms lack skilled management. Conversely it is easier for a large company to keep its new technologies under wraps until they are close to marketing, and thus to establish leads over potential competitors in terms of manufacturing and marketing capabilities, and brand recognition. (These are known as first mover advantages.)
8. Ability to *undercut smaller competitors*, either through price competition or by engineering around (or infringing) their technologies.
9. Strength at *process and incremental* innovations: Because large companies often have manufacturing facilities and development staff, while new companies need to focus all their efforts on developing one or two initial products, the large companies are better able to invest in incremental and process innovations. Such innovations can rely on existing suppliers and marketing capabilities.

Of course the goal of most new companies is to grow into large companies. Almost by definition, young rapidly growing companies are among the most successful and have contributed much to innovation. Writing in the middle of World War II before the advent of VC backed ventures, Joseph Schumpeter noted the contribution of rapidly growing companies that manage to establish market dominance. Because of their efficiency and control over many complementary productive assets, they could often innovate better than small firms. But, as part of a renewal process built into the capitalist, free market system, Schumpeter felt that most large companies were destined to be replaced by successive gales of creative destruction, as innovation driven by entrepreneurship caused old technologies and skills to become obsolete. However, he warned that this system, although advancing human

well-being, contained the seeds of its own destruction. Schumpeter predicted that as large organizations became more prevalent, most innovation would be routinized and individual entrepreneurship would be replaced by work of a team. Individual entrepreneurs would be replaced by organization men, with less entrepreneurial drive and less commitment to capitalism itself. This warning may be more prescient in the case of large Japanese manufacturers, because of their very success in terms of technology and management compared to many large US and European counterparts.

In any event, what evidence is there that small or large firms are more innovative? Throughout this book, I have tried to assess innovation in terms of actual products or processes, rather than indirectly using proxy measurements such as R&D expenditures, academic publications, or patent applications.<sup>8</sup> There are a few data sets of actual innovations by specific companies enabling analysis according to firm size. These involve mainly US inventions compiled from reports in trade journals<sup>9</sup> or UK inventions compiled by industry experts.<sup>10</sup> The UK data show that from 1945 to 1983, the share of innovations contributed by firms with less than 500 employees rose to nearly 40 percent of the total, while that of firms with 500–9,999 employees declined and that of firms with at least 10,000 employees stayed constant at 42 percent.<sup>11</sup> The ratio of inventions per US\$1 million of R&D expenditure is highest for small firms and lowest for large firms.<sup>12</sup>

However, both the US and UK data show considerable variation by industry. Among the thirty-five most innovative US industries, the number of innovations by large firms was higher in twenty-one industries while the number of innovations by small firms<sup>13</sup> was higher in fourteen industries, including the two with the most innovations.<sup>14</sup> The innovations per employee ratio for large versus small companies also varies greatly among US industries. It is considerably higher for large companies in the tire, agricultural chemical, general industrial machinery, and food products industries; and for small companies in the computing, instrument, and synthetic rubber industries.<sup>15</sup>

Not surprisingly, industries with relatively high capital costs tend to be those where large firms are more innovative, while industries where skilled labor is relatively important tend to be those where small firms are more innovative.<sup>16</sup> Also as firm size increases and the focus of activity includes more manufacturing and product refinement, a greater proportion of R&D is probably devoted to process as opposed to new product R&D.<sup>17</sup>

Although innovation decreases as industry concentration increases, the most innovative industries have large, influential firms.<sup>18</sup> However, in these industries, innovations tend to emanate more from small than large firms.<sup>19</sup> Also the balance between small and large firm innovations has changed, with small companies having become prominent innovators in IT hardware and in biomedicine.<sup>20</sup> Finally, average R&D costs per innovation do not appear

to be increasing, in other words high costs have not closed out innovation possibilities for small companies.<sup>21</sup>

In summary, these data sets of actual innovations suggest that, at least in industries where high capital costs do not pose high barriers to entry, the innovative potential of small firms is strong. In some of the industries with relatively low capital entry barriers, small firms do indeed seem to be the main founts of innovation.<sup>22</sup> Furthermore, there is little evidence that the cost of innovation in general is rising beyond the capabilities of small companies. If anything, over time independent small firms are probably accounting for a greater share of total innovations, at least in the USA and UK. However, the most innovative industries appear to be those with a mixture of large and small companies. Large companies tend to have a higher proportion of process inventions compared with small companies. These findings in turn suggest that the most conducive environment for innovation involves symbiotic relationships between large and small companies, where small companies carry on much of the discovery and early stage product development, while large companies rely to a large extent on these companies for new discoveries and concentrate much of their efforts on assimilation of outside discoveries, later stage development, manufacturing, and marketing.<sup>23</sup>

### The Importance of Ventures in Drug Discovery

Fortunately, in one industry, pharmaceuticals, we can have a fairly clear picture of where each new product originated, its degree of innovativeness, and the contribution of ventures, large companies and universities to its discovery and early development. From 1998 through 2003, the US FDA approved 169 new prescription drugs for the US market.<sup>24</sup> Most of the drugs were covered by patents. I obtained copies of the key patents covering the therapeutic compounds underlying each drug or, if compound patents did not exist, the main methods of manufacturing or using the drugs.<sup>25</sup> I identified the inventors listed on the key patents, and then confirmed their place of work and the identity of their employers at the time of the original patent applications.<sup>26</sup> Thus, I attributed a type of work organization (pharmaceutical company, biotech,<sup>27</sup> or university/GRI) and a national location of work place to each inventor. Weighting each inventor equally for each key patent, but weighting key patents according to the criteria in note 25, I attributed the proportionate origins of each drug according both to type of discovering organization and to country.<sup>28</sup>

Overall, about 40 percent of these drugs originated outside of large pharmaceutical companies, in either universities (22%) or biotechs (19%). Nearly three-quarters of university-origin drugs were licensed to biotechs, confirming that biotechs are the main initial development partners for drugs originating

in universities.<sup>29</sup> Of the seventy drugs whose origins were at least 50 percent attributable to universities or biotechs, nearly one-third were transferred to pharmaceutical companies that completed development and obtained FDA marketing approval, and over half were ultimately marketed in the USA or Europe by pharmaceutical companies.<sup>30</sup>

However, national variations in this regard are striking. Drugs discovered by biotechs, or discovered in universities and transferred to biotechs, account for 62 percent of US origin drugs, 50 percent of Canadian drugs, 14 percent of UK drugs, and less than ten percent of Japanese, German, Swiss and French drugs. This shows the importance of biotechs in drug discovery and early stage development in North America in contrast to their negligible role in Japan and Continental Europe. Of drugs discovered in biotechs, or in universities and licensed to biotechs, 84 percent were discovered in the USA or Canada.<sup>31</sup>

The FDA approval process embodies an indicator of innovativeness. New molecular entities (NMEs, small molecule drugs that accounted for 144 of the 169 newly approved drugs) are accorded *priority* review status and fast-tracked for approval, if they offer substantial benefit over currently marketed drugs. All FDA applicants want the priority designation, because it enables them to market their drugs more quickly. Priority NMEs account for just under half of all NMEs.<sup>32</sup> The proportion of priority NMEs discovered in biotechs or in universities and licensed to biotechs is over two fold that of nonpriority NMEs.<sup>33</sup> *In other words, the drugs that originate in the laboratories of established pharmaceutical companies tend to be less innovative than those discovered in biotechs or in universities and then licensed to biotechs.* The USA dominates as the origin of priority for accounting NMEs, just over half followed by the UK and Germany accounting for 9 percent each.<sup>34</sup> Biotechs, or universities licensing to biotechs, are the origin of over half of US-origin priority NMEs. *In other words, the US pharmaceutical industry now relies on biotechs to discover its most innovative drugs.*

These differences are still more striking with respect to new therapeutic biologics (NTBs).<sup>35</sup> Genetic engineering techniques using microorganisms to produce human-type NTBs were pioneered in universities and then, in a parallel fashion, in industry.<sup>36</sup> The narrow definition of *biotechnology* refers to these techniques and the underlying science. However, within industry, biotechs rather than pharmaceutical companies took the lead and have maintained it. In general, the discovery and development of NTBs takes longer and is more costly than that of NMEs, and the diseases they address are more challenging.<sup>37</sup> Only 12 percent of the NTBs originated in the in-house laboratories of established pharmaceutical companies. A full 84 percent of NTBs originated in biotechs, or in universities and were then licensed to biotechs. All but two of these biotechs were US companies.<sup>38</sup> Over 85 percent of NTBs

*Advantage New Companies*

241

are of US origin, and of these over 90 percent were discovered by biotechs, or in universities and then licensed to biotechs.<sup>39</sup>

Data on drugs still in clinical trials also indicate that the center of gravity of new drug discovery and early stage development is in biotechs rather than established pharmaceutical companies, with biotechs predominating as the sponsors of clinical trials for drugs in a variety of disease fields.<sup>40</sup>

Outside the USA, biotechs and universities that license to biotechs also discover a greater proportion of the priority NMEs than do pharmaceutical companies.<sup>41</sup> However, in the case of Japan, Germany, Switzerland, or France, no NTBs and only two priority NMEs originated in a biotech or in a university and then licensed to a biotech.<sup>42</sup> Thus, although the USA may have the most fertile or most mature environment for biotechs, they also are innovation leaders in other countries—except in Japan and the large countries of Continental Europe, where drugs discovery and early stage development relies almost exclusively on established pharmaceutical companies.<sup>43</sup>

But to reinforce an earlier point, a large proportion of the university and biotech originating drugs are licensed to established pharmaceutical companies that complete clinical trials or the drugs.<sup>44</sup> Thus, these data describe a symbiotic relationship (except in countries such as Japan, Germany, Switzerland, and France) where the center of gravity of drug discovery is shifting to new companies with close university ties, but where cooperation between biotechs and established pharmaceutical companies is essential for final commercialization. The biotechs and the universities that license to them may be leaders in discovery, but much of the heavy lifting in terms of clinical trials and marketing depends on large pharmaceutical companies. Thus there is a suggestion of a rational division of effort, mediated by much back and forth, and sometimes tense, negotiations—and also by entrepreneurship in universities and their startups.

But to observe that bioventures are now more innovative in terms of drug discovery than large pharmaceutical companies does not automatically mean that they are inherently better at early stage innovation. What if bioventures never existed? Would pharmaceutical companies have been able to produce a similar number of innovative new drugs? Prior to the advent of most biotechs, large pharmaceutical companies were developing at least some of the university discoveries that pointed toward important drugs. University or GRI discoveries pointed the way to the discovery of a majority of the most therapeutically important drugs introduced between 1965 and 1992—although, in only one case was the actual active compound synthesized in a university or GRI.<sup>45</sup> Large pharmaceutical companies developed and commercialized of all but one of these.<sup>46</sup> If this method of drug discovery and development based

solely on established companies and universities had continued, would we have as many new drugs as we do today?

It has been suggested that the playing field for large companies versus ventures is not level with respect to training and movements of personnel—more specifically, that large US companies have curtailed R&D, in part because VC financing lures key R&D employees to venture companies.<sup>47</sup> Key personnel have indeed moved from large pharmaceutical companies to biotechs. For example, George Rathmann resigned as Abbott's Vice President for Research and Development to become the first CEO of Amgen in 1980. However, this was apparently an amicable parting, and within half a year, at Rathmann's urging, Abbott became one of the largest investors in Amgen's initial round of financing.<sup>48</sup> Genentech, formed in 1976, recruited most of its key scientists from universities, as have some other biotechs.<sup>49</sup> To my understanding, poaching of lead researchers and managers by biotech companies has generally not been a great concern for the pharmaceutical industry. As for the ability to hire star university researchers away from academia, large pharmaceutical companies are probably more able to do so than new biotechs.<sup>50</sup> Thus, at least in drug discovery, the evidence seems weak that biotechs' innovation advantage is due to their poaching personnel from pharmaceutical companies or being able to out-compete pharmaceutical companies in hiring away academic researchers from universities.<sup>51</sup>

Also, there is no clear evidence that biotechs' innovation advantage stems from an inherent tendency by US universities to license to startups rather than to pharmaceutical companies. Large pharmaceutical companies often decline to license early stage pharmaceutical candidates or drug targets from universities, which end up licensing these to biotechs as a last resort.<sup>52</sup> Pharmaceutical executives have said that if they have the option to develop university and in-house-originating candidate drugs for the same disease, they prefer to develop the in-house discovered compounds, because they can retain greater control.<sup>53</sup> In other words, if big pharma wanted to license more early stage university pharmaceutical compounds, it probably could. Similarly, if it wanted to fund more research in universities and have the right to exclusively license compounds arising from such research it could do so, too. The fact that big pharma has instead chosen to let biotechs and their investors bear much of the risk for developing early stage discoveries, suggests an element of economic rationality in the present system. In other words, at least in North America, big pharma seems to have made a calculation that it makes more economic and scientific sense to let universities and biotechs discover most of the compounds that eventually become new drugs, even though they may pay substantial license fees when they eventually in-license the partially developed compounds.<sup>54</sup> This trend has continued despite university entrepreneurialism, suggesting

that such entrepreneurialism, rather than hindering innovation, may be an important part of an environment that fosters it.<sup>55</sup>

Finally, the data on drugs recently approved by the FDA provide clues as to the pace and innovativeness of drug discovery in an environment without biotechs. For practical purposes, Japan, Germany, Switzerland, and France together constitute such a region.<sup>56</sup> Using each country's share of the world pharmaceutical market in 2003 as a benchmark against which to assess its output of newly discovered drugs, it is shown that the proportion of new drugs originating in these four countries is higher than their proportion of world pharmaceutical sales—although without Switzerland, the three remaining countries' share of new drugs equals their world market share. The US proportion of new drugs equals its share of the pharmaceutical market, while the combined share of the USA, the UK, and Canada—three countries where biotechs are active in drug discovery, exceeds their combined market share.

However, considering only NTBs and *priority* NMEs, the share of Japan, Germany, Switzerland, and France combined is less than their combined share of the world market. Leaving out Switzerland, the share of the three remaining countries is considerably below their combined share of the world pharmaceutical market. In contrast, the share of the USA, the UK, and Canada combined is greater than their world market share. The US share alone is also considerably greater than its market share. Although these results do not show conclusively what the pace of drug discovery would be in the absence of biotechs, *they are consistent with the hypothesis that a pharmaceutical innovation system comprised of vibrant biotechs linked both to universities and large pharmaceutical companies produces more innovative drugs than a system with weak biotechs.* Moreover, the involvement of biotechs, not drug discovery in universities per se, seems to be the most important condition for innovative drug discovery.<sup>57</sup> The case of Switzerland shows it is possible for a country to have large pharmaceutical companies that discover a disproportionate share of the world's drugs. But perhaps this is possible only in a small country where pharmaceuticals has become the premier high technology industry.

## PART II. CAN VENTURES BE INNOVATION LEADERS ONLY IN PHARMACEUTICALS? REQUISITES FOR A FAVORABLE ENVIRONMENT

Can venture companies also be the lead innovators in other industries? In software and some of the engineering and applied physics fields of IT, they can—witness the growth of Google, Netscape, Lycos, Sun Microsystems, Cisco

Systems, and Qualcomm to name just a few. But what about other fields? Or are pharmaceuticals and IT so unique that it is unlikely that venture companies in other fields can assume the same leading role in innovation? Aside from the data sets mentioned at the beginning of this chapter and a study of the patented technologies underlying 3G mobile telecommunications<sup>58</sup>, I know of no systematic data on how various companies (large and small, old and young) contributed to the development of final products in a particular industry.

However, let us examine the possible reasons pharmaceuticals are so unique that the situation described above probably does not apply in other industries. This examination suggests that although ventures in the life sciences, and particularly pharmaceuticals, have some advantages over those in other new high technology fields, the barriers to US ventures in these other fields probably are not prohibitively high.

1. *When it comes to drugs, diagnostics and medical devices, universities and their startups have a clear advantage, access to patients, that does not apply in other industries.* The access is ideal because conditions can be controlled and monitored and because well trained research-oriented physicians, nurses, and technicians are in close at hand. With the possible exception of some fields of software, there is probably no other industry where universities provide ideal laboratories for development up to the point of commercialization. Thus there is probably no other industry where startups closely linked to universities have a similar advantage in terms of access to resources for late-stage development.<sup>59</sup> Nevertheless, major pharmaceutical companies have developed strong clinical development capabilities that are largely independent of universities. Sometimes they manage clinical trials on their own. Sometimes they rely on contract research organizations (CROs) to conduct trials. They and the CROs have their own networks of hospitals and physicians that they can use as sites for clinical trials and to recruit patients, respectively. Sometimes these are university hospitals and medical school faculty, but probably in the majority of cases they are not. Similarly, in fields such as medical devices and diagnostics, large companies routinely cooperate with universities in R&D.<sup>60</sup>

In summary, access by university biomedical startups to patients and clinical research resources probably gives them an advantage relative to startups in other fields. But these are probably not decisive advantages vis-à-vis large companies. Independent spin-offs from large companies may benefit in a similar way from knowledge related to product development and marketing that their founders gained in the parent companies. Of course, this raises the question, 'What about ventures that are neither university biomedical startups nor spin-offs from large companies, for example many of the materials science/nanotechnology start-ups in existence in 2005?' Is one of

the reasons few nanotech university startups seem to have taken off due to this absence of development facilities in universities? As of 2005, the main uncertainty among investors with respect to nanotech in general was that most practical applications seemed still in the future, and still in need more development work. So perhaps this is a key advantage of biomedical ventures. The answers are not yet clear.

2. *Particularly in the USA, university R&D is heavily weighted toward the life sciences. Thus, it is to be expected that there will be more startups in the life sciences than in other fields.* Life science accounts for approximately 59 percent of total US university R&D expenditures in all S&E fields, engineering for about 15 percent, the physical sciences (astronomy, physics and chemistry) for 9 percent, and earth atmospheric and ocean sciences for 6 percent.<sup>61</sup> Nevertheless, engineering alone accounts for about US\$5 billion in annual US university R&D. Thus, while the financial inputs for nonbiomedical academic discoveries are fewer, they are far from insignificant.

3. *A related possibility is that academic biomedical research tends to give rise to more commercially relevant discoveries per unit of R&D funding than research in other fields.* Theoretically, this might be the case, because most government funding for university biomedical R&D has the practical mission of improving the health of the American people.<sup>62</sup> The only other field that might have a similar applied emphasis would be engineering, whose funding levels are only one-fourth that of life science. However, with respect to numbers of US university patents, biomedicine does not predominate to the same degree that it does with respect to R&D funding.<sup>63</sup> Available data do not suggest that per unit of university R&D expenditure, life science R&D is more likely to give rise to commercially relevant discoveries than R&D in other fields.

4. *Even if life science discoveries fall short of a majority of university inventions, most non-life-science inventions are licensed to established companies, as in Japan.* Unfortunately, I have not found US data that address this issue directly. However, several lines of evidence suggest that a majority of non-life science university inventions are licensed to startups or other SMEs, exclusively, rather than to large established companies.<sup>64</sup>

5. *Even though SMEs may have equivalent access to university discoveries in most technology fields, the disadvantages related to size pose more severe challenges to SMEs outside the life sciences.* The success of venture companies in drug discovery indicates that the disadvantages of small size are either surmountable or are less determinative in the case of pioneering innovations—even in an industry that has high entry barriers to new companies.<sup>65,66</sup> However, their success depends on obtaining some degree of exclusive control over new discoveries, being able to avoid encroachment from larger companies, and having some of the large companies become their

customers and collaborators, rather than their competitors. Thus two areas that might distinguish life science from other industries are the attitudes of large companies toward collaborations with ventures and the effectiveness of patent protection.

6. *Patents enable ventures to appropriate returns from investment effectively in pharmaceuticals but less so in other industries.* Patents are important for most ventures, because they lack other means to protect their technologies from being copied by rivals. They have to outsource manufacturing and perhaps even some aspects of development, and thus they often cannot rely on being first to market (lead time) to secure a competitive advantage. Similarly, they usually are not able to offer complementary services or products to attract customers. In addition, their need to seek outside suppliers, manufacturers, and distributors compromises their ability to protect their technology as trade secrets.<sup>67</sup> In general, secrecy, lead time, and complementary assets protect a greater percentage of manufacturing companies' innovations from encroachment by potential competitors than do patents.<sup>68</sup> But being less able to employ these other means to prevent encroachment by competitors, many ventures rely primarily on patent protection and other forms of intellectual property.<sup>69</sup> Also the strength of patent protection may be an important factor in a large company's decision whether it will try to duplicate or engineer around a venture's technology rather than partnering with it. Thus patents are also important for ventures to attract outside financing from angels, VC funds, or corporations.<sup>70</sup>

Without effective patent and copyright protection most new discoveries would have to be developed in existing companies, most likely in large companies that have complementary assets and can effectively shield much of the development work from competitors. But this would foreclose the advantages mentioned at the beginning of this chapter, such as entrepreneurship, focused dedication, and assembling a workforce whose skills and motivations fit that of the venture.<sup>71</sup>

What do we know about the effectiveness of patent protection for ventures, particularly in nonbiomedical fields? Survey responses indicate that the costs of applying for and, if necessary, defending patents more often dissuaded small than large firms from applying for patents.<sup>72</sup> However, the extent to which small companies are unable to protect technologies that are really worth protecting is not clear. In the case of R&D intensive ventures, the answer probably depends on the availability of astute outside capital.<sup>73</sup>

In general, survey responses of corporate R&D managers indicate that patents are effective in protecting a greater proportion of a company's innovations in pharmaceuticals and medical devices than in other industries. Specifically, patents were reported to protect about half of pharmaceutical

and medical device product innovations compared to, for example, about a quarter of semiconductor innovations. However, these survey responses probably underestimate the usefulness of patents for high technology ventures in nonbiomedical industries particularly those focusing on R&D in new fields.<sup>74</sup> New R&D-intensive US semiconductor firms are among the most likely firms in that industry to apply for patents. Interviews with some of these companies indicated that they patent in order *to secure strong, 'bulletproof' proprietary rights to technologies in niche markets*, and thus *improve their competitive position vis-à-vis direct market rivals*—in other words, to prevent encroachment. As a corollary of preventing encroachment, strong patent protection is also important for these young firms to secure startup capital.

To an even greater degree than these new firms, large capital intensive semiconductor firms also contributed to a surge in new semiconductor patents from the mid-1980s to mid-1990s. However, in contrast to the new firms, these established firms usually patented to secure freedom to operate in an environment which had suddenly become more complex and sometimes threatening due to a general strengthening of patent rights.

This strengthening of rights was due, in part, to the establishment in 1982 of the Court of Appeals for the Federal Circuit (CAFC) as the US intellectual property appellate court. In carrying out its mandate to develop a coherent body of jurisprudence to interpret and uphold America's patent laws, the CAFC ruled more frequently on behalf of plaintiffs in infringement suits than had the nonspecialized federal appeals courts prior to the founding of the CAFC.<sup>75</sup> Polaroid's 1986 US\$1 billion damage award in its infringement suit against Kodak<sup>76</sup> put companies on alert that courts were ready to mete out severe penalties against infringers.

Around this same time, several large companies began to take concerted legal action to demand substantial royalties from other companies using technologies covered by their patents. Texas Instruments lead this assertive use of its patent portfolio. Others followed suit.<sup>77</sup> In a complex manufacturing environment where final products may be covered by numerous patents, this combination of enhanced patent strength and the willingness of some companies to assert their patent rights aggressively led many large capital intensive semiconductor manufacturers to amass large portfolios of patents, mainly as bargaining chips. Assessed more often on the basis of quantity than their actual specifications and claims, these patent war chests were to be used defensively if their holders encountered charges of infringement and demands for high royalties. But they could also be means to access needed technologies, for example, by gaining admission to patent pools,<sup>78</sup> and sometimes to enhance royalty flow and block competitors. There is doubt whether such uses of patents increase incentives for R&D and innovation. Nevertheless, *even these large companies, when presented with the extreme hypothetical scenario*

*of the US patent system being abolished, expressed concern about the negative effects on high technology ventures.* In other words, even with a clear eye to the negative effects of the patent system (increased expense and the threat of royalty demands or infringement suits holding up their operations), *large manufacturing semiconductor companies recognize the value of the patent system in enabling entry of high technology ventures into their industry.* Indeed, the implication from such responses is that *this is the primary value of the patent system—at least in the semiconductor industry.*<sup>79</sup>

The 1980s marked the beginning of a period of new company formation in semiconductors and related fields that is probably still continuing. A significant proportion of these companies have continued to grow, despite the 2000–3 downturn in the IT industry.<sup>80</sup> Several factors probably underlay this upturn in new company creation in the 1980s. However, the coincidence with the strengthening of US patents, the patenting behavior of the new firms, and the explanations offered by industry officials, all suggest that increased confidence that patents can prevent encroachment was an important factor underlying this upturn.<sup>81</sup>

Semiconductor products as well as other products emerging out of engineering and the physical sciences are generally complex, in that a single product usually integrates many complementary technologies. In contrast, biomedical inventions, particularly pharmaceuticals, tend to be discrete, in the sense that they are often based on a single new chemical compound or a single detection device. It has been suggested that outside of biomedicine, large companies have an advantage over ventures because the former are better able to acquire and integrate the various component technologies, and in the process they account for much of the value added of the final product.<sup>82</sup> However, the fact that ventures have flourished in a complex product industry such as semiconductors, thanks in part to patents, casts doubt on this assumption.

There is evidence that when new companies lack patent protection, or when they feel that patent protection is ineffective to prevent imitation, they are more likely to try to develop their technologies on their own and to compete head-to-head with established companies. But if their technologies are protected by patents, they are more likely to cooperate with other companies via licenses of their patented technologies.<sup>83</sup> Thus, patents have been an important factor in the vertical disaggregation of the semiconductor as well as the pharmaceutical industry. In other words, they have enabled new companies to enter the value chains in these industries with high value-added products and to negotiate partnerships with other companies in the value chain. This is also a strategy that ventures in various fields of nanotechnology are trying to pursue.<sup>84</sup>

*Advantage New Companies*

249

Patents have also proven useful for companies that had invested heavily in research and made pioneering discoveries, and then confronted similar products developed by foreign competitors.<sup>85</sup>

Thus, there seems to be little clear evidence that, in the USA, patents are effective only for protecting the fruits of innovation in pharmaceutical or other biomedical ventures. Although the patent system is probably being used for purposes for which it was not intended, it is serving a useful function in enabling the development of new technologies by venture companies in a variety of industries. My interviews with Japanese nonbiomedical ventures indicated the same is true in Japan. Patents in combination with trade secrets are important to prevent encroachment and to attract financing.<sup>86</sup>

Also by 2005, the pendulum appeared to have begun to swing in the opposite direction, away from the tendency for large companies to amass patents mainly as bargaining chips or as weapons in a patent arms race. Some companies have begun to make some of their patented technologies freely available, especially for open-source software applications, and some companies are putting information in the public domain to prevent its private appropriation by patents.<sup>87</sup>

In summary, with the possible exception of access to patients and clinical investigators in university-affiliated hospitals, there seem to be no clear attributes of the pharmaceutical or other biomedical industries per se, that make them alone favorable for high technology ventures.<sup>88</sup>

However, in order for ventures to flourish in any industry, there must be technical and business opportunities that are not being exploited by established companies and where costs of entry are not prohibitive. In other words, they need new niches where potential demand for their output is high.<sup>89</sup>

Innovative university research often suggests these niches. Thus the innovativeness of university research and an effective system of technology transfer from universities are key components of a favorable environment for ventures. Ventures do not have resources to pursue basic research for its own sake. Universities do, and thus university research can open up new fields that ventures can exploit.

Established companies pursue basic research less than in the past,<sup>90</sup> but they nevertheless make discoveries or initiate applied R&D projects that they decide not to pursue further. Thus the ease with which employees of established companies can move to ventures to pursue projects that the established companies are not pursuing is also an important component of a favorable environment for ventures.

The importance of university connections for venture companies is clear in some industries. For example, the potential of genetic engineering and the basic underlying techniques was discovered in universities, and then the development of these new technologies was carried forward in parallel by universities and industry, but by bioventures more so than established pharmaceutical companies.<sup>91</sup> Universities and bioventures also pioneered the field of cartilage regeneration, and continue to cooperate closely to develop this field.<sup>92</sup> The development of gene sequencers described in Chapter 6 is another example. As for nonbioscience fields, the development of the Internet and Internet-related technologies such as routers, browsers, and search engines also has been largely due to university research and university startups.<sup>93</sup> As of 2005, a handful of ventures were trying to integrate discoveries from various universities to develop technologies to fabricate nanoscale materials.<sup>94</sup>

On the other hand, the founding of new companies in fields such as computers, semiconductors, hard disk drives, and IT-related software has often depended on entrepreneurial or frustrated engineers, scientists, and managers leaving large companies. Some of the companies formed in this manner have become world leaders. Intel was formed in 1968 by three employees of Fairchild Semiconductor who saw unexploited potential in some of Fairchild's technologies. It went on to weather the onslaught from Japanese memory chipmakers and become the dominant designer and manufacturer of microprocessors in the industry. Control Data Corporation was founded in 1957 by engineering managers from Sperry Rand who were frustrated by that company's failure to compete with IBM in mainframe computers. By the late 1960s, Control Data had become the leading designer and manufacturer of supercomputers worldwide as well as a major producer of computer peripheral devices. Compaq was formed by engineering managers who left Texas Instruments (TI) in frustration over the failure of TI's PC projects.<sup>95</sup>

IBM, which pioneered the development of computer disk drives for its large mainframe computers, did not perceive demand from its main customers for smaller disk drives, which in any case would have been slower and had less capacity. When IBM cut back R&D on the smaller drives, some of the engineers quit in frustration to form spin-offs. In a pattern which was to repeat itself over several generations of IBM progeny, these spin-offs invested heavily in R&D aiming at a niche market of small or specialty computer makers. In the process they increased the capabilities of the smaller drives until they matched those of the larger drives, thus making possible the personal computer revolution. Over forty new companies entered hard disk drive manufacturing from the 1970s to 1990s and, of those that made any money, all but four were formed by persons who had quit established firms. Faced with price competition, the new US hard disk drive companies usually outsourced manufacturing to Asia, often to Singapore. It was a strategy that their Japanese rivals did not

match until much later when the technology had matured and consolidation was well underway worldwide. By 2005, about ten companies accounted for the vast majority of world hard disk production, but US companies remained among the leaders, and at least three of these companies, Seagate, Maxtor, and Western Digital, are descendents of IBM.<sup>96</sup> Among the R&D-oriented semiconductor ventures mentioned above, many of these are located in Silicon Valley and the majority of Silicon Valley firms are founded by employees leaving other firms.<sup>97</sup> As for outsourcing of manufacturing, Silicon Valley firms continue to rely on the fast and flexible manufacturing infrastructure in Asian countries, especially Taiwan, and recently mainland China.<sup>98</sup>

Not all ventures are based on breakthrough university discoveries or skilled personnel leaving large companies. Many university discoveries that have been successfully commercialized by startups seem to be commonsense, insightful, or assiduous applications of existing knowledge.<sup>99</sup> Also breakthrough university research is sometimes commercialized by large companies without involvement of ventures. For example, university research in both the USA and the UK provided the theoretical foundations for GE to develop MRI scanners. GE benefited from hiring university researchers and has had collaborative partnerships with various universities, but GE largely funded and guided this development effort on its own. The same is true with respect to the development of injection molding as a process to make plastic and other shaped composite materials.<sup>100</sup> Also, some successful ventures, such as Apple, Microsoft, and Qualcomm, arose on their own without close ties to universities or established companies.<sup>101</sup> Finally, some breakthrough university inventions can have a mixed development history. One example is plasma display panel high definition television (PDP HDTV) which originated in the University of Illinois in the 1960s and 1970s. The University licensed this technology to a number of large US and Japanese companies, and then, after most of the US companies dropped out, to a startup founded by the university inventors. Short of cash, the startup was eventually absorbed by Matsushita. Although PDP HDTV sets have been on the market since the late 1990s and have been a technical and commercial success, high development costs and price competition have forced many of the manufacturers to scale back their operations.<sup>102</sup>

### PART III: DO VENTURES UNDERMINE INNOVATION IN LARGE COMPANIES—OR AN ENTIRE NATIONAL INNOVATION SYSTEM?

The fact that many ventures in IT have been started by persons leaving other companies raises squarely the issue of competition for personnel between

ventures and established companies. It also raises the possibility that the movement of personnel from established companies to ventures is undermining the former and creating a situation where all companies, new and old, are at risk.

It is ironic that one company that has raised this concern most publicly and that has initiated high profile litigation to prevent former employees from working in new ventures is Intel, a company that was itself formed by persons leaving another young high technology company, Fairchild Semiconductor. Robert Noyce, one of Intel's founders, summarized the possible ramifications of employees defecting to new ventures as follows:

If we get into a situation where Company A puts an enormous amount of money into an R&D project and Company B can simply appropriate that, then the first project will never be done again. That becomes the destruction of the American industrial base....<sup>103</sup>

This statement was made in the early 1980s when Intel was fighting for its life as US semiconductor manufacturers were rapidly losing market share in memory chips to Japanese competitors, and before Intel's salvation was apparent, as the leading designer and manufacturer for microprocessors for personal computers.

Perhaps it is a sign of Intel's competitiveness and its commitment to innovation and protecting its core business, that it has continued, on a selective basis, to sue employees who leave to work in similar fields for other companies.<sup>104</sup> The persons who left Fairchild to form Intel, Sperry Rand to form Control Data, Texas Instruments to form Compaq, and IBM and its progeny to form hard disk drive companies, were apparently not prosecuted for revealing trade secrets or for violating clauses in their previous employment contracts not to engage in work that may compete with the former employer (no-compete clauses). However, outside California, high technology companies have used successfully the threat of suits alleging violations of either trade secrets or no-compete clauses to prevent employees leaving for new companies.<sup>105</sup> The fact that employers are willing to sue former employees, despite the risk of alienating current and potential future employees, indicates that high technology companies view the loss of talented employees to new companies as a real danger.

A well-known case concerns Gene Amdahl, one of the chief designers of the then state-of-the-art IBM 370 mainframe computer, who left IBM in 1970 to form a company to manufacture advanced mainframes less expensively than IBM. Amdahl's new central processors helped reduce the price of high performance computing power several-fold, but led to the establishment of a competitor (ultimately overseas based) that outstripped IBM's market share.<sup>106</sup>

Other departures that may have directly undermined high priority development efforts involved the formation of ventures to develop thin-film technologies for computer hard disks. IBM and later Burroughs and Xerox had pioneered this technology. However, IBM incorporated it in only its most expensive computers. Venture capitalists recruited key engineers from IBM and Xerox to form companies such as Komag, which became the leading manufacturer of thin-film disks, and Read-Rite, which became the leading manufacturer of thin-film disk reader heads. These ventures sold most of their output to new hard disk drive ventures such as Seagate and Maxtor, which were themselves investing heavily in R&D to develop small, high performance disk drives. In this way, the disk drive ventures and the thin film ventures surpassed IBM and other vertically integrated manufacturers in terms of technology and market share.<sup>107</sup>

What motivates persons to move from established companies to ventures is an important issue on which there is currently only anecdotal information. If most moves are born mainly out of frustration and a reasoned assessment that opportunities to develop technology are better in a new company, this would be an indication that such mobility benefits innovation on the whole. In the available case histories, *frustration* with the inability of established companies to pursue effectively projects in the employee's field does seem to be the most frequently mentioned motive for changing jobs.<sup>108</sup>

There are reasons to believe that employee mobility may benefit innovation even though companies are hurt when they lose skilled employees. Much of the success of new companies depends on assembling at the outset a core group of persons with shared goals but complementary talents. A high mobility labor market facilitates this process. From the perspective of some employees, being able to change jobs freely and perhaps to start one's own company maximizes job satisfaction. For many skilled immigrants and recent US university graduates, a free labor market has produced upwardly mobile jobs where skills and marketability rapidly increase. Information flows among companies are increased both because of actual movement of people and because of intercompany networks that are augmented by mobility. These networks, including those among immigrants from countries such as China and India, in turn aid the job matching process. In a high mobility labor market, there is an incentive to work very hard either to increase one's chances for remaining in one's current job or to increase one's reputation so that one can move to a better job.

As for the injury to companies that lose people, this is in part compensated for by the intense effort employees put into their jobs, increased access to information, opportunities for alliances with other companies, and the ability to assemble an appropriate workforce quickly and to shed labor

quickly. Companies formed by defecting employees can also spread the parent company's standards and protocols more widely, create greater demand for the parent's products and even provide technology the parent itself can use.<sup>109</sup> Also, the patent system helps to ensure that companies retain ownership of their employees' inventions even after they have moved to other companies.<sup>110</sup>

Employers usually have the option to offer increased benefits to employees to induce them to stay. They also have the option to offer retention bonuses, training and promotion opportunities to longtime employees, and traditional pension plans under which benefits vest only after twenty or so years of service. The fact that they rarely take such steps, at least in regions such as Silicon Valley where labor mobility is high, suggests that they feel that the benefits of high employee mobility outweigh the costs.

The suits by Intel notwithstanding, there usually is an unwritten understanding in most employment relationships in Silicon Valley that employers will not pursue trade secret suits against employees who leave to work for a potential rival.<sup>111</sup> Such practices and the overall weaker effect of trade secret law in California may be one of the main reasons for the vitality of its ventures and for Silicon Valley's becoming the most important center of innovation in the USA<sup>112</sup> in terms of high technology employment and output of high technology companies.<sup>113</sup> In other words, rapid labor mobility allows resources, particularly human resources, to be deployed more quickly to projects where innovation potential and economic returns are highest.

#### PART IV: IS A SYSTEM OF INNOVATION BASED LARGELY ON VENTURES SUSTAINABLE?

Are the benefits of this system of rapid company creation, sometimes equally rapid collapse, and frequent job changes sustainable from even a micro perspective, that is, from the perspective of the firms in a particular industry and in a particular region, such as Silicon Valley? One criticism of the Silicon Valley model is that many of its companies lack an integrated learning base and integrated organizational capabilities. Reflecting the destruction of the American consumer electronics industry by the early 1980s and the near destruction just a few years later of the largely Silicon Valley-based American semiconductor and computer industries at the hands of large Japanese electronics companies, it has been suggested that, except in fields undergoing revolutionary change, vertically integrated, diversified companies, such as the

major Japanese electronics companies, will usually prevail over companies with lesser capabilities.<sup>114</sup>

With the possible exception of drug discovery, as a matter of rational business practice, if a new company is to grow it usually must develop integrated competencies spanning R&D, outreach to customers<sup>115</sup> and usually also manufacturing—or at least the ability to outsource manufacturing.<sup>116</sup> In IT, many of the highly successful erstwhile ventures, such as Hewlett-Packard, Intel, Apple, Microsoft, Seagate, Sun Microsystems, Qualcomm, and LSI Logic, have such integrated R&D competencies, although as of 2005 all of LSI Logic's chip manufacturing had been outsourced. Yet compared to Japanese companies such as Hitachi, Toshiba, and NEC, even the most successful US companies have narrower business scopes.<sup>117</sup> There have been inevitable consolidations among US high technology ventures. But at least in hard disk drives and semiconductors, fields for which we have historical data, some of the original ventures remain and are now sales leaders in their fields while continuing to vigorously pursue R&D-focused growth. They have done so by working out sales and collaborative relationships with other companies, in most cases remaining focused on core competencies or closely related technologies, and by using IP to protect those core competencies, especially when they have to outsource final development, manufacturing, or marketing.

Perhaps because of labor mobility, there is less of an imperative for corporate expansion into different fields. Persons who have ideas for different products move to other companies. The value chain remains largely disaggregated. Large companies seem to have adjusted to this disaggregation, with more adopting an open innovation philosophy.<sup>118</sup> As opposed to isolated learning and organizational competencies within large, distinct companies, these competencies now reside within the system as a whole. This system-wide competency depends on free flows of information and personnel, a nonautarkic innovation strategy on the part of large companies, availability of astute financing, and IP protection that allows new companies to grow.<sup>119</sup> It also depends on the existence of some large, technically focused companies that do well in R&D, manufacturing, and marketing. Such companies simultaneously provide smaller, newer companies with markets, testing facilities, feedback from end users, skilled personnel, and often new ideas for products—a relationship similar to that between biotechs and pharmaceutical companies. The technical competence of the large companies is crucial for this dynamic exchange. It enables them to be creative in their own right, to absorb ideas from the small companies and to generate ideas for the small companies to develop.

An idealized characterization? Perhaps. But this seems to characterize the business relationships in Silicon Valley. After weathering severe competition

from autarkic, vertically integrated overseas companies in the 1980s and then over exuberant expansion followed by the bursting of the IT bubble in 2000–1, the model still seems to be functioning relatively well, at least in the Silicon Valley of 2005. Jobs in high technology sectors have continued to decline since the bubble broke. However, salaries in these same industries are increasing. Productivity per employee is about 2.5 times the national average and continues to grow slightly faster than the national average. Net new company formation continues to increase. Venture capital investment has increased for the first time since the bubble broke, as have the number of rapidly growing companies.<sup>120</sup> The system no longer seems in mortal danger from large, autarkic, vertically integrated, multi-sectored companies—foreign or domestic. As of 2005, the more often discussed challenges related to regional social infrastructure,<sup>121</sup> the outsourcing of high technology jobs overseas, and the possibility that that the Silicon Valley model will flourish in countries such as India and China where clusters of networked new companies will soon compete even in high technology fields with Silicon Valley companies.

What about the benefits of rapid company formation and labor mobility from a more macro (e.g. national) perspective? America has benefited from Silicon Valley, which owes its success in part to the way California law facilitates job transfers between companies. Should other states adopt these same policies, and would the USA benefit if employees in all regions were as free to move as they are in California? Conversely, might not the threat of losing key employees dissuade companies from pursuing important R&D, despite suggestions from California's experience that this rarely happens? Finally, if scientists and engineers nationwide feel they are treated like commodities and have little job security, might not many middle-aged Americans leave S&E careers and fewer young Americans decide to enter such careers?<sup>122</sup> The answers are not clear.

More generally, to what extent does competition from venture companies undercut profits of large companies and thus prevent them from carrying out forward looking research whose benefits may not be realized for many years, and which, when they are realized, might largely accrue to other companies? AT&T's Bell Laboratories, Xerox's Palo Alto Research Center, and RCA's Sarnoff Laboratories, all produced pioneering discoveries that proved greatly beneficial but were most often commercialized by other companies. Are whatever gains from rapid employee mobility and a fertile environment for new companies canceled out by the loss of the wellsprings of such discoveries?<sup>123</sup> One could cite a continuing stream of innovations from new high technology companies as evidence that innovation will continue apace despite the absence of large corporate basic research laboratories. Still there is room for debate and

need for investigation into whether and how universities should fulfill the role those laboratories once played.

It might be argued that high technology labor mobility is fine as long as it is within one country or there is net immigration of engineers and scientists into a country. But what if this is not the case? In recent discussions with Japanese colleagues about the benefits of labor mobility to build ventures and to diffuse technology, the most frequent cautionary response is, 'What about the Chinese scientists and engineers whom Japanese companies hire and train for important projects, who then leave to start or join a Chinese or US company that will compete with their Japanese mentor?'<sup>124</sup>

The USA has so far benefited from net immigration of scientists and engineers. In 2000, foreign born scientists and engineers accounted for 17 percent of the US total—37 percent if just Ph.D. holders are considered. They accounted for well over a third of scientists and engineers in Silicon Valley and nearly 30 percent of the CEOs of the Valley's high technology ventures.<sup>125</sup> The US biotechnology industry also depends on immigrants, with 6–10 percent of its workforce holding H-1B visas.<sup>126</sup> Venture companies may benefit even more from immigrants than established companies.<sup>127</sup>

In contrast, foreigners account for less than 1 percent of Japan's S&T labor force and the proportion is barely increasing.<sup>128</sup>

Even before September 2001, the flow of S&E professionals back to their homelands from the USA was increasing. However, these returnees often maintained strong ties with the USA and continued to build international networks that benefited the USA and their native countries. In other words, many of these returnees became part of a transnational movement of S&E professionals that brought about the previously cited benefits of labor mobility—better access to information, customers, manufacturing facilities, skilled personnel and capital, diffusion of standards, etc.—but now on an international scale.<sup>129</sup>

However, since 2001, immigration of scientists and engineers into the USA has declined sharply—largely due to stricter and more time consuming scrutiny of visa applicants.<sup>130</sup> These restrictions concern US high technology companies that rely on immigrants. *It is inconceivable that newly graduating US citizens and permanent residents can make up these shortfalls.* The number of those graduating with bachelors degrees in engineering has been declining since the 1980s, and the number of those graduating with doctoral degrees in any S&E field has been declining since the 1990s.<sup>131</sup> The recent trend to outsource increasingly sophisticated design work to countries such as India and China is driven in part by the difficulty in bringing skilled foreign workers

to the USA.<sup>132</sup> As overseas design and manufacturing capabilities grow, fueled by outsourcing and VC investments by US companies, concern is also growing that overseas companies and regional innovation centers will soon become major competitors for US counterparts—even while the benefits and necessity of international collaboration are acknowledged.<sup>133</sup>

This raises the issue of the age-related demographics of high technology ventures. Are most dependent primarily on young employees who can work long hours and who, because they do not have families (or because they have a spouse with a steady job), do not mind the prospect of job changes, perhaps even occasional unemployment? There are suggestions that in the case of many Silicon Valley ventures, the answer is ‘yes’.<sup>134</sup> Thus, as the flow of young immigrants diminishes and as the numbers of US citizen engineers and scientists remain stagnant, will the lifeblood of these companies also begin to vanish? In countries such as Japan where the population age distribution is skewed even more toward elderly persons, the demographic challenges facing ventures are even greater. These demographic challenges will only compound the difficulty ventures in Japan face in hiring skilled personnel.<sup>135</sup>

What about the scientists and engineers working in ventures who are over forty or who are the sole breadwinners for their families? If the ventures they work for have to shed jobs, can they find new jobs? Before the dot com bubble burst, it was said that failure was a mark of experience that would make one more eligible to obtain funding to start another company. But since the bubble burst, engineers and programmers over forty often encounter difficulty finding new jobs. Few data are available on the fate of these persons’ careers,<sup>136</sup> or even the fate of young scientists and engineers who lose their jobs during economic downturns. If many end up taking jobs in unrelated fields, then in many cases their S&T skills will be wasted.<sup>137</sup> As mentioned in Part V of this chapter, this inability to retain skilled S&T personnel during downturns is one of the main problems that have plagued the US machine tool industry, an industry that is based on small- and medium-size companies. Are large, established companies more likely to retain S&T professional staff during economic downturns? Again the answers seem woefully unclear, although on such answers depends employee morale and the ability of an industry to preserve its skilled personnel for better times in the future.

Inability to find new work quickly may also entail losing health insurance. Even if they manage to find jobs sometime later, their new health insurance may not cover, for a period of twelve to eighteen months, medical costs related to medical conditions existing at the time of reemployment.<sup>138</sup> The high cost of health insurance is also a burden for small ventures that do not qualify for group discounts offered by health insurers to large companies. Whether the venture pays or passes the costs on to its employees, these cost can be

substantial.<sup>139</sup> If labor mobility is to be encouraged as a means to redeploy human resources to where they can be used most effectively, and if workers of all ages are to be part of this system, these health insurance issues must be recognized as a problem that is probably unique to the USA among industrialized countries.<sup>140</sup>

Finally, there is the issue of inventive versus manufacturing competence. When the US semiconductor industry and Silicon Valley were in crisis in the early 1980s, one often cited flaw in the US innovation system was its lack of attention to manufacturing competence, to process rather than product innovations.<sup>141</sup> Twenty years on, that criticism continues to echo: Silicon Valley companies and US industry in general are great at coming up with new products, but few companies devote great care to manufacturing.<sup>142</sup> Of course this criticism must be balanced by observing that leaders in the IT industry, such as Intel, manufacture many of their products in the USA. Nevertheless, between 1992 and 2002, employment in US high technology manufacturing industries declined at a faster rate than for manufacturing as a whole.<sup>143</sup> Over this period all high technology manufacturing industries lost jobs *except semiconductor and other electronic component manufacturing* (one of three IT-related high technology manufacturing industries) and *pharmaceutical and medicine manufacturing* where employment rose 2 and 30 percent, respectively. The decline in high technology manufacturing employment is projected to continue between 2002 and 2012, although at a slower pace. Nevertheless, the three IT-related high technology manufacturing industries experienced increases in output (revenues) between 1987 and 2002 and are expected to continue to have high rates of output growth at least until 2012. Output per worker is continuing to increase for IT-related high technology manufacturing industries,<sup>144</sup> while employment decreases or remains steady.

But for all the other high technology manufacturing industries, growth in output per hour of work between 1987 and 2002 was close to or below the national manufacturing sector average of 3.4 percent per year. In other words, among all fields of US high technology manufacturing, there are only two growth sectors: IT, where output is increasing as is output per worker although employment is declining, and pharmaceuticals, where employment is continuing to increase but output per worker has remained steady.<sup>145</sup>

Because many biotech companies are classified as *pharmaceutical and medicine manufacturing companies*, it is likely that the pharmaceutical manufacturing data reflect large numbers of persons being employed in biotech companies that are pursuing mainly R&D and have little sales revenue.<sup>146</sup> One possible explanation of the IT trends is that, while much manufacturing continues to be outsourced overseas, much high value added, high profit margin manufacturing of relatively new products continues to be done in the USA.

If these assumptions are correct, then *the sectors where venture capital backed new company formation is most active are also the sectors where US high technology manufacturing remains strongest.*<sup>147</sup> More studies are necessary to show how venture companies maintain high technology manufacturing capabilities. However, the available data are consistent with such a link. In other words, the decline of high technology manufacturing in the USA may be a legitimate concern. But an environment that nourishes new company formation in high technology fields probably is more likely to create rather than undermine opportunities to develop globally competitive high technology manufacturing capabilities.

In summary, in the pharmaceutical industry there is strong evidence that innovation leadership has shifted from large pharmaceutical companies to venture companies. This shift has occurred because new companies, as a group, are probably better at drug discovery than established pharmaceutical companies, while the latter have a comparative advantage at later stage development (especially animal and human trials) and marketing—not because the new companies undermined the established companies. In other words, the ascendancy of venture companies in drug discovery reflects a mutually beneficial division of effort.

Aside from the unique advantage that university startups have with respect to access to patients and clinical research facilities provided by university hospitals, there seem to be no inherent advantages that biomedical ventures have in comparison to high technology ventures in other fields. In other words, if scientific breakthroughs with commercial potential occur in fields other than biomedicine and if institutional conditions are appropriate, venture companies should be able to assume leading roles as early stage (and sometimes also late stage) developers of these breakthroughs, just as they have done in pharmaceuticals. Their success in many fields of software and IT-related engineering suggests that innovation leadership is not limited to ventures in biomedicine.<sup>148</sup> Moreover, even with respect to skilled personnel leaving established companies to work for ventures, the evidence that ventures harm the long-term innovative strength of established companies, is weak. Rather than a zero-sum game where the success of one type of company undermines the other type, more often mutually beneficial relationships are worked out, not unlike the relationships between biotechs and large pharmaceutical companies.

Finally, the system of venture companies assuming lead roles in innovation while maintaining close ties with universities and other companies has endured several crises. It has contributed to overall long-term industrial progress and national economic well-being. Although care must be taken

to maintain the institutional conditions for ventures to flourish, the system itself seems robust. Its greatest future challenges probably come not from large, vertically integrated, diversified overseas companies, but from the need to ensure a long-term supply of skilled, highly motivated labor despite the uncertainties inherent in a system of rapid labor mobility. This includes the need to ensure that skilled S&T labor will not be permanently lost from S&T fields during periods of downturn.<sup>149</sup> More broadly, it will require the USA to maintain public support for R&D funding and R&D careers, to remain open to immigration, and to develop mechanism to help its S&T labor force deal with the stresses of job mobility. It will require all countries to recognize the mutual benefits of open science and free movements of people and capital.

The future health of American industry depends on preserving an environment where new companies continue to be created and to flourish. Is America unique or does this conclusion also apply to Japan and other countries?

#### PART V: TO WHAT EXTENT DOES THE DEARTH OF HIGH TECHNOLOGY VENTURES HURT JAPAN?

The above analysis focused mainly on the USA. Various factors discussed later in this chapter make the environment for ventures less supportive in Japan than in the USA. But first let us consider available evidence that Japan's global competitiveness in particular industries has eroded (or has remained weak) because it has not had vibrant R&D-focused ventures.

At least in pharmaceuticals, Japan's weakness can be attributed to its dearth of bioventures. This is clear because, as autarkic innovators, Japanese pharmaceutical companies having shown considerable innovative strength. They have discovered some of the world's most important drugs, although this is often not known because they are distributed outside Asia by US or European pharmaceutical companies that rarely reveal their Japanese origins in promotional materials.<sup>150</sup> They have done so relying primarily on their in-house laboratories and research teams. Relative to a particular company's number of in-house researchers, R&D expenditures, or global pharmaceutical sales, the ability of the in-house research teams of the better known Japanese pharmaceutical companies to discover innovative new drugs is no worse (and may even be better) than that of the research teams in their larger US and European counterparts.<sup>151</sup>

Nevertheless, Japan's recent output of new drugs, particularly innovative drugs, is low relative to the size of Japan's pharmaceutical market. In contrast, output of innovative new drugs relative to market size is high for the USA.

But remove biotech drugs, and the USA would lag farther behind than does Japan in terms of output of new drugs relative to market size. Japan, Germany and France are weak in terms of discovery of innovative new drugs. America is strong, but its advantage is accounted for entirely by discovery and early development work done in its venture companies.<sup>152</sup>

In the case of other fields of technology, I am struck by the frequency with which colleagues at my research center who cooperate closely with Japanese companies identify new (or relatively new) US companies as the main competitors of their Japanese collaborators. This was the case with respect to optical switching devices and tunable lasers mentioned in Chapter 6. Although anecdotal, these are unsolicited assessments by technical experts who understand the capabilities of the companies they are collaborating with and who also are aware of what leading groups the world over are doing in their fields. The development of gene sequencers also fits this pattern. Discussions with persons in government, industry, and science and engineering research in Japan indicate deep concern that Japan's large high technology manufacturers are being squeezed between Asian competitors who can manufacture increasingly high quality products more cheaply, and new US companies (often university startups) that are discovering new technologies and developing their applications more quickly.

However, the final verdict is not in and, as described below, established companies are pursuing alternative strategies to remain competitive in newly emerging fields of technology.

#### PART VI: WHAT UNDERLIES JAPAN'S STRENGTH IN INNOVATION?

If Japan now needs new companies, why did it do so well from the 1960s to the 1990s? And why is it that in some industries, for example automobiles, machine tools and some fields of consumer electronics, its companies in 2005 are still undisputed world leaders in terms of innovation and manufacturing? Succinct answers are not possible. While relying on a close follower strategy<sup>153</sup> may have worked in the 1960s and 1970s, by the 1980s the strongest Japanese companies had become the world's leading innovators in many technologies. The fact that many have maintained this leadership suggests that autarkic innovation can be globally competitive in some industries. As suggested in Chapter 6 and Parts 2 and 3 in this chapter, such fields typically are those with high capital costs to entry, where progress is incremental in the sense that it builds closely on already commercialized discoveries rather than new

technical fields, and where university discoveries or defections from large corporations are unlikely to create niches that can be commercialized before established companies do so.

Nevertheless, the success of large Japanese companies suggests that additional factors have made the Japanese environment particularly supportive of early as well as late stage innovation in large companies. The remainder of this part considers some of these factors, specifically:

- The possibility that entrepreneurial companies have in fact contributed substantially to S&T innovation in Japan behind the scenes, examining in particular the case of the machine tool industry,
- Japanese industrial policy, examining in some depth government sponsored consortium research and whether this has helped or hindered innovation, and
- The strong internal innovation capabilities of large manufacturing companies, based largely on personnel management policies, predicated on lifetime employment.

This will show that some of the factors underlying Japan's strength in innovation favor established companies and are detrimental to the formation of ventures with high growth potential.

### **Japan's Entrepreneurial Potential: The Case of its Machine Tool Industry**

One explanation is that entrepreneurial companies have indeed played a major role in Japan's economic success—that behind Japan's large companies are many small or new companies that have produced innovations that have been effectively incorporated into final products by large internationally known manufacturers.

The history of the machine tool (MT) industry shows not only Japan's potential for entrepreneurship and innovation based in small or new companies, but also, ironically, some of the weaknesses of small-company based innovation in the USA. The outlines of the story are as follows: US companies dominated the MT industry in the postwar years until the 1970s. By and large, they were small. Japanese companies tended also to be small and independent.<sup>154</sup> Repeated efforts by MITI to promote consolidation, in the belief that some companies would achieve economies of scale and thus become more competitive internationally, were not successful. The companies successfully resisted consolidation among themselves and also with the end manufacturers.

The Japanese companies were the first to exploit the potential of computerizing the numerical control devices in machine tools. Fanuc, originally a joint venture between Fujitsu and Makino, one of Japan's younger MT companies, built its first computerized numerical controller (CNC) in 1972. By 1975–6, these were being rapidly incorporated into Japanese machine tools. This was probably the first large-scale application of microprocessor technology—even earlier than personal computers.<sup>155</sup> These made MTs more versatile, as well as easier and less expensive to operate. Sales increased not only to large Japanese automakers and other large manufacturers, but also to small manufacturers. The latter could use relatively small MTs with CNCs to create high quality customized parts for a variety of end users. Throughout the 1970s and 1980s the vitality of small-scale manufacturing in Japan remained high, as did the ability of small companies to maintain independence with respect to larger companies, thanks in part to these machines and the technical skill of their craftsmen. As a result of this strong domestic demand, Japanese MT manufacturers began to benefit from economies of scale that made their products more competitive internationally.

The traditional customers of American MT manufacturers had tended to be large manufacturers who did not need the versatility of CNC machines, and military contractors that often needed precision parts but who usually did not face stiff price competition. However, by the early 1980s US MT companies found themselves competing against Japanese machines that offered better quality and versatility for price. Employment and production in the US MT industry fell sharply in the early 1980s. Since the late 1980s, US MT production has lagged behind that of Germany, Japan, and sometimes also the USSR or Russia, Italy, China, and Taiwan.<sup>156</sup> Consolidations and bankruptcies swept the US industry. Conglomerates acquired many firms and then, unwilling or unable to invest the effort to turn them around, sold or closed them. Workers who were laid off during downturns found jobs in other fields. When upturns came, many companies could not invest in training new workers, and even the stronger companies found that availability of skilled workers was their most severe problem.

A revival began in the mid-1980s and continued until the late 1990s as many of the remaining companies adopted state-of-the-art technologies, improved quality, produced new products in shorter development times, provided better customer service and began to pursue exports. Although import penetration was high, US manufacturers were reaping an increasing proportion of sales through exports, which helped buffer the frequent downturns in domestic demand characteristic of the industry.<sup>157</sup> During this revival, the larger firms tended to fare better in terms of growth in sales, employment, R&D and exports. The smallest firms were often dependent on a few nearby customers

and lacked the resources to improve their product line or broaden their customer base.<sup>158</sup>

US MT consumption and production again declined sharply beginning in 1998. Another recovery began in 2003, but by this time the largest firms, including industry icons, had gone out of business or been acquired by foreign companies.<sup>159</sup> The remaining firms were even more export-oriented.<sup>160</sup> They were also more oriented toward the special needs of small-scale manufacturers, ironically assuming a similar strategy with respect to the global market that Japanese companies had assumed thirty years earlier. The largest of the US MT manufacturers in 2005 was Haas Automation, a relatively new firm located near Los Angeles, far from America's traditional manufacturing region near the Great Lakes. Haas eschewed the normal practice of shedding workers during economic downturns. Between 2000 and 2005 it continued to employ about 200 engineers and computer experts for design work, while its total workforce expanded from about 700 to 1,100.<sup>161</sup>

Similar to the US, most Japanese MT manufacturers are small, while the leading manufacturers are generally medium-size independent firms.<sup>162</sup> Japanese companies remain leaders in MT innovation and in manufacturing control systems.<sup>163</sup>

More remarkable, however, is the history of the development of this industry during the years of Japan's economic miracle from the 1960s to 1980s.<sup>164</sup> This period saw frequent entry by new companies and displacement of old ones. Subcontracting was common, but subcontractors usually sold to several companies. Some companies that were small subcontractors in the 1970s grew to be among the leading companies in 2005.<sup>165</sup> As they tried to catch up to overseas competitors and also meet the demands of a wide range of customers (whose needs were not being met by large overseas manufacturers), the larger Japanese manufacturers experimented with products and production processes. This need to experiment required them to give their subcontractors freedom and incentives to do the same, and this created an environment that encouraged innovation in small companies and formation of new companies. Fanuc's pioneering large-scale production of CNC devices for MT machines allowed small and new firms MT to respond to these opportunities. At least in the 1980s, the Japanese MT industry was among the most vertically disaggregated in the world, with the major MT firms producing considerably higher numbers of machines per employee than those of any of their major foreign competitors. They did so through a networked system of production, similar to the modular innovation and production methods that became popular later in the USA.<sup>166</sup> The final machine tool incorporated components from many independent suppliers. At least among smaller firms that were not direct competitors, sharing of information

was common, and they occasionally shared marketing and research costs.

To some degree, this favorable environment for entrepreneurship existed throughout Japanese manufacturing. Small companies became the training grounds for skilled craftsmen and innovators. Between the 1960s and 1970s it became commonplace for young craftsmen in their late 20s to leave to establish their own companies. In the smallest firms, almost half the workforce would be expected to leave to start their own companies.<sup>167</sup> Their employers took such departures as a matter of course, not unlike most employers in Silicon Valley. Once they became company head, their salaries increased to above the level of craftsmen in large companies. Thus, when considered across an entire career, salary differentials between large and small companies were small. Only production employees who remained in small firms beyond their mid-30s suffered large wage gaps. Some craftsmen moved from company to company, and in some specialized fields, professional bonds among persons with the same skills were stronger than bonds to the companies in which they worked.<sup>168</sup> Subcontracting was common, but probably not quite so much as in the case of MT companies. In several industries the necessity for large end user manufacturers to experiment to meet customers' needs fostered experimentation among their subcontractors. In turn, the small manufacturers made the Japanese manufacturing system more flexible, compared with a dominant focus on achieving efficiency through mass production that may have characterized the automobile and other industries in the USA.<sup>169</sup>

As noted in Chapter 6, the innovative strength of Japan's automobile industry has been attributed in part to the freedom of subcontractors to develop their own designs for products and to market these to various large manufacturers.<sup>170</sup> Loan financing was available from a network of private and public financial institutions specifically intended to provide capital to small businesses. The Government played an important role in establishing and funding public institutions such as the Small and Medium Enterprise Corporation (1953) and the Central Commercial and Industrial Bank, as well as private mutual banks, credit associations and credit unions. Of all the government's policy measures in the postwar period, this probably resulted in the greatest benefit to Japan's MT industry and to small manufacturers in other industries.<sup>171</sup>

Except for the financing mechanisms, there are notable parallels with vertically disaggregated innovation in the US IT industry characterized by high labor mobility, rapid new company formation and outsourcing of innovation and R&D by large companies to independent smaller companies. Even the role of Fanuc in developing a widely used platform technology that increases innovative capabilities for new companies and provides the means for them

to make additional modular innovations echoes IBM's development of the PC (or IBM's letting other companies develop compatible peripherals for its mainframes) and the development of standard operating systems such as DOS/Windows and Unix. Also, the way Japanese MT manufacturers were able to meet the latent needs of small-scale, nonmilitary US manufacturers<sup>172</sup> has parallels with the way small disk drive startups were able to respond to the needs of companies that IBM had ignored. These parallels aside, at the very least, the Japanese MT experience shows that, given a supportive environment, entrepreneurial innovation can flourish in Japan, large companies can be supportive of innovation in independent companies, and technically skilled people are willing to take the risks associated with careers in small companies.

In the course of investigating various topics mentioned earlier in this book,<sup>173</sup> I have been struck by the large number of engineering and chemical companies incorporated in the 1950s and 1960s that are independent mid-size companies today. These would have been young companies in the early decades of Japan's economic miracle. The degree to which Japan's economic growth depended on these companies is not absolutely clear, but this shows that as Japan's economy was taking off, many technology companies were being formed and they undoubtedly contributed in some measure to the miracle that became evident in the 1960s, 1970s, and 1980s.

However, there are cautionary lessons from both the US and Japanese MT experiences. The US experience shows the limitations of small size (at least in the absence of financing and good management that enable a small firm to grow quickly). The smallest firms are generally the weakest because they lack resources to improve quality and performance, develop new products, and attract new customers. As for Japan, it appears that rates of formation of new high technology companies in manufacturing in general have fallen substantially from levels in the 1970s, although it is not clear this is the case in the MT industry itself. This is due in part to the long downturn in the Japanese economy and the shifting of many manufacturing operations overseas. Also, until at least 2003, small manufacturers faced increased difficulty recruiting and retaining skilled workers as downward pressure on wages increased, fewer young people were attracted to jobs in these companies, and immigration remained tightly controlled. Also launching a new company has become more difficult. Land, buildings, and machinery are more expensive and more technical and managerial skills are needed for a viable new company. The advent of CNC-controlled machines helped small manufacturers to overcome to some extent the dwindling numbers of craftsmen with specialized skills and also to attract new young employees.<sup>174</sup> Perhaps, however, these positive benefits have now largely run their course, and the lack of new technical breakthroughs limits both the technical opportunities for entrepreneurial companies to exploit

and makes recruitment difficult. In any case, this shows that if technical and business and demographic conditions change, vibrant entrepreneurial activity can come to an end.

It also suggests that access to new technologies is vital for ventures and probably is the prerequisite for their being competitive with respect to large companies. This in turn suggests the importance of access to university discoveries and entrepreneurial researchers for ventures. The flowering of innovative entrepreneurship in the machine tool industry, coupled with the fact that Japan's university system was and to a large extent remains closed to ventures (not to mention the barriers to forming independent high technology spin-offs), gives a hint of what innovation might have been otherwise. The loss in forgone entrepreneurial innovation may be great.

### **The Importance of Industrial Policy**

It has been suggested that Japan's bureaucracy has skillfully guided the allocation of public and corporate resources so as to promote the growth of internationally competitive industries, has provided just enough shielding from foreign competition for its growth industries, and has helped to ensure that competition promotes innovation while limiting resulting destruction and waste. It is beyond the scope of this book to analyze this perspective. However, this explanation for Japan's success has been questioned. In any case, with the possible exception of consortium research projects promoted by the government, they probably do not explain the continued strength of some Japanese industries.<sup>175</sup>

However, government-sponsored R&D consortia deserve special attention, because they remain an important feature of the Japanese S&T landscape and, as explained in the following pages, they hinder the growth of high technology ventures by allowing large companies to preempt potential markets and the attention of university researchers.

### **Government Consortia, and the Preemption of New Technologies by Established Companies**

Government-sponsored R&D consortia have been defined as cooperative R&D projects involving two or more companies that were initiated in part by the Japanese government.<sup>176</sup> The government usually plays an important role in defining the field of R&D and recruiting participants. Its support can range from a modest level of cofunding to covering all costs. Based on the recent

consortia with which I am familiar, the government's contribution usually falls in the range of 50 to 70 percent of project costs, although participating companies on their own can pursue related research. The government often encourages involvement of GRIs and universities, sometimes directly and sometimes as subcontractors to the companies. Sometimes the government establishes dedicated laboratory facilities, but probably it is more common for R&D to be conducted in existing corporate, university and GRI laboratories. Government-sponsored consortia began in Japan in the late 1950s and became increasingly frequent, so that by the late 1980s and early 1990s there were over 100 consortia projects ongoing at any time.

Consortium research organized by NTT in 1973 was instrumental in enabling three cable companies, Fujikura, Furukawa, and Sumitomo Electric, to match Corning's breakthrough in low-signal attenuation fiber optic cable. However, the success of this consortium probably depended most on the strength of NTT's laboratories and the hub and spoke type collaborations between these laboratories and the three cable companies, not on collaboration between the cable companies themselves.<sup>177</sup> Probably the best known of the consortia has been the Very Large Scale Integration (VLSI) project, which brought together Japan's main semiconductor manufacturers in a successful effort to improve the quality and reliability of their semiconductors and manufacturing methods.<sup>178</sup> The project was launched by NTT in 1974 (and then joined by MITI which took on the lead role) in response to plans by IBM to develop by 1980 a new Future System computer that would use 1 megabyte DRAM chips. In retrospect, the timetable was unrealistic and IBM abandoned the project. However, in 1974–5 this seemed a mortal threat to Japanese semiconductor makers still lagging technologically behind US rivals and facing greater competition as Japan reduced tariffs on computers and semiconductors. Thus the leading manufacturers urged the government to launch a project to help them catch up, and were prepared to cooperate among themselves in some fields of R&D. However, it was probably the efforts of each participating company's researchers working independently from those of other companies—not close cooperative research among scientists and engineers from fiercely competing companies—that contributed most to success. Additional important factors were substantial METI financial support and intense research in NTT's laboratories (probably the best at the time in Japan in basic VLSI technology), the results of which NTT shared freely with three of the participants. Again this suggests the importance of public scientific resources made available to individual companies, rather than the government's ability to promote cooperation among companies that otherwise would be reluctant to cooperate.<sup>179</sup> In any case, by the late 1970s, the DRAMs of the Japanese participants began to surpass those of US companies

in terms of capacity, quality, and price. No longer in danger of seeing its semiconductor and computer industry overwhelmed by foreign competition, it had to deal with increasing alarm from the USA which saw this fate about to befall its semiconductor industry.<sup>180</sup>

After VLSI, new consortium projects tended to focus more on forward looking S&T issues rather than applied research that was of immediate commercial applicability, and they also tended to be smaller scale.<sup>181</sup> Nevertheless, some of the consortium projects ongoing in 2005 aim at specific commercial applications, and some are quite large. For example, METI/NEDO's nanotechnology program, encompassing numerous projects organized under several R&D themes, had annual budgets of approximately US\$100 million in both 2003 and 2004.<sup>182</sup>

METI has allocated about US\$200 million to the Extreme Ultraviolet Association (EUVA) to develop technologies to use extreme ultraviolet lithography to make the next generation of chips with circuits only 45 nanometers wide. The EUVA seeks to promote collaboration among most of the Japanese companies involved in the manufacture of IC chips and the equipment for making such chips.<sup>183</sup> Like the VLSI consortium, METI formed EUVA in 2002 largely in response to overseas EUV lithography consortia, such as the EUV LLC initiated by Intel, and the concern that overseas rivals would obtain dominance in this technology. Like the VLSI consortium, there are indications that it is hampered by rivalry among its members.<sup>184</sup>

It is unclear what proportion of Japan's current S&T budget supports consortium R&D. In the 1980s and early 1990s, consortium projects accounted for approximately 5 percent of total annual government S&T expenditures.<sup>185</sup> However, they probably accounted for between 17 and 43 percent of *extra-mural*<sup>186</sup> *project-specific* expenditures, 23–84 percent if MEXT-grants-in-aid are excluded.<sup>187</sup> Although consortium research probably does not constitute a majority of government funding for research even in priority fields such as IT, materials, energy or environment, and biomedicine, in certain subfields where commercial applications are likely to follow closely from basic research discoveries, consortium projects do constitute a significant proportion of such funding, especially if MEXT grants-in-aid are excluded.

The following observations regarding projects initiated in 2005 under some of Japan's main S&T programs elaborate on this point:

I began by reviewing the funding announcements for new *NEDO projects*.<sup>188</sup> The new 2005 NEDO projects run the gamut from numerous small-scale field tests for photovoltaic solar panels, and a large number of demonstration projects for biomass energy production, to major projects in biomedicine,

wireless communication, micro-electrical mechanical systems (MEMS) and nanotechnology. In between are a large number of NEDO awards for R&D projects proposed by companies and university researchers for R&D likely to have applications in various industries. Only a minority of the NEDO projects appear to qualify as consortium research. Many involve support to a single university laboratory, TLO, or company. There are many examples of support to small companies and to regional universities and their TLOs.

However, in research fields where international competition and the potential for commercial application are high, consortia-type projects linking major university laboratories to established companies is a common form of research organization. For example, the nanotechnology projects initiated by NEDO in 2005 typically involved teams consisting of a university (or GRI) and two companies, one usually a major company and the other a small company.<sup>189</sup> Examination of the participants in projects initiated in prior years under METI/NEDO's nanotechnology initiative suggests that large companies play an even more dominant role.<sup>190</sup> NEDO R&D projects in MEMS, semiconductors, digital display and networking, fuel cells, and various fields of biomedicine, show similar patterns. Typically several large companies and universities are involved in a subproject—less frequently just a single large company and one or more universities and sometimes also a small company. Projects funded by the Key Technology Center also have aimed at developing industrially relevant technologies via consortia consisting of universities and large companies, although recently in biomedicine and software, small companies have also been frequent participants.<sup>191</sup>

Lists of R&D projects initiated in 2005 by the *Ministry of Internal Affairs and Communications (MIC)*<sup>192</sup> also show a diverse range of projects and participants. About a quarter involve large companies and about half of these also involve at least one other large company, a university, or both. These latter consortium-type projects appear to be the most broad and technically advanced of all the MIC R&D projects.<sup>193</sup> Also, when universities are partnered with companies, generally better-known universities are partnered with large companies, while regional universities are partnered with the small or regional companies.

Most of *MHLW's* support for extramural biomedical R&D is disbursed as grants-in-aid to university researchers.<sup>194</sup> However, about 25 percent is disbursed as projects funded by *OPSR*,<sup>195</sup> of which about 10 percent involve private companies—about half of which are large.<sup>196</sup> In addition, since 1988, *OPSR* has initiated at least fifteen incorporated consortia to pursue and commercialize R&D in fields such as drug delivery systems, gene therapy, and noninvasive diagnostic methods. The number of corporate participants in

each consortium has ranged from two to twelve. All but two of the participants were founded before 1954 and have over 1,000 employees.<sup>197</sup> OPSR invested a considerable sum, between 7 and 40 million US\$, in each consortium.

*JST CREST* projects usually involve 2–5 university/GRI laboratories working on a particular project. About 10 percent also involve companies. But in IT fields, about 20 percent of participants are companies, and the majority of these are large.<sup>198</sup>

Most other *MEXT* R&D support does not involve companies. However, its Special Coordination Funds do fund some joint research with companies, notably the *Joint Industry, University and Government Cooperative Research Program* which initiated twelve consortia in 2005. Led by university researchers, all the corporate participants are large companies.

This summary of current consortium research in several major government R&D funding programs suggests that consortia that include large companies are an important part of the S&T landscape in fields likely to have near or mid-term industrial applications—and such projects are also an important part of the university R&D landscape in such fields.<sup>199</sup> Compared to earlier consortia, current consortia are more likely to have small companies as participants, while participation by rival large companies is less frequent.<sup>200</sup> Nevertheless, in most of the projects in advanced fields of technology where commercial applications are apparent, large companies are frequent participants.

Are such consortia effective in promoting innovation? Even if they are, do they result in large companies preempting the results of publicly funded research and new market opportunities that ventures might otherwise exploit?

The first question continues to be debated the world over, and this book does not attempt a definitive answer. In the context of Japan, some studies have addressed this question by analyzing joint publications by university and company researchers, and/or patents by consortia or their member companies. The implications of these analyses are not clear. One study that compared participants with nonparticipants suggested a small benefit in terms of issued US patents in the years following the initiation of consortium research.<sup>201</sup> With a few exceptions, anecdotal comments prior to 2003 by academic and industry researchers about the value of consortia have ranged from noncommittal to negative, while my analysis of patents related to the OPSR consortia suggests that only a small proportion of consortia can claim success.<sup>202</sup> However, beginning around 2004 perceptions seemed to shift. Both university and industry researchers began to speak more favorably about *joint research*, although the industry researchers either do not distinguish between *government-initiated* consortia and *company-initiated* joint research projects, or confine positive assessments to the latter.

Studies of consortia participants indicate that consortia facilitate diversification of existing companies into high-growth industries. This diversification often is into fields occupied by either the suppliers of inputs to the consortium participants or by clients of the consortium participants. The prospect of upstream or downstream diversification is probably the primary motivation for companies to participate in consortia.<sup>203</sup> The consortia with which I am familiar generally support this conclusion—although government prodding often plays a role. Sometimes the diversity of participants reflects specific sub goals of a consortium (e.g. developing a particular instrument that other members can use) or the government's attempt to promote the diffusion of knowledge from stronger to weaker companies.<sup>204</sup> Thus *consortia may facilitate vertical integration by existing companies*—or at least they offer old companies a chance to learn new tricks.<sup>205</sup> While this may benefit established companies, *it tends to limit the niches available for new companies*. More specifically it reduces their potential customer base, and it limits the scope for startup formation from universities.

The following account from the CEO of a recently formed bio-startup illustrates this phenomenon. The startup specializes in a field of protein biology applicable to drug discovery and the reduction of adverse side effects. About the same time as the startup was formed, a government agency launched a consortium dealing with the same field of protein biology. The consortium members included three of Japan's largest pharmaceutical companies, six midsize pharmaceutical companies, several chemical companies, a major electronics company, three universities, one GRI, and another government organized consortium. The founders of the venture were invited to join but declined because of distance to the consortium's dedicated laboratory. If they had become involved, the startup may never have been formed. The startup has not been able to recruit clients from among the consortium participants, even though the midsize companies probably constitute a good match in terms of their needs and the services the startup can provide. The startup's CEO attributes most of this difficulty to financial and bureaucratic factors within the member companies and to loss of market opportunities caused by the consortium.

Each corporate member had to pay over 1 million USD to participate in the consortium, an amount that senior officials in the corporate hierarchy had to approve. Not being experts in the field, these officials expected that their companies would learn all they needed about this particular technology through joining the consortium. They viewed participation as an opportunity to evaluate particular compounds of interest to their companies using tests that were similar to those constituting my start up's core business. They also felt that the consortium fees had exhausted the funds they were willing to allocate to exploring the usefulness of this method of drug discovery. This

in itself probably cost our company business. Without the consortium, some of the members would likely have become our customers.

But in addition, we believe our specific analytical technology is superior to the consortium's, and we offer better ongoing analysis geared to the specific long-term R&D needs of pharmaceutical companies. After all, the goal of the consortium is to pursue exploratory R&D relating to the underlying science and various analytical methods—not to be a test laboratory to meet the specific commercial needs of members. But it has been difficult to convince senior management in the member companies that we offer better analysis than the consortium provides. Even when we convince the bench level corporate scientists, it is hard for them to convince senior management that we offer more than what their company has already paid for through consortium membership.

Establishment of consortia does not always lead to preemption of a new field by the established consortia members. For example, there are several bioventures developing drug delivery technologies, even though this was the subject of one of OPSR's most successful consortia.<sup>206</sup> But drug delivery is a wide field. In narrower fields, the efforts of S&T agencies to promote consortia as a means to create synergies among companies and to transfer expertise to existing small companies may have negative overall effects. They thwart new companies that might otherwise have made new technologies their own niche; attracted customers, capital, and personnel; increased capabilities; and then attracted more customers in a virtuous cycle. They diffuse a certain amount of knowledge among member companies, often enough so that the members feel they can go it alone and pursue autarkic development in the particular field. But rarely does any member emerge from consortia R&D with a new commitment to advance the consortium technology, to 'run with it' or 'make it its own'. Indeed, because of the sharing of information and IP rights inherent in the consortium structure,<sup>207</sup> this would be difficult. In short, the government's continuing policy of promoting consortium research paradoxically promotes the persistence of autarkic innovation within existing companies, and quenches market forces that might otherwise have fostered the growth of strong new companies. It creates another tragedy of the commons.<sup>208</sup>

NEDO, JST, and OPSR probably seek to include ventures in their consortia whenever possible. Ventures generally welcome invitations to participate. For them the main incentive is access to government funding, not collaboration with other companies interested in the same field.<sup>209</sup> Usually the CEOs of ventures that have participated in consortia say they must be circumspect regarding disclosure of their technology to other members, and they must file patents on their own before collaboration.<sup>210</sup> For them and their investors, any requirement that the venture's inventions be jointly owned either by

the consortium or by other members is usually a major disincentive to participate.<sup>211</sup>

As for entrepreneurial university researchers interested in forming a startup, they often practice *entrepreneurship under the gaze of large collaborators* because they are frequently involved in consortia or in joint research with large companies.<sup>212</sup> The more interesting and commercially applicable their research, the more likely their collaborators are to be interested in it, even though these collaborators may not follow through with a concerted development effort. This has probably led to a tendency, to found startups that have a circumscribed technical focus and thus limited prospects for growth.<sup>213</sup> Patents and copyrights covering early-stage inventions often enable pharmaceutical and software startups to protect *final commercial products*, and thus may prevent encroachment, even at an early stage, by companies engaged in consortium or other joint research with the founder's laboratory. However, this may rarely be the case in other technical fields. Recalling the above discussion whether patents are effective protection only for pharmaceutical ventures, this perhaps qualifies my conclusion (based on the US experience) that they do protect ventures in other industries. In other words, if a startup emerges under the gaze of collaborating companies with vastly superior R&D resources, patents that do not cover final products can either be engineered around or countered by patents that cover final products. In either case, if the startup does not grow quickly and if the larger companies decide to develop the technology themselves, the startup will likely be forced into unfavorable cross-licensing situations that leave markets for high value-added products in the hands of the large collaborators.

One exception to the dearth of promising university startups outside biomedicine and software is a venture based on novel materials-chemistry technology. The founder filed the first patent applications related to this technology around 2000. Soon companies began to inquire about the technology. The founder initially refused to enter into joint research contracts with them because he knew that under the terms of such contracts, the companies could probably insist on co-ownership of related inventions. Instead, he would send samples to them and do other work for free. In 2005, shortly after the founding of the startup, approximately ten companies representing various industries were engaged in informal collaborations with the founder's laboratory. Some of these provided ideas for specific commercial applications of the startup's technology. His company has issued limited-field-of-use exclusive licenses to some of these companies. It remains to be seen whether these collaborators will become customers of the startup, or whether they will simply try to monitor R&D progress and position themselves to take over the commercialization of whatever prototype products the startup develops. After some

painful lessons,<sup>214</sup> the founder and the startup have learned how to protect their IP position. But with a staff of less than ten, it is not clear that it can grow rapidly into a company that can command a monopoly over high value-added products and services that it can sell to many customers.<sup>215</sup>

However, probably the greatest negative impact of consortia and other joint research on university entrepreneurship is that *they decrease incentives for faculty to start companies and for students to seriously consider jobs in ventures*. When the founder was asked if any colleagues were following his example and establishing their own companies, his reply was negative.

Although we all hope to see practical benefits to society emerge from our research, most university researchers prefer to leave development and commercialization to existing companies. It is much easier that way. Besides, cooperating with large companies under joint research contracts or consortium agreements provides a steady stream of financial support, and sometimes the collaborators dispatch researchers to the university laboratories contributing to the overall research effort. To be a university entrepreneur is still to swim against a swift current, especially when it is so hard to find skilled managers and to recruit skilled researchers. It has taken much time and effort.

At least in elite universities, the same perspective prevails among masters students, who constitute the majority of S&T graduate students. The students who are doing well on the joint research projects are often recruited into the collaborating companies. There they often can continue the same line of research. They are well paid. Their future is secure—probably. There is a reasonable chance that their efforts will result in some tangible product or social benefit. To work in a venture seems like risky small potatoes. Life in a big company is so much easier—and respectable.

It has been suggested that consortia are particularly appropriate for Japan because company creation is difficult in S&T fields. Thus the only way to commercialize new S&T opportunities is for established companies to diversify into these new fields, and consortia help facilitate this diversification. Similarly, consortia are a means of promoting interfirm communication, which would otherwise be low due to the system of lifetime employment and the tendency for autarkic innovation that it engenders.<sup>216</sup> However *promoting consortia helps to perpetuate the very conditions it was intended to alleviate*. How much harm consortia do to entrepreneurship and venture companies is still an open question. My sense is that the harm is significant.

If consortia provided benefits for established companies that outweighed the negative effects on ventures, promoting consortia projects could probably be justified. However, to answer the question posed at the beginning of this subsection, on the basis of available statistical and anecdotal evidence *the benefits of consortia for established companies seem modest at best*.<sup>217</sup>

But in the case of *privately initiated joint research*, there is considerable evidence that such research has helped large companies, and sometimes small companies as well. In the long run, the improved environment for joint research might help shift the balance in terms of access to university discoveries from established to new companies, but in the near term, it seems that it is enabling established companies to claim a significant proportion of university discoveries, at least in non life science fields.<sup>218</sup> Time will tell whether these closer ties with universities will enable established Japanese companies to be the engines of innovation that venture companies are in the USA.

### Strong Internal Innovation Capabilities

So if consortia and other forms of industrial policy are not the reason for Japan's innovative strength, what is? Japanese writers generally mention teamwork, attention to quality, continuous innovation, and persistent long-term focus on the core business and on the laboratories, shop floors, marketing offices, retail shops, and service centers where value-adding activities occur.<sup>219</sup> More specifically, analyses of the computer, chemical/materials, and machine tool industries have shown closer linkages between research/design, product development, and manufacturing in Japan compared with the USA. These linkages are built largely on personnel transfers: especially from research laboratories to the more applied, product development laboratories; but also between product development and manufacturing. Such transfers can ensure continuity in the progression from research, to design, development and finally manufacturing.<sup>220</sup> These linkages are also built on close communication between shop-level workers and design engineers, in other words, on active feedback between R&D professionals and manufacturing/production staff.<sup>221</sup>

These strengths depend in large part on a long-term commitment on the part of employees to work diligently for the same company throughout most of their careers (and to be willing to forgo near term wage increases in the interest of long-term corporate profitability), and a reciprocal commitment on the part of managers to protect the interests of incumbent employees, particularly job security. The personnel management policies listed below have helped to create this commitment. Along with a high general level of education among even blue-collar workers, they have also facilitated the teamwork and the delegation of substantial decision-making authority to the team level (at least in production operations) that in turn has facilitated rapid improvements in products and manufacturing processes:<sup>222</sup>

1. Early, prolonged and *company-specific training and acculturation*: Most new hires are new university graduates with BS or MS degrees who enter the company at one time (usually in early April). Each year's cohort undergoes an introductory training program that lasts several months and constitutes an intense shared experience that provides the basis for horizontal communication long after they have been assigned to various different posts. The first two years of an engineer's career are spent largely in apprenticeship roles. New recruits who do not seem to fit are encouraged to leave during this initial period. Large companies still prefer to hire masters or bachelor degree graduates and to train them in house. Thus the number of corporate researchers with university Ph.D. training, and thus transferable high level skills, are limited.<sup>223</sup>
2. *Salary grades and job titles are uniform* throughout a corporation, so that no particular branch has more distinctive titles or higher salaries, thus facilitating the transfer of employees widely among the corporation and establishing nominal status equality among all branches of the corporation.<sup>224</sup>
3. Authority over recruitment and job rotations is concentrated in a *central personnel office*, unlike the USA where recruitment and initial promotions are the responsibility of individual research groups. Thus the interest of the entire corporation is paramount in these decisions. Unlike US engineers who spend most of their time in a particular laboratory developing expertise in a particular area, Japanese engineers are rotated to facilitate knowledge sharing, to instill in individual employees a broad familiarity with the corporation and a multi-development-stage perspective on problem solving, to discourage identification with a specific subunit or specialty, and to ensure continuity in the development of new products: the maxim 'to move information, move people' governs many personnel assignments. In case special skills are needed, the maxim 'make, don't buy' usually governs. Thus when Toshiba needed linguistic expertise to help develop software for a Japanese-language word processor, instead of hiring a linguist it sent one of its own engineers to Kyoto University to study linguistics for a year.<sup>225</sup>
4. *Promotions* are decided by relatively senior section chiefs who are usually responsible for evaluating a larger number of persons than their US counterparts. Whereas US evaluations emphasize technical achievements, sometimes over a short time on one particular project, Japanese evaluations consider performance over a longer period and emphasize social and psychological qualities—effectiveness of relationships with coworkers, communication skills, drive and initiative, dependability,

and (in the context of promotion to R&D team leader) administrative ability.<sup>226</sup> Not until mid-career, however, do differences begin to appear among members of the same entry cohort with respect to job rank and salary.<sup>227</sup> Ability and good performance are rewarded by more interesting assignments, opportunities to study abroad or to do research that might be submitted to a Japanese university for a doctoral degree, the respect of superiors and peers, and the expectation that one has a good chance to become a senior manager in a product division or (if exceptionally talented or lucky) a senior manager in an R&D laboratory. In the case of less productive workers, transfers are often arranged to subsidiary companies where salary scales are lower.

5. For employees hired before the late 1990s, it is necessary to work until at least age 50 to receive substantial *pension benefits*. In the case of large manufacturing companies, these are often paid out in lump sums on retirement, typically US\$200,000 to 300,000 for a senior engineer who retires at the mandatory age of 60.<sup>228</sup> Although government mandated pension programs also provide benefits, when amortized over an expected post-retirement lifespan the lump sum corporate pensions usually account for about half of total post-retirement income.<sup>229</sup> Therefore, except in the case of recently hired employees, the pension system creates a strong incentive to keep working in the same company until retirement age. Leaving to join a venture at age 40 is a costly option, and usually there is no bridge back because large companies rarely recruit personnel from other companies in mid-career.<sup>230</sup> Coupled with the threat of transfer to a subsidiary, the traditional pension system creates considerable incentives to remain with large manufacturing companies until retirement.

However, thanks to changes in pension systems implemented around 1999, newly hired employees in many of the major electronics companies have fewer constraints on changing jobs.<sup>231</sup> Newly hired employees usually have a choice to manage all their retirement funds on their own or to accumulate benefits as they work.<sup>232</sup> In either case, benefits accrue approximately *linearly* and vest immediately. Thus if an employee hired after 1999 leaves at age 35 or 40 after ten or fifteen years of service, he or she will receive pension contributions from his or her employer amounting roughly to the same proportion of cumulative salary as if he or she had worked to age 55 or 60. *This represents a major change by major Japanese manufacturers.* When I asked about the rationale, the response was that this was a step to enhance employee mobility and to move away from the system of lifetime employment.<sup>233</sup>

Almost all young new employees select the new 'standard' plan that lets pension benefits accrue and at a steady rate, but leaves management up to the company—only mid-career hires choose to manage pension contributions on their own.<sup>234</sup> It is probably too early to tell if these pension reforms will affect the rate at which employees change jobs.<sup>235</sup>

With the exception of these recent pension reforms, the same personnel policies that have strengthened the innovation capabilities of large, established companies have also reduced growth opportunities for new high technology companies. Capable managers and researchers face financial sacrifice if they leave large companies in their 30s or 40s, unless they were hired after the late 1990s. In addition, even the best engineers in large Japanese companies are probably less likely than their US counterparts to regard themselves as *masters of a particular technology* which they could conceivably spin off into an independent venture in the way that US counterparts have.

As for partnering with ventures formed by outsiders, a strong preference probably remains, reflecting the 'make, don't buy' maxim, to have insiders take on potentially important projects rather than to leave them to outsiders. Also, large companies probably still prefer to innovate by developing an in-house knowledge base rather than pursuing breakthrough innovation that might likely require thorough reorganization of R&D teams.<sup>236</sup> The more finely interconnected and balanced an organization is internally, the more disruptive may be incorporation of an independent outside partner.

Finally, the flip side of being thoroughly acculturated to a particular organization is insularity. A retired Japanese electronics industry executive who became a venture business manager and consultant recently said that scientists and managers in large IT companies have difficulty conceptualizing why outside partnerships might be valuable and how partnerships might work—let alone communicating to potential partners a vision of a mutually beneficial collaboration. He also noted that obtaining permission to attend an outside conference is difficult. 'Unless you are a senior researcher, you can only go as part of a team.' This is consistent with observations that, in order to limit leakage of information to outsiders and prevent possible defections, while at the same time being able to negotiate information trades, large Japanese companies have information *gatekeepers*—senior researchers and managers with exclusive responsibility to represent the company at conferences and to negotiate transfers of information.<sup>237</sup>

In my discussions about the barriers to collaboration with ventures, these issues come through in a nuanced manner. Scientists and managers in large companies usually do not say that they prefer self-reliance because communication with insiders is easier than with outsiders, nor do they say they do not want to deprive their own researchers of work opportunities. More often

their reasons for not seeking out collaborations with new companies tend to be that senior corporate officials do not understand or trust the technologies of the new companies, their budgets for collaborative activities are insufficient, or they simply do not have offices or personnel whose main responsibility is to initiate and manage collaborative R&D.<sup>238</sup> In other words, the proffered reasons for autarky are quite prosaic. However, I suspect that these budgetary and administrative reasons reflect a corporate ethos and *modus operandi* that are geared toward self-reliance, maintaining the integrity of the corporate body with all its employees, and engaging in outside collaborations only if they do not threaten to destabilize the corporate body.

Collaborations do occur, especially with other large companies and overseas ventures, and once an agreement has been worked out, the collaborations generally are stable and both sides are satisfied.<sup>239</sup> But my impression is that collaborations usually take a long time to work out and must be highly choreographed, in part to address internal personnel,<sup>240</sup> communications,<sup>241</sup> and technology-sourcing issues on the Japanese side.

Finally, large Japanese corporations seem to enter more quickly into partnerships with independent small companies when the latter's business is circumscribed. They are ready, for example, to negotiate exclusive licenses to candidate drugs from biotech companies. They are comfortable working with a university startup whose only business is to manufacture specialty IC chips in small quantities for sale to large companies for developmental work.<sup>242</sup> After considerable negotiations, they are willing to purchase machines that make products central to their main business, and even to invest in the company that makes the machines.<sup>243</sup> But as other examples in Chapter 4 indicate, they take a long time to become customers of new companies developing technologies with broad, multiple applications that relate to their core business. With a few exceptions, they do not invest in Japanese biotechs that have promising drug development programs and want to maintain their independence.<sup>244</sup> Partnerships with ventures to jointly develop pioneering, risky technologies that nevertheless have considerable commercial potential seem difficult to negotiate and carry forward.<sup>245</sup>

More information on how companies make decisions concerning collaborations would be helpful to confirm what these anecdotal cases suggest: *the autarkic innovation practices of large Japanese companies, which are to a large extent the product of their personnel management system, limit growth opportunities for new companies.*<sup>246</sup> For new companies, simply discovering promising niches in which to develop new technologies is usually not sufficient. Large companies also need to believe that it makes business sense to rely on new companies to develop early stage technologies and to encourage their long-term growth—including sometimes ceding to them the initiative to

pursue development. Japanese companies appear to lack this ability to accept independent new companies as such a resource, even though in doing so they would be leveraging outside capital and letting others bear much of the early development risk.

Because their personnel management policies are the source of considerable strength in their core fields of business, large companies will hesitate to change these policies quickly. The following part examines other factors that inhibit change and alternative strategies for established companies to remain in the forefront of early stage innovation.

## PART VII: PROSPECTS FOR CHANGE IN JAPAN

### **Lifetime Employment and Labor Mobility**

Among Japanese manufacturing industries, employment data usually show a sharp increase in 2002 in the numbers of male employees leaving jobs in large companies, but by 2004, the rates of these mid-career job departures had decreased to 1995 levels.<sup>247</sup> This indicates that during the worst period of Japan's recent recession, an unusually large number of employees left large firms in mid-career, but as the economy recovered, these departure rates receded to levels when lifetime employment seemed more secure. Acquaintances in large high technology manufacturing companies generally describe the same phenomenon: after a round of shedding employees around 2002, companies are now lean and profitable and few employees (especially those in R&D) are leaving in mid-career.

The data in Appendix 7.4 cover all employees, not just those in R&D. Between roughly 2000 and 2005, all Japanese electronics manufacturers wanted to downsize their work forces by 10–20 percent.<sup>248</sup> Nevertheless, they tried to avoid dismissing design engineers and scientists, that is, those involved in research and new product development. One senior manager, confronted with the problem of what to do with engineers who had developed expertise in technologies his company no longer needed (and having no funds available for retraining) took on himself the task of retraining these engineers on weekends, so that they could either take on different work in his own division or move to other divisions. He described this as a 'slow, resource intensive process, which nevertheless might pay off because the engineers, although no longer young, are motivated and bright. Having them leave the company was to be avoided, if at all possible.'

*Advantage New Companies*

283

Nevertheless, large electronics companies have tried various strategies to reduce even their engineering workforces. Some entered into joint ventures with other companies to spin off noncore operations. Personnel dispatched to the venture might have their salaries guaranteed for two years, after which time they would be solely under the jurisdiction of the venture. On at least one occasion, however, parents of the transferees complained so bitterly to the parent companies (they wanted their sons to continue working for a brand-name company, asserting that when their sons were hired there was mutual expectation of career-long employment), that the plan to form the venture was abandoned. Some large electronic companies have sold off noncore operations, often to foreign buyers. However, the sales contracts usually stipulate that no workers will be dismissed, at least within a defined time period. Therefore, the spun-off operations usually are not very profitable.<sup>249</sup> A traditional practice has been to push workers over 50 into subsidiaries. However, at the depth of Japan's recession, the subsidiaries could not absorb all the transferees. Another strategy has been to offer severance packages, in addition to accumulated pensions, to encourage early retirement. In the case of one company that offered over two years' total salary (including bonuses) most of the persons who accepted the packages were over 50 and they simply ended their working careers.<sup>250</sup> A final strategy is to switch employees to work under a private outside contractor.<sup>251</sup>

As for smaller manufacturing companies, the overall mid-career job departure rates suggest that job losses began earlier and were more prolonged than in the large companies. Generally the rates in small firms were about twice those in large firms, except in 2002 when the large firm departure rate began to approach that in small companies (see Appendix 7.4). However, some of the departures among the younger age groups (30–39 years of age) may be persons starting their own firms. Also, somewhat surprisingly, while total male manufacturing employment in large companies decreased nearly 30 percent between 1994 and 2004, it decreased only about 10 percent in companies with fewer than 1,000 employees. Perhaps this was due to job circulation among small firms and also to the smaller companies absorbing some of the persons laid off from large companies.<sup>252</sup> Female manufacturing employment is only 4 percent of male manufacturing employment and declined in firms of all sizes between 1995 and 2004.<sup>253</sup> *Thus although the overall size of the large company manufacturing sector has decreased, lifetime employment still endures despite a blip of mid-career departures around 2002.* In smaller manufacturing companies, lifetime employment (to the extent it ever was the norm) eroded more quickly and has recovered more slowly, but total sector employment has declined only slightly.

In early 2006 as a sustained recovery of the Japanese economy seemed underway, the chairman of the Japan Business Federation,<sup>254</sup> Hiroshi Okuda<sup>255</sup> summarized the perspective of many large manufacturing companies regarding R&D and employment. Mr Okuda attributed Japan's economic recovery in part to companies treating R&D as a *sanctuary* amidst the cost reductions they had to make during the recession. He also praised Keidanren companies for following *Japanese management principles* based on *respect for human beings* and *taking a long-term perspective*. As a result, unemployment did not exceed 5.5 percent during the worst period of the prolonged economic slump, while it would have reached 10 percent if companies had they followed the American model of large-scale layoffs in times of economic distress. These Japanese management principles allowed companies and society to adjust gradually to forces of globalization without large-scale disruption.<sup>256</sup> The truth of these assertions aside, these remarks suggest that the system of lifetime employment, particularly among R&D personnel in large companies, has not drastically changed. Thus the negative effects of this system on S&T ventures will probably persist for some time.

Responses to a questionnaire I give yearly to new graduate students in my university center suggest that very few want to work in venture companies where risks and potential rewards are high.<sup>257</sup> Available survey data suggest that the expectation of lifetime employment was greater in 2004 than in 1999, even among persons just starting their careers.<sup>258</sup>

The extent to which companies can use laws to prevent unfair competition to prevent R&D employees from changing jobs has not been clearly tested in Japanese courts. However, the principal law in this area was strengthened in 2005 primarily to prevent Japanese technology leaking to rival companies overseas (particularly in Asia). The revised law authorizes criminal penalties for the disclosure of trade secrets even when acquired in the normal course of an employee's work.<sup>259</sup> Judicial procedures now permit in camera disclosures of confidential business information in unfair competition cases, removing a major disincentive for companies to sue former employees for trade secret infringement.<sup>260</sup>

In addition, provisions in employment contracts<sup>261</sup> that forbid employees to engage in subsequent work that will involve disclosure of trade secrets will likely be upheld by Japanese courts if the time period is 'reasonable'. Courts would probably consider both the previous employer's investment in the technology<sup>262</sup> and the rate at which the knowledge will become obsolete to determine what a 'reasonable' period should be. Generally Japanese attorneys think that most courts would accept a one-year limitation. Limitations of as long as five years might be acceptable in certain circumstances.<sup>263</sup>

I have yet to find a court decision that deals specifically with an R&D employee leaving to work in a new company where she or he will continue the previous line of work but where the only information taken to the new job is in the employee's head. In cases that raise similar issues, however, courts seem to be reluctant to find employees who change domestic employers liable either for violating trade secret laws or noncompetition agreements. Nevertheless, the courts have implied that might find former employees liable if trade secrets are clearly defined and if no-compete clauses are clearly drafted.<sup>264</sup> In other words, the door seems open for companies to try to prevent their employees moving to rivals by designating broad swaths of their R&D activities as confidential to be treated as trade secrets, and then including provisions in employment/severance contracts that prohibit work in these areas with another company. Attorneys familiar with trade secret issues say that many companies are taking these steps.

Nevertheless, as indicated by the changes in corporate pension plans, companies are becoming more permissive toward valued employees changing jobs. But how one leaves is important, and the best assurance that one will not be sued is to reach an understanding with the current employer about the scope of one's future work. The sorts of job changes that gave birth to Intel, other Silicon Valley companies, Amdahl Computers, and some of the hard disk drive spin-offs (departures to new companies that were going to compete with the former employer) would be extremely risky in Japan.

I have heard of only one case where threats under unfair competition laws were used to prevent an employee moving to an S&T venture. Ironically but not surprisingly, this involved a potential job change between two ventures.<sup>265</sup>

Finally, social pressure to work in large companies, particularly from parents and wives, remains high. The factors behind this are complex but probably include the difficulty Japanese women face balancing the expectations of work and family. Families with children (or elderly parents requiring care) where both spouses have professional careers are rare.<sup>266</sup> Thus the family faces high risks when the main breadwinner moves from an established company to a venture.

Another underlying factor relates to the educational system, especially the monopoly on *gateways to success* held by a small number of schools and the grueling childhood-long preparation for examinations to enter those schools.<sup>267</sup> Early in life, largely as a result of parental pressure, learning and the notion of what constitutes meaningful life work become subsumed by the need to pass a series of examinations that stress accumulated knowledge. Children learn that the paths and gateways to success are few, and that internalization of these standards of success<sup>268</sup> is necessary to pass through the

gateways and reach the stage where they have the social standing to chart their own destinies.<sup>269</sup>

However, by this time the damage has already been done in the case of many bright, energetic students. Having been forced so long to conform to these externally set criteria for success, and having learned to regard knowledge mainly as accumulation of facts in order to provide the correct response to examination questions, the natural trajectory for many bright new graduates is to continue to conform to the expectations of family and the large companies in which most S&E graduates from prestigious universities find their first jobs. To preserve or re-ignite a maverick or independent mind set after long years of accumulating facts, or simply to pursue a new line of work because one finds it enjoyable, is difficult.

Once one joins a large company, the process of in-house training, intense acculturation and frequent job rotations, does little to reignite such a maverick spirit. Of course, even those who are bent to the system do develop their own interests up to a point. Among those serious about learning and who desire professional careers, a few are willing to pursue their own interests even to the point of having nonconforming, unconventional careers. I have taught some such students. I have interviewed others who are now running their own companies and some who still remain in large companies. But my sense is that the numbers are small. In other words, the educational system, family pressures, and the system of personnel management in large companies, make the likelihood that a bright, energetic scientist, engineer, or R&D manager will want to leave a large company (or a secure university position) to work in a venture company considerably less than in the USA.

This is not to argue that the US educational system is superior, or that Japan's educational system will tend to evolve naturally toward that of the USA. (Indeed, in the latter regard, the opposite is more likely.<sup>270</sup>) Japan's primary and secondary schools have produced graduates with higher proficiencies in mathematics and science than those in the USA.<sup>271</sup> The flip side of not having to cram for one exam after another is that US students tend to enter university with less proficiency in core areas than their Japanese counterparts, and that valuable time must be spent on remedial courses. The confidence that helps Americans to form ventures may be a confidence born out of a seemingly naive lack of awareness of their own limitations, which their Japanese counterparts do not share because they have gone through grueling knowledge accumulation, testing and ranking against their peers.

There are some fundamental changes that favor ventures. Unlike the situation described twenty years ago,<sup>272</sup> my conversations with S&T professors and students indicate that graduating students now have primary responsibility for finding jobs. They are the ones who initiate contact with potential employers.

Their professors are willing to recommend company contacts, if asked, and a letter of recommendation from the professor can clinch a job. But at least in the case of graduates from top tier universities, students are now responsible for charting their entry into the working world. This is important, not only because it indicates they are assuming responsibility for their own careers, but also, if they should later want to leave their initial job, they no longer have to feel they are sully their professor's reputation with their first employer.<sup>273</sup>

Also, it no longer seems the case that leaving a company to join a new company is automatically regarded as *betrayal*. The former chairman of the entertainment subsidiary of a large S&T company recently said,

Things are different now. It is possible for an important employee to leave to start his or her own company and even continue to have business relations with the former employer. What matters is employee's reputation before departure. Was s/he reliable and of good character? Was the decision to leave made with serious consideration?

Others have remarked, 'How one leaves is important'. I believe this means that if one has the reputation of being capable and sincere, if one can convince the company that the decision to leave makes sense from the standpoint of the employee's inner motivations and his or her business plans, and if one will not act against the company's interests, then departure can often occur amicably. Nevertheless, changing jobs probably still raises more sensitivities on both sides than in the USA.<sup>274</sup>

As noted earlier, some major manufacturing companies have changed their pension systems so that pension funds accrue and vest linearly. Therefore an employee who changes jobs can collect accrued pension funds on departure and does not forgo pension benefits. This ought to decrease disincentives to changing jobs for employees who want to leave to join ventures, as well as those whom the company wants to ease out. However, any positive effect for ventures probably will not become apparent until about 2010 or later.

Many companies have adopted merit pay systems. However, whether these systems will undermine lifetime employment and promote labor mobility is not clear.<sup>275</sup>

The rate of cross-company and long-term shareholding has decreased in Japan.<sup>276</sup> Thus in theory, Japanese companies are exposed to more pressure from shareholders to show profitability—and to make potentially painful workforce reductions in order to do so. However, it appears that so far such pressures have been muted. Reciprocal obligations between employer and employee are still widely felt, and widely regarded as a positive social norm.

Of course, only a few persons need become entrepreneurs in order for entrepreneurial companies to thrive. The cases in Chapter 4 indicate that a small stream of experienced engineers and managers are leaving large companies to form the backbones of a small but steadily growing number of IT hardware ventures. But for the reasons already mentioned, it is unlikely that the small stream will grow wider soon.

Lack of skilled researchers and managers moving from pharmaceutical companies to bioventures has been one of the latter's greatest problems, although since 2005 such transfers have been more frequent. Whether this is a one-time infusion due to mergers and reduction of R&D in some pharmaceutical companies, or is a sign of increasing interest among pharmaceutical employees in changing jobs is an open question. However, considering the advantages of bioventures relative to other ventures,<sup>277</sup> if the flow of personnel from pharmaceutical companies will continue to grow, then their overall long-term outlook is probably fairly bright.

#### **Universities: Wellsprings of New Companies or Contract Researchers for Old?**

University and GRI research is becoming increasingly important for both established and new companies. If few persons will leave large companies to form independent spin-offs, then universities have to be the origin of most new discoveries that form the basis of new companies. As corporate basic research declines,<sup>278</sup> universities also become the source of most fundamental discoveries that will be the basis of many of the next generation products by established companies. In the USA, venture companies now are the main intermediary between university discoveries and pharmaceuticals. This probably is also the case in other industries.<sup>279</sup>

The environment for university startups in Japan has improved greatly thanks to reforms of the system of IP and technology management in universities and also to increased access to venture and government financing. Nevertheless, the overall system of university–industry cooperation still favors transfer of university discoveries to large companies. As shown in Chapter 3 and the discussion of consortia in this chapter, the reasons have little to do with laws, but much to do with:

- the weakness of university administrations and of most TLOs,
- hesitancy on the part of even the strongest universities to confront companies and demand higher license fees and stronger control over sponsored research,

- long established patterns of university–industry cooperation, in particular the preference of professors to work directly with companies without university interference and to favor large companies as partners,
- the active presence of researchers from large companies in many leading university laboratories,
- career preferences of graduates and their families that favor large companies,
- the tendency of Ph.D. programs and postdoctoral programs to be filled primarily with persons desiring academic careers—students interested in careers in industry having left after a bachelors or masters degree for company-specific training and acculturation in established companies, and
- issues related to promotions and research funding in universities; particularly peer review and university recruitment systems that are not geared to detect, and promote novel scientific research; emphasis on applied research that meets the needs of existing companies; and the continued prominence of consortium research.

In other words, the reasons that large companies are still the favored recipients of university discoveries have to do with institutional and social factors that are not easy to change and to the very success of policies to encourage closer collaboration with industry.

As for large Japanese manufacturers, since 2004 their senior officials frequently stress the need to engage in more cooperative research with Japanese universities in order to acquire new ‘seeds’ to develop into successful products. However, cooperation with Japanese ventures or other SMEs is hardly ever mentioned. The upsurge in joint research projects with universities, the prevalence of industry researchers on campus, and the high proportion of large company–university joint inventions, show this strategy is being pursued in earnest. Large manufacturing companies are now speaking favorably about collaborations with university laboratories. Researchers from Continental European countries at the University of Tokyo remark with admiration and a twinge of envy on the close cooperation between large companies and University of Tokyo laboratories.

This close collaboration, however, is resulting in the preemption of a large proportion of university discoveries, as well as the time and energy of university researchers. This is not to argue that such collaborations decrease the overall quality of university science, although this issue deserves further investigation. My impression is that scientists respected for their academic work and fundamental insights in fields relevant to industry are also those that

have many cooperative projects with industry. Ventures are not excluded from university–industry partnerships, but if they are included at all in cutting edge projects, it is most often as junior, limited-role partners with large established companies.

Thus we have in the making a great natural experiment comparing two different innovation systems. Will Japan's large companies rejuvenate themselves and become pioneer innovators in newly emerging fields of technology by partnering with universities? In new fields of IT materials, and energy-related technologies will they take back much of the discovery initiative that now seems to be held by new US companies? Will they compete effectively with large integrated companies in other countries, such as Samsung, that itself has dense, close ties with universities in its home country? We should have answers within a few years.

But one cautionary observation from Japan's own history is that its large companies have always had close ties with universities. Yet with a few exceptions, such as NTT laboratories assisting in the development of fiber optic cable and the VLSI project, or universities assisting in the development of amorphous silicon-based solar cells,<sup>280</sup> universities and GRIs probably were not critical contributors to Japan's economic miracle of the 1960s to 1980s. So if these close ties have always existed but were not crucial in the past, what has changed to expect that they will be crucial in the future? Perhaps now, with more of their employees on campus and faculty more attuned to commercial interests, the interaction will prove to be more productive. Also many of the joint research projects as well as many of the government funded consortia projects could be classified as translational research.<sup>281</sup> Assuming that there are more translational research projects now than ten years ago,<sup>282</sup> maybe this increase in publicly subsidized translational research will be sufficient to encourage established companies to pursue the development of new technologies arising in universities. Nevertheless established companies could have done all these activities under either joint research agreements or donations twenty years ago and received essentially the same degree of IP protection they obtain today. For established companies, the degree of access to university research has not changed, only the degree of public cofunding and perhaps the level of commercial interest among faculty.

The coming years will also provide insight into the most effective form of university–industry cooperation. Is the optimal system to commercialize university discoveries based on entrepreneurial faculty and strong entrepreneurial university administrations that control technology transfer via formal licensing and close oversight over contract research—realizing that this type of technology transfer system can lend itself well to creation of startups but

sometimes results in adversarial relations with existing companies? Or is the Japanese system based upon direct cooperation between professors and established companies, allowing the latter a free hand in technology management and downplaying entrepreneurialism a better way to promote the development of new technologies? The answer depends on whether new or established companies are better at early-stage innovation.

Japan's system is not necessarily inimical to startups. However, recent experience suggests that, in a weak entrepreneurial environment, a formal, US style technology transfer system promotes the formation of startups by providing an alternative to direct pass through of university discoveries to established companies and by raising faculty consciousness about the commercial potential of their discoveries. On the other hand, in an entrepreneurial environment where venture capital and other resources for startups are readily available, a system that leaves discretion about technology management largely in the hands of university inventors may be equally likely to promote startup formation (or even more likely, if TLOs are not competent).

## PART VIII: CONCLUSION

### **Japan: Shumpeterian End Game?**

For the foreseeable future, Japan will continue to be a country that relies on large established companies for innovation.

With a few exceptions, the Japanese government has already enacted most of the feasible legal reforms necessary to create a more hospitable environment for ventures. But the differences in innovation nevertheless persist. Whether large Japanese companies with their enhanced ties to universities can become innovation leaders in new fields of technology will become clear in the next few years.

However, it may be difficult for Japan to remain at the forefront of countries in terms of early stage innovation relying solely on its established companies, even if they have close links with universities. In other words, without vibrant new companies, Japan probably will not develop and commercialize early stage discoveries, especially in new fields of technology, as quickly as countries with such companies. The reasons include the following:

First, the handoff of new technologies from universities to industry is problematic. If an established company is already pursuing a particular line of R&D, the young researchers it sends to universities may learn useful things

about this field which they will take back to their companies and use. However, they will be less able to focus on new university discoveries with which they are relatively unfamiliar and even less able to convince their seniors in their companies to devote corporate resources to developing these new areas. Even if their seniors are present in the university laboratories, it will still be hard for them to convince the upper echelons of their companies to pursue promising university discoveries, unless the discoveries are so clearly winners that they would be developed in any innovation system. In contrast, university startups and independent spin-offs have a built in growth dynamic focused on new technologies. They are founded by university researchers or former employees of existing companies and their financial backers who believe there is commercial potential (often not immediately obvious) in particular university discoveries and who are committed to developing those discoveries.

Second, internal corporate decision-making and funding processes decrease the likelihood that new discoveries will be developed rapidly. Large established corporations tend, perhaps with good reason, to focus on existing lines of business and the products or services they are already producing well. For them to devote resources to develop new technologies in-house is a decision they have to undertake with some caution. Thus the approval and funding process tends to be bureaucratic and slower than in the case of a new company, which focuses just on one or two new technologies and (provided it operates in an open, rather than autarkic, innovation environment) aims to develop them for a wide variety of uses and markets.

Third, and perhaps most speculatively yet importantly, both small size and newness tend to enhance the motivation of employees and cooperation among them. Researchers and managers identify closely with the goals of their company and cooperate readily with each other to achieve these goals. At least in the case of managers and main researchers, working in a small company provides a sense of control over their destinies that most cherish and, for the preservation of which, they will work concertedly.<sup>283</sup>

The desire for independence and control over one's destiny is probably just as strong among Japanese as among westerners. As counterpoint to the oft-heard refrain that Japan's is fundamentally a village society—closed, hierarchical with strong communal obligations—one need only look out over a typical Japanese urban landscape to notice that most people live, not in apartment buildings, but in densely packed individual houses. In this respect, the contrast to the ubiquitous large apartment buildings of Singapore, Hong Kong, any modern mainland Chinese city, and even New York, Paris and Geneva is striking.<sup>284</sup> Families and individuals want their own space and privacy, limited

as they may be. It may be that crowding in Japan's small habitable land area has engendered a degree of sensitivity to others and a tendency to self-censorship that are unusual in other cultures. Nevertheless, desire for independence is not far below the surface.<sup>285</sup>

Perhaps one of the tragedies of Japan's modern systems of industrial organization and education is that they have not accommodated this desire and motivating force—at least not in realms that offer the greatest prestige and access to resources. It is as if the structures of government, education, and industrial organization took on too readily the closed, communal, and hierarchical characteristics of feudal/village Japanese society, relegating the individualistic aspects to the periphery.<sup>286</sup> As the section on machine tools indicated, small businesses have long been a refuge for 'individualists' in Japanese society.<sup>287</sup> Yet, except for a few cases of entrepreneurial companies rising to industry leadership,<sup>288</sup> such companies (and individual initiatives in general) seem to have a second caste status in Japan.

It has been said that the style of in-house innovation in Japanese corporations, where most employees expect to work until retirement and horizontal coordination is encouraged,<sup>289</sup> is superior to the innovation system in 'typical' large Western manufacturing companies so long as technology and the business environment is changing at a *moderate* rate.<sup>290</sup> However, as university R&D and globalization increase, in many fields the pace of technical and business change will increase, and it is not clear that even this more flexible type of in-house innovation will be quick enough to compete with new companies that can network quickly and effectively with other companies—and then, when their technologies have been eclipsed, let their employees join other companies.

Japanese companies will remain strong in manufacturing at least for some time to come. They may be able to shield themselves from lower cost overseas competitors in some high technology fields that require delicate, black-box know-how that they can keep in house.<sup>291</sup> Yet such a tacit-knowledge-based innovation strategy seems to offer limited opportunities for synergy with universities or other companies. It also probably has nearly zero tolerance for mid-career departures of the key persons who understand the black-box aspects of the technology. If the key black-box knowledge resides in a relatively small number of craftsmen or engineers, the same strategy can probably be replicated by small companies in China, India, or the USA.

The fundamental problem facing Japanese industry is that it is not well suited to take the initial steps to develop new technologies, and this is largely because it lacks new high technology companies. Some companies have

been good at developing a steady stream of new high quality products. But companies such as Toyota, Canon, Toray, and Chugai cannot possibly develop all the promising early stage technologies in their fields. Japan cannot rely on them for all its innovation needs. It needs more independent high technology ventures to increase the speed and flexibility of innovation by its industry. Without them, it risks being squeezed between countries that can rely on new companies to bring new technologies to proof of concept stage quickly, and countries where manufacturing can be done at lower cost with almost the same level of quality.<sup>292</sup>

### **American Entrepreneurship: Born Out of Adversity**

The reasons that ventures have thrived in the USA are of equal interest as the reasons they have not thrived in Japan. Maybe it is not Japan that is unique, but rather America. Moreover, while the past three or four decades have shown that the US system of innovation based largely on new companies is robust, its continued vitality cannot be taken for granted. This book has noted multiple factors that are necessary for vibrant S&T ventures: financing, managerial talent, pools of skilled researchers willing to work in ventures, customers that include large companies, strong IP protection, generous yet astute public support for basic university research, competent university technology management that is supportive of startup formation, effective management of conflicts of interests that preserves academic integrity and core academic values, and the ability of R&D researchers and managers in established companies to leave to set up independent spin-offs. Take away any of these elements, and the system is undermined. There are many ways to fail, but only a few ways to succeed.

Regions of the US where ventures are scarce offer some insights. Recently a manager of a VC fund returned from meetings with local venture businesses and officials of a particular state's main university and medical school. Accompanied by a business adviser to that state, his goal was to assess prospects for bioventures and investment opportunities for his firm. He remarked that some of the discoveries emerging from the medical school seemed quite interesting. However, financing was problematic, an observation confirmed by some of the entrepreneurial scientists whom he met, who had to work very hard to obtain funding for their companies. This particular state is geographically distant from major centers of VC financing. Although a few VC funds have representatives near the university, attracting their interest or pulling together investment syndicates has been difficult. Also managers are scarce. One of the most successful ventures is still run by its scientist-founder. Most Ph.D. students are not interested in careers as entrepreneurs. However, what struck

both the VC financier and the adviser most was the lack of focused efforts by university officials to improve the environment for ventures. Inventories of university research that might have commercial potential were not available. Neither were lists of university scientists that had expressed interest in forming companies. Plans to provide incubator space were still on hold. The TLO was preoccupied with normal licensing and material transfer agreements and did not have experience or resources to focus on inventions that might be the basis of a successful startup. Such proactive steps may not have been necessary in a region imbued with venture culture and infrastructure, such as San Francisco Bay area, but their absence in this state confirmed in the mind of the VC investor that this was not an attractive investment environment.

A colleague at the University of Tokyo who is from the bioscience department of a well-known university in another US state remarked that, although success rates on NIH grant applications are fairly high, few scientists think about forming companies. Awareness of the commercial potential of their discoveries is low. 'It is much more entrepreneurial here at the University of Tokyo', he remarked.

Even the continued vitality of entrepreneurial regions should not be taken for granted, nor the importance of chance and serendipity. George Rathmann, Amgen's first CEO, noted recently how hard it was to obtain investments from large pharmaceutical companies, as well as the danger that investing companies would want control, as they usually do in Japan.

... In the early days, there was a lot of cynicism on the part of Big Pharma. They called it 'hype' and 'flash in the pan.' We went out on tour and could barely get interviews with pharmaceutical companies, despite that Genentech was already a success. ... Then we developed bona fide products, and suddenly we got respect. ...

I had a lot of fear eight or nine years ago that Big Pharma would own the biotech industry. ... It turned out a lot better than we had thought. ... But a lot of the money [now] is being spent in fields where the payback is instant. [Big Pharma] is looking around for companies that are in late-stage clinical development. That doesn't help build good R&D. They need to take a gamble and respect R&D.<sup>293</sup>

There are also longer-term challenges, especially due to declining numbers US graduates in S&T fields and declining immigration of foreign scientists and engineers. The age demographics of ventures still are not clear. Can they still be innovation leaders if the pool of young scientists and engineers begins to decrease? Could an older workforce cope with the prospects of layoffs or frequent job changes that are supposedly part of the venture scene? Do ventures depend on immigrants more than established companies? Can venture companies or their employees pay the high premiums for individual or small group health insurance, and will the high cost of health insurance and the

prospects of being without insurance for long periods following job changes dissuade persons from working in ventures?

The rebound of venture funding after sharp declines from 2001 through 2003 and the rise in funding even for new ventures shows the system is resilient.<sup>294</sup> The proportion of total industry R&D that is accounted for by small companies continues to grow and is now over 20 percent.<sup>295</sup> High technology venture investment constitutes a larger proportion of GDP in the USA than any other country except Israel. In contrast, in Japan this proportion is the lowest among major OECD countries, although it is also low in most countries of Continental Europe.<sup>296</sup>

For R&D personnel, working in large companies is probably more attractive relative to ventures in Japan and Continental Europe compared to the USA. The prestige of working in a large Japanese company has been discussed. Salaries tend to be somewhat higher than in ventures.<sup>297</sup> This is probably also the case in Continental Europe.<sup>298</sup> But probably the most telling difference between the USA on the one hand, and Continental Europe and Japan, on the other, is job security. The preceding discussion shows that lifetime employment is still the standard in large Japanese manufacturers, especially for R&D employees. On the other hand, job stability fell in the USA due to layoffs during economic downturns.<sup>299</sup> In the USA, legal protections against layoffs are the lowest among OECD countries, while in the countries of Continental Europe they are the highest. In Japan they are lower than in most European countries but higher than in the USA. Indeed, there is a rough inverse correlation between the level of such protection and VC investment in high technology industries as a proportion of GDP—although Japan and Sweden do not fit this correlation relationship well.<sup>300</sup> In other words, the easier it is for companies to dismiss employees, the more attractive the environment for entrepreneurial high technology companies. The most likely explanation for this phenomenon is that weak protection against dismissal is an incentive for employees to be more mobile, and this mobility is vital for high technology ventures to meet their personnel needs.

This is not to say that risk of dismissal from a venture is much higher than from a large company in Japan or Continental Europe. There have been few outright failures among Japanese ventures in biomedicine, the field with which I am most familiar. There have been some consolidations, and there has been movement among senior managers. However, as noted in Chapter 4, probably just one of these companies, MBV, has over 100 employees and only about 5 others had over 50 employees in 2005. As with all Japanese companies, they are reluctant to dismiss employees—perhaps more so than established

companies because they know their ability to recruit in the future will be damaged by a reputation for involuntary dismissals. Also to some extent, government contracts provide some cushion when income from private sources is scarce, and to some extent the overlap with university R&D allows scientists and technicians to rely on university salaries for some of their company-related work. As for German biomedical ventures, a large proportion are focusing on research tools and research services where they have a steady, modest income stream, as opposed to drug discovery and development where the needs for R&D personnel are high but the risk of failure (and attendant large-scale layoffs) is also high.<sup>301</sup> Among Japanese bioventures focusing on drug discovery and development, a common strategy is the *no-wet-lab* venture which in-licenses candidate compounds that other companies have decided not to develop and then contracts out all the optimization, animal, human, and other laboratory work. In this way the number of employees dependent on the venture for their livelihoods is kept low.<sup>302</sup> In other words, ventures in countries with low labor mobility avoid employing persons who may later have to be laid off, but this diminishes their chances for success in risky but potentially lucrative fields such as drug development where rapid ramp-up of employment is often necessary.

Job security is also less for US academics compared with their Japanese and perhaps also European counterparts. US junior faculty (assistant professors) must begin to obtain grants to fund their salaries and research expenses soon after they start work. Japanese faculty rely instead on the resources of the professor's laboratory (*kouza*). Even tenured US university faculty must keep obtaining competitive grants in order to receive their full salaries, have time for research, and to pay for laboratory facilities, equipment, graduate students, and postdocs. Although more emphasis is being placed on obtaining competitive research grants in Japan, salaries are still independent of outside funding and, to a larger extent than in the USA, so are laboratory space and students. Thus in comparison to an academic career, working in a venture may seem more attractive in the USA than Japan.

However, high job security may be just one prong of policies that enable large companies to hold on to their employees for most of their careers. The other prong is that large Japanese and European companies may be more attractive places to work—not only in comparison to ventures in their own countries but also in comparison to typical large US companies. I have already mentioned the reciprocal obligations felt by Japanese managers and their subordinates, and the renewed commitment within high technology manufacturing companies, to lifetime employment. In Germany, nationwide collective labor contracts have continued to give workers in large companies

generous wages and benefits that many small companies have not been able to match. Large employers agree to these generous benefit packages *in order to guarantee peace, predictability, and labor cooperation, which have become dear to firms in an era of just-in-time production.*<sup>303</sup> In contrast, anecdotal reports suggest that employees in US corporations, including skilled engineers, are more often viewed as interchangeable or replaceable commodities.<sup>304</sup>

The following comments by a senior software engineer may reflect the frustrations and uncertainties US high technology workers feel working in some large companies and how these frustrations encourage movement to ventures. The company in question is a leading developer of software for a particular industrial application. It established its leadership position when it was still a young venture, but it was then taken over by a large diversified company. The engineer joined it during its independent growth years and has witnessed its transition to a fully controlled subsidiary of the large corporation:

When worker morale is high, when communication is good and there is a sense that 'We are all in this together,' workers deliver not just 100 percent but 180 or 200 percent. They cooperate well and they put in 16 to 18 hours of work a day to get the job done. But when they feel management is not paying attention to their ideas and makes decisions that compromise the basic goals of the company and its dedication to its customers, then performance falls not just to 80 percent of what is expected, but much lower. And performance is even lower if layoffs are threatening. I have seen this happen in my company after its incorporation into XXX Corporation. It's not that my company's management is especially incompetent or self-serving. But within the enlarged corporate structure, capable dedicated employees no longer feel that their efforts on behalf of the company are rewarded, recognized or even utilized for the benefit of the company.

What are layoff rates among engineers and scientists in ventures compared to large companies? How does job satisfaction in ventures compare with that in large companies or academia? Is job satisfaction among scientists and engineers higher in large Japanese or European companies compared with their US counterparts? These are questions that cry out for answers. Despite accounts of exploitation and summary dismissals in ventures, there are indications that many engineers and scientists prefer working in small companies.<sup>305</sup> The software engineer quoted above added:

Most of the software companies related to my industry were formed as spin-offs. The pay is good in my current company. But especially now when everyone is concerned about receiving pink slips, there is a good chance I will soon join one of these new companies or form one myself. There is a process of renewal in both a personal and professional sense that occurs when one joins a new company.

Thus, the strength of US ventures may depend on factors that undermine innovation in large companies. Specifically, the availability of skilled people willing to work in ventures depends to some extent on pressures large companies face to shed employees during economic downturns, which reduces their ability to sustain R&D initiatives through such downturns.<sup>306</sup> The departure of R&D personnel in turn undermines R&D and manufacturing projects, interferes with quality control, and reduces in-house tacit knowledge important for ongoing R&D and product improvement. If human resources really ought to be shifted to other fields to take advantage of new technical and business opportunities, this sometimes involuntary mobility may be good for the economy as a whole. However, it may sometimes result in well-integrated, productive R&D teams being broken up sooner than necessary, and the premature departure of skilled scientists and engineers from S&T occupations.

Conversely, the attractiveness of large companies as places to work in Japan and Continental Europe may be one of the main factors holding back the flowering of S&T ventures in those countries. In other words, the adversity of employment conditions in established companies in the US has contributed to its uniquely strong entrepreneurship.

### Innovation Systems

The discussion above may provide further insight into why the environments in different countries seem to be conducive to either *radical* or *incremental* innovations, a distinction put forward in the *varieties of capitalism* literature.<sup>307</sup> In particular, US firms are said to excel in radical innovations while German firms excel in incremental innovations.<sup>308</sup> This is attributed to US companies being able to shift resources quickly to pursue new technologies even if it means disrupting ongoing projects. German companies cannot shift resources so easily but, because they are assured of a stable supply of capital and skilled labor, they can devote more effort to long-term improvement of existing products.

Deeper insights might, however, be gained from examining which innovations arose from new-or-small versus large-and-established companies. I suspect this would show that the differences between the innovation propensities of the USA and Germany in various industries (and also, between the USA and Japan) are largely explained by whether new companies are major innovators in these industries. In other words, the industries Hall and Soskice designate as characterized by radical innovation are probably those where a significant proportion of patents are emerging from new (often US) companies, while those labeled as incremental innovation industries are those where the

contributions of new companies to innovation are minor and most patents are being obtained by established companies.<sup>309</sup> If this is indeed the case, it suggests that the differential impact of the two main varieties of capitalism is mediated largely through their effects on new companies. In other words, from the standpoint of the vitality of an innovation system as a whole, the greatest benefit associated with a liberal market form of capitalism may be that it creates a more favorable environment for innovation by new companies.<sup>310</sup>

Furthermore, this analysis might shed light on the question that began this chapter, 'are new-or-small companies more innovative than old?' Distinguishing between radical and incremental innovations must be done with caution.<sup>311</sup> However, if reasonable criteria are used to distinguish radical and incremental innovations,<sup>312</sup> I suspect that this would show that industries with a high proportion of new companies are those characterized by a high rate of technological change. It might even show that within these industries new companies are the source of a high proportion of the most innovative discoveries.<sup>313</sup>

### To Alter Destiny

The preceding discussion suggests that the Japanese system cannot change quickly, and that America will have to continue to rely on new companies in order to remain in the forefront of innovation. The source of each country's innovation strength with respect to either established or new companies is also the source of its weakness with respect to the other type of company. Japan has done most of what it can in terms of government policies to try to create a more favorable environment for ventures. While it is still too early to judge with certainty their effects, they appear modest. For the foreseeable future Japan will have to rely on its large companies for innovation.

I suspect that the situation in Continental Europe is similar, in terms of long-standing factors limiting labor mobility and the limited improvements that recent reforms are likely to bring in the short term. Both Germany and France rely on large companies for innovation. In both countries, legal barriers to dismissing employees are higher than in Japan.<sup>314</sup> Japan has no system of national unions that negotiate employment terms applicable across the country as does Germany. The role of Japanese corporate unions is less formalized and probably less influential than the legally mandated German works councils ensconced in companies to represent workers' interests.<sup>315</sup> Yet, in Germany, as in Japan, there are pressures on corporations to pay more attention to profitability. A 2003 German law reducing taxes on sales of corporate cross-holdings led to a large unbundling of cross-held corporate shares.<sup>316</sup> Equity financing by German corporations has increased.<sup>317</sup> But, although it

may be premature to judge, these reforms do not seem to be translating into increased labor mobility.<sup>318</sup> How much more it will take in Japan, Germany, or France to create the degree of labor mobility needed by ventures to thrive is not clear. The US case suggests this may require substantial dismantling of legal and social barriers against dismissals. In Germany it appears that this would only come about after a difficult political process, and in Japan only after a sea change in social expectations with respect to large companies. The fact that both the Japanese and German economies seem to be in sustained recoveries means that the pressure to change is now low, although this may create an opportunity for political change in Germany.

The situation may be different in China, India, and perhaps also Eastern Europe where new companies offer some of the most attractive employment opportunities for bright energetic scientists, engineers, and S&T managers.

In contrast, to Japan and countries such as France and Germany, the USA will be a country that relies to a large extent on new companies for innovation, particularly in areas where university discoveries hold the key to new commercially relevant products. Nevertheless, it is not certain whether ventures can be engines of innovation in emerging fields of technology outside life science, software, and some IT-related fields. These are the areas in which they have already proved themselves and also, coincidentally or not, where US high technology industry is strongest in terms of manufacturing and employment growth. If they cannot, it is not clear that established US companies, innovating on their own, can be internationally competitive either.

Despite these barriers to change, Japan should try to create a better environment for high technology ventures in ways that do not require drastic reshaping of its innovation system. Too much is at stake, and there are too many warning signs concerning the innovative capacity of established companies, to proceed further into the new millennium relying only on large, established companies for early stage innovation. The most appropriate place to start probably is universities, where there is room for reforms. The following suggestions are not far-reaching (except for perhaps the first and last), but they should equalize the playing field between new and established companies with respect to access to university discoveries, encourage more entrepreneurship among university researchers, and give startups more breathing space vis-à-vis large companies. They should also increase the quality of university science.

The primary recommendation is for the government to stop cobbling together research consortia and earmarking large chunks of research funding for consortia. The evidence that consortium projects result in meaningful cooperation or technical progress that would not otherwise have occurred is scant. On the other hand, there are real grounds for concern that government organized consortia are preempting new areas of technology that would be

fertile fields in which ventures could develop. This is a variation on *trying to pick winners* that is unnecessary, in view of the advanced technical level at which Japanese companies are competing internationally, beyond the capacity of the government to do effectively, and inherently anticompetitive. Of course researchers from various universities and companies should be free to submit joint research proposals to government funding agencies, but these proposals and the claimed synergies from collaboration should be evaluated case by case on their merits.

Second, funding agencies should carefully scrutinize university funding programs that tend to support applied research. In general, only if there are clear reasons to believe that private industry on its own cannot fund such research, or that government funding is necessary to ensure benefits are widely available, should such university projects be funded. Otherwise there is substantial risk that public resources will be wasted or end up subsidizing established companies, and opportunities will be lost to make progress in new areas of science—areas that might be fertile grounds for ventures to develop.

Third, improve the quality of peer review for all competitive funding programs open to university researchers. At stake are taxpayers' funds; the quality of scientific research; and the careers of university researchers. Although the peer review system has improved over the past ten years, much room for improvement remains. The need for expert, objective peer review is especially high in the case of applied research projects, because of the risk of misdirecting resources mentioned above, and also because the results of applied research projects may be less subject than basic research findings to critical evaluation in academic publications and other open fora.

Fourth, with respect to technology transfer and joint research, universities should make sure that the scope of joint research projects are well defined and commensurate with the funding from the sponsor, that sponsors obtain IP rights only to inventions that fall within the scope of projects, and that claims of company coinventorship are scrutinized. If sponsors want exclusive rights to inventions, they should negotiate for them case by case.<sup>319</sup> To these ends, universities must develop their own professional competence in contract management and hire persons whose careers are devoted to this field and who are paid salaries competitive with those in private business. Government and universities have to be clear that universities' primary goals are education and research, and that, while joint research that serves these goals is welcome, universities are not to be contract research laboratories for companies seeking to leverage taxpayer finances resources to conduct research of primary value to them alone.

Fifth, the remaining barriers to universities taking equity in lieu of cash for licenses to startups should be removed.

Sixth, there should be real, substantial moves away from the kouza system so that young researchers have the means and the independence to pursue their own research ideas. New young faculty must have their own laboratories and graduate students and reasonable prospects for tenure. This in turn requires reforms with respect to funding, peer review, and how faculty are recruited. The present patronage system will not do. There must be some system to incorporate objective external evaluations into the appointment and promotion process.

Beyond the realm of universities, tax deductible loss carryovers for angel investors should be easier. Also, the JPO and judicial agencies should keep track of suits initiated under the Law to Prevent Unfair Competition (LPUC), to determine the extent to which that law prevents employees of established companies from starting their own spin-offs. If the threat of suits under that law are indeed preventing persons from changing jobs to new domestic R&D companies, then consideration should be given to interpreting the law narrowly in such cases.<sup>320</sup> Also the JPO and Japanese courts should be cautious about broadly interpreting Japan's already generous prior use rights with respect to patents, lest the ability of ventures to prevent rivals from encroaching on their technologies be undermined. The current guidelines of concessionary stock exchanges that strongly recommend that bioventures have alliances with large companies prior to public listing of their stocks should be interpreted flexibly. Finding alliance partners is harder for independent ventures in Japan than in the USA. Public investors should be justifiably on guard if a bioventure does not have alliance partners. Nevertheless, requiring such partnerships tilts the bargaining tables even more in favor of established companies. In view of the autarkic innovation modus operandi of large Japanese companies and the way this increases the financial challenges facing Japanese ventures, Japan must be receptive to foreign investment in high technology companies. Some of Japan's most successful ventures owe their business breakthroughs to foreign companies.

America, for its part, should realize the extent to which it relies on new companies for innovation—to develop new ideas (whether originating in universities, corporate laboratories or the minds of independent inventors) to the point where larger companies are willing to commercialize them, or the new companies themselves are able to commercialize them. It should also consider the possibility that the primary social benefit of a user-friendly patent system that provides strong protection for inventions; a system of university IP ownership that encourages university, faculty and student entrepreneurship; and even its system of liberal market capitalism, is that these facilitate the creation and growth of new companies. These systems have their faults, but reforms should

not undermine this basic benefit and function.<sup>321</sup> It is fortunate that, at least in the case of patent system reforms, advocates often acknowledge the need to ensure that the system supports high technology ventures.<sup>322</sup>

In addition, America needs strong public support for basic science research in nonbiomedical as well as biomedical fields. Its science agencies need to remain strong and to keep in touch with the other branches of government, the scientific community and the general public, in order to set reasonable scientific priorities and plan how to achieve them. They also need to maintain effective systems of peer review so that research funds are allocated fairly to researchers most likely to make progress. Despite legitimate concerns about terrorism, espionage, S&E wage increases being held down, brain drains and reverse brain drains, America must keep its doors open to immigration of scientists and engineers. Available evidence suggests that America's high technology ventures depend disproportionately on such immigrants, and that their international mobility benefits both America and their countries of origin in the long run. Either at the federal or state levels, mechanisms should be worked out to allow small venture companies to pool the health care costs of their employees so that these costs are manageable. Finally, the USA must also provide a healthy environment for its *large* high technology companies, because new companies cannot be engines of innovation without strong large companies as customers and as sources of discoveries that sometimes end up being left to new companies to develop.

Developing countries should plan national development strategies that encourage the growth of new technology oriented companies. While a short-term development strategy might justifiably emphasize low-cost manufacturing that might best be done by large companies, the infrastructure to support entrepreneurship should also be nurtured. This involves establishing effective university technology management systems, caution with respect to reliance on industry to fund a substantial portion of university R&D, strengthening IP laws and facilitating their use by small companies to protect their discoveries, facilitating establishment of VC funds and other financial institutions to support new companies, strengthening equity markets for small high technology companies, keeping open the door to foreign investment in high technology companies, establishing a system of portable individual pension accounts to allow employees to accumulate retirement funds as they work and to transfer these to new accounts if they change jobs, and caution in adopting laws that limit the ability of employers to dismiss and hire workers—while doing what they can to provide a safety net for persons who lose jobs (and their families) and facilitating retraining and information networks to help them find new jobs.

APPENDIX 7.1

Table 7A1.1. Intellectual property holdings according to size and age of Utah and New York bioscience companies

	years since incorporation		≤50 employees		>50 employees		per firm means		per employee means (unweighted)	
	≤10	>10	≤50 employees	>50 employees	≤50 employees	>50 employees	≤50 employees	>50 employees	≤50 employees	>50 employees
# firms in sample			74	12	52	45				
# patents							6.9	51.2	0.9	0.4
							4.5	34.2	0.4	0.2
# trade secrets							8.2	37.1	1.3	0.3
							20.7	46.0	2.0	0.3
# total IP items*							20.5	154.6	3.0	1.5
							36.1	120.3	3.7	0.9

\* Total IP items means the sum of patents, trade secrets, copyrights, trademarks, and licenses & options. Source: Willoughby (1997, 1998).

APPENDIX 7.2: ORIGINS OF NEW DRUGS APPROVED BY THE  
US FDA 1998–2003**Table 7A2.1.** Numbers of new FDA approved drugs by type and type of organization  
(where inventors worked)

	Pharma	Biotech	University licensed 1st to pharma	University licensed 1st to biotech	Total	Total nonpharma origin
Priority NMEs	35.05	11.25	4.65	12.05	63	27.95 (44%)
Nonpriority NMEs	61.40	7.40	5.70	6.50	81	19.60 (24%)
NTBs	3.00	13.17	1.10	7.73	25	22.00 (88%)
Total	99.45	31.82	11.45	26.28	169	69.55 (41%)

**Table 7A2.2.** Number of new FDA approved drugs by type of drug, type of employer institution, and location of laboratory where the inventors worked (with share of global pharmaceutical market as a benchmark reference)<sup>1</sup>

Country	Share of 2003 world pharma mkt.	All new drugs			Nonpriority NMEs			Priority NMEs			NTBs		
		Total	Biotech	% biotech	Total	Biotech	% biotech	Total	Biotech	% biotech	Total	Biotech	% biotech
USA	44.4%	75.7	46.7	62	22.5	10.0	44	32.0	17.4	54	21.2	19.3	91
UK	3.8%	17.6	2.4	14	10.3	1.0	10	5.8	0	0	1.5	1.4	93
Japan	12.3%	16.9	1.0	6	12.4	0	0	4.5	1.0	22	0	0	
Germany	6.0%	16.6	1.0	6	10.9	0	0	5.7	1.0	18	0	0	
Switz	0.6%	10.4	1.0	10	5.1	1.0	20	5.2	0	0	0.1	0	0
France	5.7%	6.0	0	0	3.0	0	0	1.8	0	0	1.2	0	0
Canada	2.1%	4.0	2.0	50	2.0	1.0	50	2.0	1.0	50	0	0	0
Other <sup>2</sup>	25.1%	21.8	4.0	18	14.8	0.9	6	6.0	2.9	48	0.2	0.2	20
Total	100%	169.0	58.1	34	81.0	13.9	17	63.0	23.3	37	25.0	20.9	84

<sup>1</sup> See notes 25–8 and accompanying text for data sources and methodology. ‘Biotech’ includes drugs invented in universities that are licensed/transferred to biotechs.

<sup>2</sup> The other countries of origin are Italy, Finland, Sweden, Denmark, Israel, Czech Republic, Hungary, Belgium, Australia, Spain, Korea, Austria, and Egypt (listed in approximate order).

**Table 7A2.3.** Share of new FDA approved drugs from regions with few biotechs compared with regions with many biotechs (with share of 2003 global pharmaceutical market as a benchmark reference)

	Fr, Ger, Jpn, Switz	Fr, Ger, Jpn only	Canada, UK, USA	USA only
No. new drugs (all types)	50.0 (30%)	39.6 (23%)	97.2 (58%)	75.7 (45%)
No. NTBs + priority NMEs	18.5 (21%)	13.2 (15%)	26.4 (71%)	53.2 (60%)
% world pharma market	25%	24%	50%	44%

APPENDIX 7.3: THE JAPANESE MACHINE  
TOOL (MT) INDUSTRY

**Table 7A3.1.** Leading Japanese machine tool companies ranked by 2004 sales

World rank	Name	Inc. Year	Employees 2005	MT revenue FY 2004 (M USD)	Total revenue	Comments
2	Yamazaki Mazak	1919	5,000	1,576	1,576	
5	Fanuc	1972	4,549	1,280	3,079	Builds mainly CNC controllers. Fujitsu affiliate.
6	Amada	1946	1,599	1,256	1,674	Has many affiliates for which it acts as designer & distributor
7	Mori Seki	1948	3,012	1,137	1,137	Small subcontractor until 1970s
8	Okuma	1918	1,897	1,073	1,073	
10	Toyoda Machine Works	1941	3,878	772	2,272	Affiliate of Toyota Motors and its weaving machine parent.
11	Makino	1937	907	734	879	
27	Aida	1917	1,087	395	407	

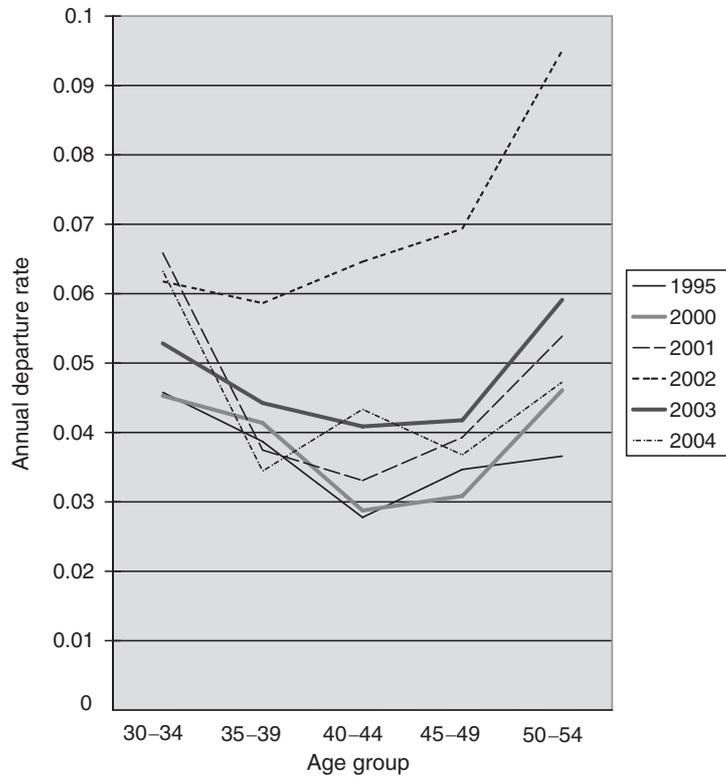
*Source for revenue data:* 2005 Machine Tool Scoreboard.

In comparison, the largest US companies in 2004 were Unova (a mini-conglomerate which sold off its MT operations in 2004–2005) ranked eighteenth with MT sales of US\$470 M and Haas, ranked nineteenth with sales of US\$464 M. The precise rankings should not be emphasized, however, because they fluctuate.

APPENDIX 7.4: EMPLOYMENT TRENDS IN JAPANESE  
MANUFACTURING BY INDUSTRY, SIZE OF COMPANY,  
AND AGE RANGE

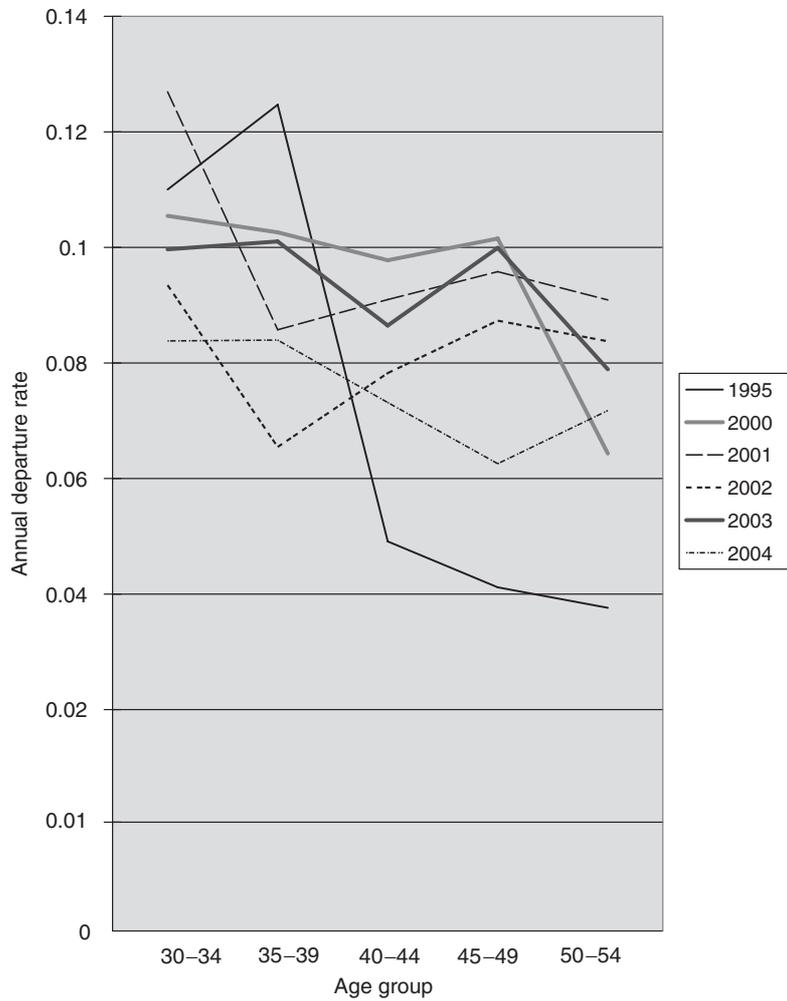
The following are representative graphs of my analysis. In total I analyzed age-specific employment trends for men in companies with at least 1,000 total employees in all manufacturing industries and then in each of nine specific industry categories (electrical machinery & instruments, precision machinery & instruments, general machinery, chemicals, plastics, nonferrous metals, metal products, transport machinery, and steel). I did the same analysis for all manufacturing industries combined for each of the following size categories of companies (total number of firm employees): 300–999, 100–299, 30–99, and 5–29.

I am grateful to the Ministry of Health, Labor and Welfare (MHLW) for providing raw data on numbers of employees and numbers of departures by industry, gender, 5-year age groups, and year.



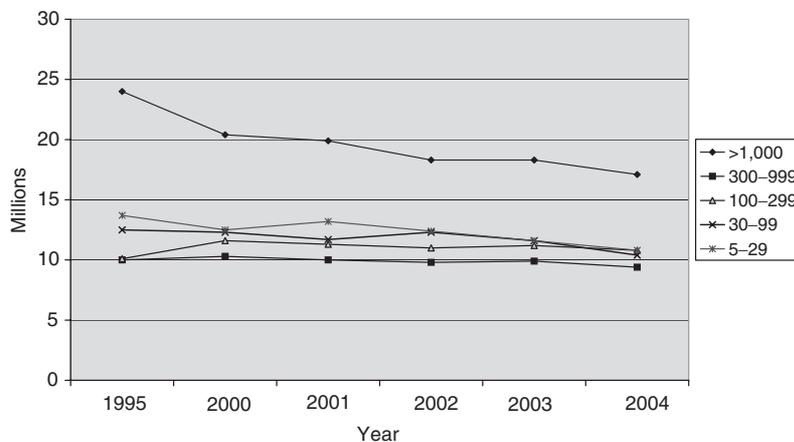
**Figure 7A4.1.** Age-specific mid-career departure rates for men in all manufacturing firms with  $\geq 1,000$  employees

*Advantage New Companies*

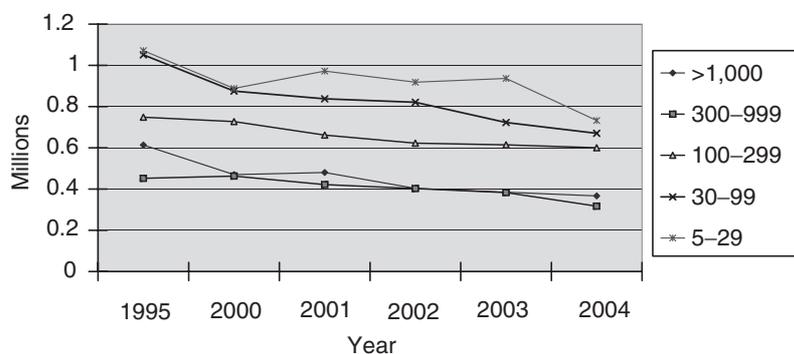


**Figure 7A4.2.** Age-specific mid career departure rates for men in all manufacturing firms with 30-99 employees

*Advantage New Companies*



**Figure 7A4.3.** Total male employees in manufacturing industries by firm size (no. of employees)



**Figure 7A4.4.** Total female employees in manufacturing industries by firm size (no. of employees)

## NOTES

1. At times I use the terms *new* and *small* interchangeably, because it is not clear whether newness or smallness is most closely tied to innovation potential. Acs and Audretsch based their analyses on size. My analysis of patents in Chapter 1 is based on age, mainly because I wanted to include new firms that had grown to considerable size along with new firms that are still small. Also where to divide small from large or new from old varies. Acs and Audretsch use 500 employees as their dividing line, consistent with the US Small Business Administration's definition of 'small businesses'. Japan's official definition of a small- or medium-size enterprise is a firm with no more than 300 employees.

In the Chapter 1 patent analysis and the analysis later in this chapter of the origin of new drugs, I make 30 years of age the dividing line between old and new firms. This is partly because I feel that the organization and culture of a 30-year-old firm probably has more similarities with a 10- than a 60-year-old firm, at least in pharmaceuticals. Also, I wanted to be able to include any relatively new Japanese firm, there being so few in the entire 0–30 age range that are patenting in high technology areas (at least in the areas that I sampled) or discovering new drugs.

One of the few datasets with innovation data for very small firms has been compiled by Willoughby. It covers all manufacturing or R&D-oriented bio-science firms (including those focusing primarily on medical devices, bioremediation, bioprocessing, etc., as well as pharmaceuticals) in Utah and New York (see Table 7A1.1 in Appendix 1). As expected, these data show that patents and other IP increase with firm size, although as firms employ more people, the number of patents and other IP per employee declines. However, for firms of approximately the same size, newer firms hold more patents than older firms, and this trend remains even on a per-employee basis. (There is a slight trend for trade secrets to increase with age, even on a per-employee basis.) Thus these data are some indication that, when measured by patents, younger firms may be more innovative than older firms, and thus age rather than size probably is a more crucial determinant of innovativeness.

2. See generally Christensen (1993), Cohen and Klepper (1991), Hyde (2003), Rothwell and Dodgson (1994), Scherer (1991), Wilson (1985a), as well as earlier writings of Richard Nelson and Michael Tushman.
3. Branchflower and Oswald (1992, 1998) and Branchflower, Oswald, and Stutzer (2001). These studies are based on UK and US survey data. In interviews with entrepreneurs Wilson (1985a) found that 'freedom of action' and 'having your hobby be your job' were the main motivations and rewards of forming new businesses (p. 212). Friedman (1988) and Whittaker (1997) make clear that the desire to be one's own boss is probably equivalently strong in Japan. My interviews with the CEOs of Japanese ventures indicate similar motivations are strong.

4. Two examples of such constraints are offered later in this chapter. One is IBM's failure to develop small disk drives because its main customers did not need computers with small drives. The other is the development by large diversified vertically integrated Japanese electronics companies *for the Japanese market* of IT systems, architectures, and customer support systems—which later proved inappropriate for overseas markets.

Another example is a small Japanese company developing and distributing software for oil and gas exploration. Its main clients are Japanese energy companies. This company has declined alliance overtures from overseas programmers that might allow it to offer substantially improved software (e.g. to improve offshore exploration capabilities) and expand its client base beyond Japan. Its main clients are satisfied with the service it currently provides and they have their own in-house programmers that can adapt the small company's products to fit their needs.

5. See Karen Pallarito, *Best Places to Work 2006: Industry*, The Scientist (April 2006 online). This latest annual survey based on responses from readers in the biomedical industry shows that all the top ten ranked companies are biotechs formed no earlier than 1976, except for Monsanto (ranked 10th). Moreover, 6 of the top 10 had fewer than 1,000 employees, while the top 2 (Tec Laboratories of Albany, OR and Transform Pharmaceuticals of Lexington, MA) had fewer than 100. The highest ranked pharmaceutical company as well as the top ranked non-US company was Astra Zeneca (twelfth).

Chesbrough (1999) emphasizes the ability of venture companies to give key employees generous financial incentive packages. He quotes from Block and Ornati (1987) the following remarks of a venture capital manager, 'The only reason for our existence is the inability of corporations to provide the financial incentives which can be achieved in an independent start-up.' This comment implies that the main motivator for entrepreneurship is financial. It may also imply that the motivating factor that is most important for venture success is the incentive package for the venture's top officers, who may be seconded from a lead investor VC fund. However, the studies mentioned in note 3 above cast doubt on the assumption that entrepreneurship in either the USA or Japan is motivated mainly by quest for financial gain.

Of course, the assumption that success of ventures hinges primarily on the compensation packages for top officers raises the question about compensation for all employees, which in turn raises questions about the distribution of stock options. It is clear that abuses of stock options have occurred, and managers have taken advantage of employees. (See Hyde (2003: 194) for an account of how Steve Jobs used his control of Pixar to deprive key engineers of their stock options once the success of the company became evident.) However, Hyde (2003), Barley and Kunda (2004), and my own conversations with persons who have worked in ventures suggest that, even though compensation packages may differ widely between the CEO and 'average' employees,

employees of ventures are sensitive to issues of fairness and the possibility of exploitation. If a company has the reputation of treating its employees in an underhanded manner, the repercussions in terms of defections and diminished performance can be severe.

6. e.g. see the account in Chapter 6 of the race to develop gene sequencers.
7. See generally Acs and Audretsch (1991), Branchflower and Oswald (1998), Chandler (1990, 2001), Chesbrough (1999), Merges (1995), Scherer (1991), and Shane (2004).
8. Although sometimes, as in Chapter 2, the only measure available for comparative analysis is number of issued patents.  
An alternative approach has been to examine the proportion of total sales accounted for by products newly marketed (or substantially improved) within the past five years. Using this approach for a sample of fifty-one German metal working firms in 1977–9, FitzRoy and Kraft (1991) found that this ratio tended to be higher for smaller firms, indicating that smaller firms have newer product lines.
9. These consist primarily of (a) data on 635 US inventions between 1970 and 1979 compiled by Gellman Research Associates (on contract to NSF) from 14 trade journals (but primarily the magazine *Industrial Research and Development* which annually announces awards for the 100 most innovative newly marketed inventions), (b) data compiled by Scherer from *Industrial Research and Development*'s annual top 100 inventions probably from 1963 until the late 1980s, and (c) data on 8,074 new inventions introduced in the US in 1982 compiled by the Futures Group (on contract to the US Small Business Administration) from over 100 technology, engineering, and trade journals covering nearly all the manufacturing industries listed under the 247 four-digit standard industry classifications (SICs) (Scherer 1991; Acs and Audretsch 1988, 1991).
10. The Science Policy Research Unit (SPRU) of the University of Sussex compiled a database of 4,400 newly marketed inventions by UK companies between 1945 and 1983 on the basis of queries to industry experts asking them to identify significant technical UK innovations (Rothwell and Dodgson 1994; Pavitt, Robson, and Townsend 1987).
11. The share of small firms rose from 24.3 to 38.4%. That of mid-size firms fell from 33.6 to 19.2% (Rothwell and Dodgson 1994).
12. According to the UK SPRU data, in 1975 firms with 100–499 employees accounted for 2% of total manufacturing R&D expenditure in the UK but produced 21% of total inventions for an R&D efficiency ratio of 10. Firms that employed more than 10,000 persons accounted for 80% of national R&D but accounted for 43% of inventions, for an R&D efficiency ratio of 0.5, one-twentieth that of the small firms.

The US Gellman-NSF data show a similar declining trend of inventions per unit of R&D expenditure in relation to firm size. Firms with less than US\$100 million in sales in 1985 had on average 0.09 new products per

US\$1 million of R&D while firms with over US\$4 billion in annual sales had less than 0.002 new products per US\$1 million in R&D, approximately one-fiftieth the rate of firms in the smallest sales category (Rothwell and Dodgson 1994). As for innovations per employee, the US Small Business Administration's dataset shows that the ratio is about 2.4 times greater for small firms than for large (Acs and Audretsch 1988, n. 6).

13. Large firms are defined as those with at least 500 employees, small firms have less than 500 employees.
14. Electronic computing equipment (large:small firm innovation ratio 0.7) was first with 395 of the 8,074 inventions in 1982, while process control instruments (innovation ratio 0.7) was second with 165 inventions (Acs and Audretsch 1988).
15. Acs and Audretsch (1987).
16. Rothwell and Dodgson (1994).
17. (Scherer 1991). A somewhat different line of analysis suggests that while R&D tends to increase in rough proportion to firm size, innovations per unit of R&D expenditure tends to decrease (Scherer 1991; Acs and Audretsch 1988, 1991).
18. i.e. innovation tends to be correlated with proportion of the industry workforce employed in large companies.
19. Acs and Audretsch (1988).
20. Rothwell and Dodgson (1994).
21. Scherer (1991).
22. Of some interest, pharmaceuticals was not one of these industries detected by these early surveys. This is another area where new companies have emerged to overtake large companies in innovation leadership.
23. Echoing one of the main themes of this book, Rothwell and Dodgson (1994) also note the importance of partnerships for small companies to realize their innovation potential.

One can only speculate about the insights that would be gained if these datasets were also analyzed according to age of the innovating companies.

24. This total excludes ten drugs approved during this period that were either imaging agents, dialysis solutions, chemical warfare skin protection agents, or contraceptive rings or patches.
25. Fortunately, in the case of 144 new molecular entities (NMEs, i.e. small molecule drugs) the FDA approval process has a built in filter to designate the most important patents. Under US law, companies submitting NMEs to FDA for marketing approval must designate active US patents covering the NMEs. These patents are listed in the FDA Administrative Correspondence (AC) related to the NME. If I had any doubt about whether the patents listed in the AC were the key patents, I cross-checked with O'Neil (Merck Index) (2006). When the AC listed multiple patents for an NME, I gave greatest weight to those covering the therapeutically active chemical compound upon which the drug is based. Among these, I gave greatest weight to the earlier patents

so long as they indicated proof of concept in a mammalian system. If the only patents listed in the AC or Merck Index pertained to manufacturing methods, methods of clinical use, delivery systems, etc., I weighted these according to their importance with respect to discovery of a workable therapy. Three NMEs did not have any patent record, but I determined their likely origins with the help of a colleague in the orphan drug industry and the Merck Index. As for the 25 new therapeutic biologics, Rader (2006) provides information on their development histories and key patents. More information about methodology is in Kneller (2005*a* & *b*) and a forthcoming article.

26. I was able to do so for over 90% of all the listed inventors. The most frequent method was, for each inventor, to obtain at least one scientific article co-authored by the inventor (preferably on the same topic as the invention), written close to the time of the initial patent application, and that identified the inventor's affiliation. My main sources to find such articles were Google Scholar and NIH's PubMed database. Very often, one or two key articles would be co-authored by many of the inventors on the same patent, thus reducing the number of articles I had to obtain. In the case of the 18 NMEs that had Japanese inventors, I also used various online Japanese sources to determine the inventors' employment.
27. For the purpose of this analysis, I use the terms biotechnology company (biotech) and bioventure synonymously to mean companies either (*a*) with fewer than 500 employees at the time the drug was discovered or (*b*) formed after 1975 that concentrate on science-based discovery of drugs and other biomedical products/processes. Thus this term includes (*a*) small pharmaceutical companies and (*b*) relatively new, independent, companies that, at least until later in their development, did not devote substantial resources to later stage clinical trials and, in particular, to marketing. I did this with the express purpose of including some companies that have grown quite large, such as Genentech (founded 1976) and Amgen (founded 1980), in the set of companies that I contrast with traditional pharmaceutical companies. My reasons include an intuitive sense that age is a more important differentiator of innovative potential than size, and that there are residual influences related to their founding within the past thirty years that result in a different innovation environment than exists in a large company that has been in existence since before World War II. Moreover, if I excluded relatively young companies that have become large from the set of greatest interest, I am deleting precisely the types of companies that I postulate this group is inherently likely to give rise to. In other words, I would be penalizing this group for the very success I want to measure. In addition, the drugs that I classify as biotech origin that were approved by FDA between 1998 and 2003 were drugs that have been in development by biotechs for approximately ten years. This makes their origin the 1980s or early 1990s. Even the oldest and largest biotechs would be considered young at the time they began discovery/development of these drugs.

With respect to US-origin drugs, the inclusion of small pharmaceutical companies within my definition of *biotechs* is immaterial, since all drugs

*Advantage New Companies*

319

- classified as *biotech origin* were from companies formed after 1975. However, a few of the European drugs classified as *biotech origin* were from small pharmaceutical companies formed before 1975.
28. My allocation among the various categories was usually according to tenths (one decimal place). In the case of drugs with more than one key patent, I combined the allocations of the individual key patents according to the weighting system described in note 25 to calculate a weighted overall allocation for each drug, where the total value assigned to each drug was “1.” This “1” was allocated separately according to type and location (country) of inventing workplace.
  29. See Appendix 2, Table 7A2.1. In the case of US university-origin drugs, the number of transfers from universities to biotechs is ninefold greater than the number of transfers to established pharmaceutical companies.
  30. Pharmaceutical companies obtained marketing approval FDH for 121 drugs, and biotechs obtained approval for the remaining 48. Of these, at least one quarter (13) were transferred from at least one biotech to another prior to approval.
  31. Appendix 2, Table 7A2.2. Only 11.4 drugs attributable to university discoveries were passed directly to pharmaceutical companies. Patterns in how the proportion of such drugs varies by country. The UK is highest, with such drugs constituting 15 percent of its total. The USA and Japan are among the lowest, although for different reasons, as discussed in the text. See also note 57.
  32. 63 (44%) of the 144 NMEs approved between 1998 and 2003. Appendix 2, Table 7A2.1.
  33. 37% compared with 17%. Appendix 2, Table 7A2.2.
  34. The USA accounted for 32 of 63 priority NMEs (51%), but only 28% of nonpriority NMEs. As a benchmark, in 2003 it accounted for 44% of world pharmaceutical purchases. Appendix 2, Table 7A2.2.
  35. NTBs usually replicate or modify naturally occurring proteins such as hormones, or are antibodies designed to affect naturally occurring enzyme systems or neutralize disease causing substances. Most NTBs are much larger in size than typical NMEs. The US FDA approved twenty-five NTBs between 1998 and 2003 (Appendix 2).
  36. McKelvey (1996) and Zucker and Darby (1997).
  37. See Crabtree (2006), citing studies by the Tufts University Center for the Study of Drug Development released in 2005 and 2006, respectively, on the costs of developing NMEs and NTBs.
  38. Adalimumab (Humira®, approved 2002 for rheumatoid arthritis) was co-discovered by researchers at Cambridge Antibody Technology (a UK biotech) and Knoll Pharmaceutical’s Massachusetts (USA) laboratory using antibody technology from the Australian biotech, Peptech. At the time of Humira’s discovery in the mid-1990s, Knoll was a subsidiary of BASF, which sold the Knoll research facilities to Abbott in 2001 along with rights to Humira.
  39. Appendix 2, Table 7A2.2.

40. Data published by the Pharmaceutical Research and Manufacturers of America (PhRMA) under PhRMA's *New Medicines in Development* series shows that of approximately 346 new drugs in clinical trials for cancer in 1999, 62% were sponsored by biotechs and only 20% by pharmaceutical companies, with drugs sponsored by NIH, or other government or nonprofit organizations accounting for the remainder. Of 123 drugs in clinical trials for cardiovascular diseases in 2001, 55% were sponsored by biotechs and 45% by pharmaceutical companies. Of 251 drugs in clinical trials for infectious diseases in 2002, 77% were sponsored by biotechs and 22% by pharmaceutical companies. However, not all of these drugs are undergoing trials for first time approval, some are in trials for additional medical indications. See Kneller (2003) for a more complete discussion of these data.
41. As for non-US origin NMEs, biotechs outside the US (and non-US universities licensing to biotechs), discovered 19 percent of priority NMEs but only 6.7. 7 percent of non priority NMEs, a nearly three-fold difference. Appendix 2, Table 2.
42. Rescula® (unoprostone isopropyl ophthalmic solution), approved in 2000 for glaucoma, was discovered by R-Tech Ueno, a small independent Osaka company founded in 1989, which licensed the drug to Ciba Vision. Sacrosidase (Sucraid® approved 1998 for congenital sucrase-isomaltase deficiency) was discovered by clinical researchers in Munich hospital in the 1980s. There is no history of any patents. Orphan Medical, Inc. (Minnesota) sponsored the drug for FDA approval.
43. Perhaps this suggests the large companies in these countries are *crowding out* ventures by preempting human resources, capital, distribution networks, etc.
44. However, in the case of NTBs (which were pioneered by biotechs rather than pharmaceutical companies) from the beginning it has been common for the biotechs to complete development and even undertake marketing.
45. This was cisplatin for cancer. See the discussion in Cockburn and Henderson (1997) of the basic discoveries underlying twenty-one of the most therapeutically important drugs initially marketed during this period.
46. Since the latest date of synthesis of any of the active compounds was 1988 (sumatriptan for migraine) with the second latest date being 1985 (erythropoietin for anemia), it would not be expected than many of these drugs would have been developed by biotechs. Among the twenty-one drugs, only erythropoietin appears to have been developed by a biotech, Amgen.
47. See, e.g. Florida and Kenney (1988), especially n. 29; and Wilson (1985a: Chapter 13). These writers raised this issue primarily in the context of IT and other nonbiomedical industries, and I return to this argument in Part III of this chapter.
48. Rathmann (1991).
49. McKelvey (1996). As another example, see Ganguli's history of Alexion (2006), developer of eculizumab to treat paroxysmal nocturnal hemoglobinuria and other diseases caused by poor regulation of the complement immune system.

50. A well-known university researcher may hesitate abandoning an academic career to work for a small company that may not exist in five years, but would be more likely to do so if he or she could head a large research organization and have many years of committed research support. For example, in 2002, Novartis recruited Dr Mark Fishman, to head its new Institute for Biomedical Research in Cambridge, MA, to pursue drug discovery research. Dr Fishman was previously chief of cardiology and director of cardiovascular research at Massachusetts General Hospital and professor of medicine at Harvard Medical School. Academics who retain biomedical university positions consult frequently for large pharmaceutical companies, just as they do for biotechs.
51. In some nonbiomedical fields, there is evidence of real annoyance and harm to established companies caused by employees leaving for new ventures—as discussed in Part III.
52. Shane (2004).
53. Probably more bothersome than royalty obligations is universities' frequent insistence that they have the right to terminate an exclusive license if the pharmaceutical company is not developing a candidate drug and to relicense it to another company. The director of the IP department of a major Japanese pharmaceutical company remarked, 'Sometimes after investing millions of dollars investigating a candidate drug, rational business reasons lead us to halt development. It is not fair if the university can then terminate our rights and re-license to one of our competitors.' However, universities also have a legitimate interest in preventing licensees, that turn out not to be serious about developing candidate drugs, from using their license rights to prevent other companies from developing the drugs. Some pharmaceutical officials have said that if the university license gives them three to five years of exclusive control over the compound, this is sufficient, and beyond this time it would be reasonable for a university to request return of IP rights if the pharmaceutical licensee was not developing it.
54. Confirming this phenomenon, licensing officials at the US NIH report that most licenses for NIH-discovered candidate drugs or drug targets are now licensed to biotechs. Big pharma is simply not interested in early stage licenses they report. In contrast, approximately ten years ago when I was working in technology development at NIH, a substantial proportion of such licenses did go to big pharma.

In addition senior managers in one of the largest medical device companies told me in 2006 that in the field of devices, their company also has come to rely mainly on ventures for new technologies, many of these ventures being university startups.
55. This entrepreneurialism has been characterized as greed resulting in excessive payments to universities akin to nonproductive rents, especially when universities occasionally reap high royalty windfalls from licenses for compounds that later turn out to be the basis for successful drugs (see e.g., Leaf 2005).

In Germany at least up to 2002 and in Japan even to 2006 (and perhaps also in France and Switzerland), universities are less demanding than US and Canadian universities about ownership of IP rights and obligations to pay royalties. Thus, pharmaceutical companies could have chosen to fund substantially more research in Japanese and German universities and, following minimal negotiations with university authorities, they could have obtained complete control over resulting lead compounds and yet not have had to pay royalties on the scale they would have had to pay to US universities. Nevertheless, despite the more demanding and entrepreneurial nature of US, Canadian, and perhaps also UK universities, pharmaceutical companies probably direct more of their research monies to them than to docile Japanese and Continental European universities (based on conversations with pharmaceutical and university officials).

Jensen and Thursby (2001) and Thursby and Thursby (2003) indicate that financial incentives for university researchers and TLOs are important for technology transfer from universities to industry to be effective.

56. Appendix 2, Table 7A2.3. See Casper's (2000) description of the tendency of German biotechs to focus on research tools and other platform technologies rather than drug discovery.
57. Among the 11.4 drugs discovered in universities and licensed directly to pharmaceutical companies, half are non-priority NMEs, while among the 26.3 university-discovered drugs that are licensed to biotechs, three-quarters are NTBs or priority NMEs (Appendix 2, Table 7A2.1). With only a few exceptions, all the NTBs and priority NMEs originating in universities were licensed to biotechs. The principal exceptions are the NME, sirolimus (Rapamune®), approved in 1999 to prevent transplantation rejection, which was invented by Roy Calne of Cambridge University and licensed to Wyeth; the NME temozolimide (Temodal®), approved as an anticancer drug in 1999, which was co-invented by researchers in Nottingham and Aston Universities, Charing Cross Hospital, and the pharmaceutical company May and Baker (all in the UK), and later licensed to Schering Plough); the inhaled gas NME, nitric oxide (INO max®) approved in 1999 to treat pulmonary hypertension in new borns, invented by Swedish and US academic researchers and transferred first to a large manufacturer of anesthesia equipment, Ohmeda, and then to a Swedish industrial gas company, AGA AB; and finally the NTB, Rebif®, the most recently FDA-approved version of recombinant interferon beta-1a for multiple sclerosis, which was based upon discoveries at the Weizmann Institute (Some made in collaboration with a researcher at the Pasteur Institute), which were licensed from the Weizmann Institute to the Israeli subsidiary of the Swiss pharmaceutical company, Serono.
58. Goodman and Myers (2005). Note 313 summarizes this study's conclusions.
59. Murray (2002) has documented the close links between bioventures and universities that benefit from access to patients, as well as the clinical research of some of the academic advisers and founders of the ventures.

60. Confirmed, e.g. by discussions in July 2004 with the former director of corporate licensing for GE.
61. These percentages are for 2001 when total US university S&E R&D expenditures were US\$32.7 billion. The federal government's share of this support ranged from 57% for engineering and 58% for life sciences to 70% for the physical sciences. Most university life science research is funded by NIH which, with an annual budget of over US\$30 billion, has by far the largest nonmilitary R&D budget of any US government agency. However, other US agencies, notably NSF, the Department of Energy, and the Department of Agriculture also fund significant university life science R&D (National Science Board, Science and Engineering Indicators 2004, A5-8, 9).
62. While in other fields, economic theory and public policy generally holds that government R&D support should be confined to basic research, leaving private companies to fund R&D with commercial applications. Otherwise government funding for commercially relevant R&D would tend to favor certain companies or industries and distort market forces. On the other hand, because the commercial payoffs from basic research are usually uncertain and far in the future, private companies are unlikely to fund basic research. Moreover, basic research is akin to a public good in that the findings and newly trained scientists can benefit many companies. Therefore, according to economic and public policy theory, government support of basic research is appropriate and necessary, but this is not so in the case of R&D with direct commercial applications, barring some other public purpose such as promotion of health, defense, or alternative energy sources.
63. Of 31,570 patents identified as issued to US universities between 1980 and 2001, 12,648 (40%) were classified by the US PTO into one of the following categories: pharmaceuticals, biotechnology, agriculture, medical equipment, and medical electronics. Pharmaceutical and biotechnology patents accounted for 28% of the total. Even considering only the 3,094 patents issued to universities in 2001 (the most recent year for this dataset), life science inventions accounted for 42%, with pharmaceuticals and biotechnology accounting for percent 34%. (Data courtesy of Professor Diana Hicks, chair, School of Public Policy, Georgia Institute of Technology.) In contrast, 59% of university R&D funding was life science related. (National Science Board, Science and Engineering Indicators 2004, A5-11.)
64. The vast majority of university patents (90%) are licensed exclusively, either in their entirety or (more commonly) for a specific application or geographic region (Shane 2001 & 2004 and follow-up conversation with Shane in 2004), and startups or other SMEs are the recipients of most university exclusive licenses (76%, 2004 AUTM Survey Summary, Table US-14). Thus, even assuming that approximately half of US university startups are life science focused (as suggested in Shane, 2004), the fact that about 60% of US university patents are non-life-science related (previous note) indicates that a large proportion of these are probably being licensed exclusively to startups or other SMEs. If this

were not the case, universities would have to be licensing the vast majority of their life science patents but only a small proportion of their non-life-science patents. This would not make sense from a technology management perspective, and there is little evidence this is occurring.

65. Pharmaceuticals have traditionally been a vertically integrated industry where the time, expense, and risk associated with development are high. Returns to scale in terms of R&D are presumed to be high, at least this is one of the oft-cited rationales for the recent series of pharmaceutical mergers. It requires strong complementary assets, including facilities for high throughput screening, personnel and outside networks to conduct clinical trials, networks with regulatory agencies, and large sales forces. Also, some therapeutic fields have become quite crowded.
66. An opposite reason for small size to handicap ventures less in biomedicine is that many nonbiomedical discoveries have short product development cycles and commercial life spans. Thus it would not make sense to invest the effort to build a company to develop such discoveries, when they could be licensed to companies already in existence with resources to handle development, manufacturing, and distribution. However, licenses could be made to existing SMEs that already have done similar development work. Also, the sorts of pioneering inventions with which this book is mainly concerned probably are not inventions whose market will be short lived.
67. i.e. in-house know-how that is not to be shared with outsiders.
68. Cohen, Nelson, and Walsh (2000).
69. See Merges (1995), Hall and Ziedonis (2003), Cohen, Nelson, and Walsh (2000) and the following text. In the case of software companies, copyright can also be a means of protection. US copyright law protects computer source and object codes and US courts have generally adopted a 'substantial similarity' test for infringement, even in the absence of actual duplication of source code (Gorman and Ginsburg 1993: 719).
70. Cohen, Nelson, and Walsh (2000). Willoughby (2005*b*) found that bioscience firms that receive VC financing have more patents per employee than do firms that do not receive such financing.
71. Merges (1995).
72. Cohen, Nelson, and Walsh (2000) found such responses across a wide range of industries.
73. The cost of obtaining a US patent is roughly US\$10,000. The cost of obtaining protection in the US, Japan, and major European countries is approximately US\$100,000. The legal costs of infringement litigation can be much more, and an adverse final judgment can be devastating for a small company, although it can also bring a great windfall. On the other hand, there were probably over 50,000 investments totaling over US\$22 billion by American angels in 2004. A median range angel investment has been estimated to be on the order of US\$300,000. VC investments, although fewer (2,876 in 2004, most of which were mid or late stage) were larger (median per financing round about

US\$7 million). Total VC investment in the USA was about US\$21 billion in 2004 (Angel Capital Association, Aug. 2005, using data from Dow Jones VentureOne/Ernst & Young). Thus, while expensive, the cost of obtaining patents is probably not prohibitive in relation to the funding that promising ventures can usually expect to raise from outside sources.

The data in Appendix Table 7A1.1 show that even small, young New York and Utah ventures in biotechnology, medical devices, and other life science fields have on average about seven issued patents.

74. The survey findings of Cohen, Nelson, and Walsh (2000) are based on responses to a 1994 questionnaire from R&D managers in over 1,100 corporate laboratories in a cross section of US industries, asking them to report the percentage of their product and process innovations for which each of a variety of mechanisms had been effective in protecting the firm's competitive advantage during the prior 3 years. The specific mechanisms surveyed were: secrecy, patents, other legal mechanisms, lead time, complementary sales and services, and complementary manufacturing capabilities. The survey included firms with as few as twenty-five employees and with annual sales as low as US\$1 million. However, firms without either US\$5 million in annual sales or a business unit of at least twenty people were excluded. Also, Fortune 500 firms were over sampled. Since the initial sample frame was R&D laboratories or business units, some laboratories included in the final analysis are within the same large firm. Thus the overall results generally reflect the responses of large companies.

Within individual industries, the number of total respondents is not large. For example, with respect to product innovations, there were only forty-nine responses for pharmaceuticals, sixty-seven for medical equipment, twenty-two for computers, eighteen for semiconductors and related equipment, and thirty-five for precision instruments. Thus in specific industries where patents are important to innovative small or new firms, their responses would be obscured by responses from large firms.

The authors note when responses from small companies differ from the overall responses. However, if among small firms in a particular industry relatively few are engaged in the discovery or development of new products, but those that are include innovation leaders for the entire industry, responses by these few firms to the effect that patents are important will be obscured by responses of the majority of small firms across all industries that are not pursuing early stage innovation and do not rely on patents.

This likelihood is increased because the survey sampled firms engaged in manufacturing as well as those concentrating primarily on R&D. Manufacturing-related innovations (e.g. manufacturing processes, products that are intermediate in the manufacturing process, and refinements or combinations of existing products) probably are less reliant on patents than are R&D related innovations, especially R&D innovations in new fields of technology. Thus the proportion of a company's innovations that rely on patents

to ensure appropriability may diminish as more of a company's value-added shifts toward manufacturing as opposed to R&D (see Hall and Ziedonis 2003). Therefore, industries where manufacturing accounts for a high proportion of the value added will report that patents are effective in protecting a lower proportion of their innovations, compared to industries where a relatively high proportion of firms are engaged mainly in R&D. Drug development is probably in this latter category, because the value added by many bioventures consists mainly of R&D. However, in industries such as precision instruments, where a large majority of firms (large and small) are probably engaged in manufacturing, responses applicable to manufacturing-related innovations probably obscure responses applicable to R&D-related innovations. The authors acknowledge that by asking for the percentages of total product or process innovations that were protected by various mechanisms, a firm may indicate that patents were effective in protecting a relatively low percentage of innovations, even though patents were effective in protecting its most important innovations.

75. The following table is based on data from Kortum and Lerner (1999):

District court decisions	Percent upheld by	
	Federal appeals courts 1953–1978 (%)	CAFC 1982–1990 (%)
Holding patent to be valid and infringed	62	90
Holding patent to be invalid or not infringed	88	72

76. The patents at issue covered Polaroid's instant cameras and related technologies.
77. For example, Motorola, ATT, and IBM began to inventory their patents and collect royalties more deliberately (Hall and Ziedonis 2003).
78. Patent pools are formed by organizations that each have rights over various technologies that need to be combined to develop a particular line of products. For example, the MPEG system for digital compression and transmission of video data involves technologies covered by patents held by several companies and universities. Typically, members of a patent pool have preferential rights compared to outsiders to use the pooled patents.
79. The four preceding paragraphs are based largely on Hall and Ziedonis (2003), although I am also indebted to Cohen, Nelson, and Walsh (2000), Barnett (2003), Merges (1995), and Fransman (1995). Except for the last two sentences, which are my own, the sections in *italics* are near verbatim quotes from Hall and Ziedonis's work. Any misinterpretation of their work is, however, solely my responsibility.

As for the ability effectiveness of the Japanese patent system to protect the interests of ventures, see Chapter 4, notes 52–61 and accompanying text.

80. Hall and Ziedonis (2003) describe the growth of R&D intensive, design focused, and mostly recently formed semiconductor firms up to about 1990.

*Advantage New Companies*

327

Hyde (2003) discusses in more general terms the continuing birth of Silicon Valley IT firms up to the bursting of the IT bubble in 2001. He notes that the newer firms are often fabless operations (i.e. they focus mainly on design and do not do commercial manufacturing), or else their manufacturing is done overseas (i.e. a large proportion of the newer firms are R&D intensive design firms).

A partial list of the firms included in Hall and Ziedonis's survey is available in an earlier version of their paper at <http://jonescenter.wharton.upenn.edu/papers/2000.htm>. This list includes forty semiconductor firms whose first issued US patent was filed after 1980. The following table shows 1994 and 2004 sales data for the subset of these firms whose 1994 revenues were over US\$300 million:

Name of firm	Year of first successful patent application	1994 sales (\$M)	Approx. 2004 revenue (\$M)* or fate of firm
LSI Logic	1982	902	1,700
VLSI Technology	1982	587	bought by Philips in 1997 for ~ \$ 1 B
Integrated Device Technology	1982	422	390, to merge in late 2005 with Integrated Circuit Systems
Cypress Semiconductor	1984	406	950
Atmel	1987	375	1,650
Xilinx	1984	355	1,600

\* In some cases, revenue is for fiscal rather than calendar year. Also if the 2005 fiscal year ends before July 2005, I report FY 2005 sales. SEC reports and online investor information are the sources for sales data.

However, I have follow-up information on all forty companies. Among these, seventeen were still independent firms in 2005 and had 2004 revenues at least double their 1994 sales. (These seventeen do not include LSI Logic which has the highest revenue among all these firms.) Only six of the forty had ceased operations or had 2004 sales less than 80% of their 1994 sales. Twelve of the remaining companies had been bought by other companies—a few when in a state of distress, but probably a majority when revenues were at least equal to 1994 revenues. In summary, the forty new companies Hall and Ziedonis surveyed in the 1990s do not appear to have done poorly over the subsequent ten years.

81. Other factors include greater availability of venture capital made possible by a 1979 ruling by the US Department of Labor clearing the way for pension fund managers to invest in VC funds for the purposes of *portfolio diversification*, reductions in capital gains tax rates, the culture and infrastructure of regions such as Silicon Valley, which provided a fertile environment for the formation of S&T companies, and profit squeezes that forced manufacturing and financial corporations to seek high returns from their financial resources.

In addition, the restructuring of many large corporations in response to profit squeezes and conglomerate type mergers may have caused skilled employees to leave for ventures.

The 1980 Bayh-Dole amendments to US tax law probably facilitated the formation of university startups, because it encouraged universities to apply for patents on their discoveries and facilitated the transfer of IP rights to companies, particularly small businesses.

Most of the case studies in Chapter 4 suggest that patent rights have also been important for the formation of Japanese ventures.

82. See, e.g. Shane (2004) and Cohen, Nelson, and Walsh (2000).
83. Gans, Hsu, and Stern (2000). See also Arora and Merges (2004).
84. Examples include Nanosys in the field of fabrication technologies and Nanophase Technologies which is developing powders for sunscreens and other uses, NVE, which is developing a system to store and transmit information based on electron spin rather than electron charge and several new companies working in nanoscale drug delivery systems.
85. Fransman (1995: 173, and 203–54) provides two examples: Between 1971 and 1977 NEC, which had been following Intel closely, produced microprocessors that were modeled on Intel's and were Intel-compatible. However, shortly after this period, NEC switched to its own proprietary microprocessor design, which was incompatible with Intel's, largely out of concern that the Intel-compatible microprocessors would infringe Intel's intellectual property. Despite the switch, Intel did sue NEC for infringing its microprocessor code. Other Japanese electronic companies also developed their own proprietary microprocessors and microcontrollers. This fragmented the domestic Japanese market not only for hardware but also for software, and made these microprocessors unattractive overseas where there were few incentives to develop software for the various proprietary Japanese microprocessors and their operating systems. NEC's microprocessor became neither the industry standard that Intel's became for PC applications, nor could it benefit from the standards that Intel set.

The second example is the development of high efficiency (low signal attenuation) fiber optic cable. The breakthrough method to limit signal transmission loss was worked out by Corning Glass in the late 1960s. In response, NTT (then a subsidiary of the Ministry of Posts and Telecommunications) launched a cooperative R&D project with Japan's three major cable companies, Sumitomo Electric, Furukawa Electric, and Fujikura, Ltd. to produce a Japanese alternative to Corning's method and invent around Corning's patents. Building on prior competence in optical research and information from AT&T/Bell Laboratories (which was also doing research in fiber optic signal transmission and which could use Corning's patents under a preexisting cross licensing agreement), NTT researchers developed a similar method which they shared with the three Japanese cable companies, which also made important improvements. By the late 1970s, world records in low signal attenuation were

being set in NTT's laboratories. In the early 1980s Sumitomo Electric began exporting fiber optic cable to Canada and setting up a production plant in North Carolina. Corning sued, alleging patent infringement. In 1987, the New York District Court ruled that Corning's patents were valid, that Sumitomo's technology was *equivalent* to Corning's, and that Sumitomo had to cease production at its North Carolina plant. Sumitomo entered into a joint venture with AT&T under which AT&T received a majority stake in the North Carolina plant and could sell its cable output.

In the late 1980s with the entry of MCI into the newly deregulated US telecommunications market and MCI's decision to install fiber optic cable connections extensively in the USA, Corning's persistence began to pay off as sales of fiber optic cable finally took off. In 1987, Corning held 40% of the North American market for fiber optic cable, AT&T (using Japanese technology) 43%. Corning's Japanese applications for the same patents that were upheld in New York were not approved by the JPO. The 1987 Japanese market was split largely between Sumitomo (35%), Fujikura (22%), and Furukawa (21%).

Although the 1987 ruling of the New York District Court was a winner-take-all verdict based on inherently slippery judicial concepts (i.e. the *equivalence* of inventions), it nevertheless resulted in a deserved reward for Corning, justifying its risky decision around 1970 to invest heavily in a new technology for which market demand was uncertain. At the same time, the Japanese companies were also rewarded (and their scientific backer and main customer, NTT, vindicated from an industrial policy perspective) for their rapid improvement of the basic method, which pushed Corning to devote more resources to its own improvement efforts, which resulted in this new technology becoming more rapidly available.

In 2005, high technology Japanese companies were involved in several high stakes suits alleging IP infringement by lower cost competitors in Korea and China.

86. The companies summarized in Chapter 4 generally said that patents in combination with trade secrets are important to prevent encroachment. The same probably applies to US nonbiomedical ventures (Cohen, Nelson, and Walsh 2000). See also Appendix 1, Table 7A1.1 based on data from Willoughby.

Approximately one-third of the companies in Willoughby's dataset are working primarily in medical devices in contrast to pharmaceuticals or biotechnology. Preliminary analysis of these data indicates that this phenomenon of mixed trade secret and patent protection is a characteristic of new small medical device firms as well as those focused on pharmaceuticals and biotechnology (see Willoughby 2005a, 2005b).

87. IBM has been a leader in making large numbers of patents freely available for use, especially by developers of open source software. Other companies such as Nokia, Red Hat, and Sun Microsystems have also decided not to assert some of their patent rights (Cukier 2005, 'An open secret'). For an analysis of

private parties putting patentable discoveries in the public domain, see Merges (2004).

88. One additional possible advantage (suggested by McKelvey 1996: 271) is that meeting pharmaceutical regulatory requirements requires drug companies to devote a great deal of their resources to this downstream activity, leading perhaps, to pharmaceutical companies being more locked in to particular lines of research than large companies in other industries. This leaves new ventures with more niches to exploit with respect to new drugs, than is the case in other industries. However, the extent to which this phenomenon actually exists in pharmaceutical companies is not clear. Clinical trials and procedures for manufacturing and quality control (activities that may have to be tailored to a particular type of drug) do indeed account for a large proportion of pharmaceutical companies' expenses [about US\$9.3 billion (44%) of total US pharmaceutical R&D expenses of US\$21 billion in 1998]. But marketing, which presumably could adjust easily to different types of medicines (at least for the same disease category), accounts for even more, US\$12.3 billion in 1998 (PhRMA, Pharmaceutical Industry Profile 2000: 26 and 2002: 18). My impression is that pharmaceutical companies' networks of CROs, physicians, etc. can adapt relatively quickly to carry out clinical trials for either small molecule drugs or antibodies to treat rheumatic disease, just as one example. These networks may even be able to adapt to drugs to treat different types of diseases. In any case, it would be surprising if lock-in due to downstream development infrastructure is significantly greater for pharmaceutical companies than for large companies in other industries.
89. This hypothesis is supported by Lerner's analysis of the patenting behavior of biotechnology companies (1999). It is also supported by McKelvey's account of the development of recombinant DNA technology and how favorable perceptions of ultimate technical feasibility and the medical/market demand for genetically engineered drugs guided both academic and corporate scientists (many of the latter in Genentech) to pursue R&D in this area.
90. The relative scale of corporate basic research is less in 2005 than it was in the 1960s. Gone are the days when large groups of scientists and engineers in AT&T's Bell Labs, RCA's Sarnoff Center, and Xerox's Palo Alto Research Center pursued largely curiosity driven, often fundamental, research—that nevertheless led to many of the products we enjoy today. As of 2005, IBM still did some fundamental research, mainly at its Thomas J. Watson Research Headquarters in Yorktown Heights, New York, as did General Electric at its Global Research Center near Schenectady, New York.

As for the central research laboratories of large Japanese electronic companies, some industry observers contend they never have done fundamental exploratory research—with the possible exception of NTT's Basic Research Laboratory and Communications Science Laboratory. In any case, their central research laboratories now depend mainly on contract research from their design and production divisions, and engineers and scientists are being

transferred to these divisions. Of course all large high technology corporations do research, but usually applied research with specific commercial potential in mind. Intel, for example, is known as a company whose future depends on fast paced R&D. But Intel's policy is that all research should have a definite business objective in mind.

91. The university research that gave rise to genetic engineering technology culminated around 1973 when Professor Stanley Cohen of Stanford and Professor Herbert Boyer of UCSF jointly developing a series of techniques to cut and paste genes from humans or other organisms and to insert these into bacteria so that the bacteria would produce the proteins (e.g. human insulin or growth hormone) coded for by those genes. Stanford and UCSF jointly applied for a patent on this invention in 1974, which was granted by the US PTO in 1980. Cohen's and Boyer's discovery was preceded by other university research, primarily in the USA and UK. Boyer went on to found Genentech in 1976, thus providing a bridge between university research and industry R&D efforts in this area, most of which were conducted by bioventures. Later some large pharmaceutical companies tried to master this technology, and Lilly notably made good progress (McKelvey 1996: especially Chapters. 4, 5; Zucker and Darby 1997). However, the above analysis of NTBs approved by the FDA indicates that venture companies are still the unquestioned leaders in this field.
92. Murray (2002).
93. For an account of government funded university research that prepared the way for the Internet see Roessner et al. (1997). See also the histories of companies such as Cisco Systems and Sun Microsystems, both of which are based on Stanford technologies.
94. For example, Nanosys has obtained exclusive licenses from MIT, UC Berkeley, Lawrence Berkeley National Laboratory and other universities and GRIs, of patents covering nanomaterials and nanofabrication methods. As of 2005 Nanosys's staff of approximately thirty-five was developing customized applications of these technologies for companies such as Sharp, Intel, DuPont, and Matsushita, as well as US government agencies.
95. These examples and others are from Hyde (2003), Chandler (2001), and Christensen (1993).
96. The historical account up to 2000 is based on Christensen (1993) and Hyde (2003). Seagate, Maxtor, and Western Digital had 2004 revenues of approximately US\$8, US\$4, and US\$4 billion, respectively. Hewlett Packard also manufactures disk drives, as does Adtron, founded in the 1970s and based in Arizona. Non-US manufacturers include Fujitsu, Hitachi, Samsung, and Toshiba. In 2005, Seagate claimed to sell more units than any other company.
97. Hyde (2003: 31). My review of the forty ventures in Hall and Ziedonis's 1990s analysis (see note 80) also indicates that most were formed by persons with experience in other R&D or device manufacturing companies.

98. Saxenian (1999).
99. See Association of University Technology Managers (AUTM) Product Stories at [http://www.autm.net/aboutTT/aboutTT\\_prodStory.cfm](http://www.autm.net/aboutTT/aboutTT_prodStory.cfm)
100. Roessner et al. (1997: Chapters. 2, 3).
101. Steven Wozniak and Steven Jobs founded Apple in 1977, sensing both the commercial potential for a small computer and the feasibility of building one by combining many new component technologies. Microsoft was founded in 1975 by Bill Gates and Paul Allen to provide control programs for radio controlled model airplanes (Chandler 2001).
- Irwin Jacobs founded Qualcomm in 1986 to develop digital wireless communication. He soon decided to use code division multiple access (CDMA), developed for military communications, as the mechanism to transmit digitalized mobile telephone messages. Qualcomm was neither a university startup, nor a spin-off from a large company, yet it went on to commercialize the mobile wireless applications of CDMA. By 2005 it held more of the essential patents covering third generation wireless communication technology than any other company (Goodman and Myers 2005). However, Dr Jacobs's previous experience as head of another venture, Linkabit, which was involved in scrambled communication over satellite terminals, may have provided him and his early Qualcomm colleagues with the same sort of hands-on industry knowledge that was valuable to the engineers who left IBM and Intel to start their hard disk drive and semiconductor spin-offs.
102. The university startup, Plasmaco, was short of funds from the time of its founding. Its founders managed to show proof of concept at a 1994 industry convention. Plasmaco then entered into a joint development program with Matsushita, which bought Plasmaco two years later. Other Japanese companies also cooperated with University of Illinois scientists. Fujitsu, in particular, also made important improvements to the basic technology. However, by 2004 Fujitsu had sold most of its stake in PDP televisions to Hitachi and then in 2005 Hitachi partnered with Matsushita, essentially leaving Matsushita as the largest manufacturer (Hutchinson 2002; 'Flat-panel TV makers doing deals,' *Nikkei Weekly*, Feb. 14, 2005, 14; Takato Daisuke. 'Price Competition Drives Pioneer to a Loss,' *International Herald Tribune*, Nov. 1, 2005, B2).
103. Quoted in Wilson (1985a: 191).
104. See examples in Hyde (2003: 27–8, 38–40).
105. California law is unique in that its courts will not enforce no-compete clauses. Whether employers in California can use trade secret law to the same effect by arguing that for former employees to work for a competitor inevitably will disclose the former employer's trade secrets is still an open question. However in most other US jurisdictions, both these weapons are likely available for employers, particularly the use of no-compete clauses, provided they are of *reasonable duration and geographic scope* (Gilson 1999). See Hyde (2003) for an analysis of these laws and their effects on ventures and the people who work in them.

106. Wilson (1985a: 215).  
Unable to raise sufficient venture capital, Amdahl turned to Fujitsu for financing. Coincidentally, MITI had just designated Fujitsu and Hitachi to build a computer equivalent to the 370, as the center piece of MITI's New Series Project to maintain Japan's competitiveness in computer technology. Fujitsu invested over US\$50 million in Amdahl's company. By 1976 it was marketing a mainframe similar to the 370. Amdahl relinquished control in 1979 when Fujitsu raised its equity stake in the company to 47%. Fujitsu's acquisition of IBM mainframe technology via Amdahl assured the success of the New Series Project. After this Japanese computer manufacturers came to dominate the European mainframe market (Siemens-Nixdorf also came to rely on Fujitsu for technical and product development expertise for mainframes sold under its brand name), and by 1996 they held nearly two-thirds of the world market. That year Fujitsu lead the world in mainframe computer sales, its sales of mainframes exceeding those of IBM's by 15%. In 1999 Siemens-Nixdorf was incorporated into a joint venture with Fujitsu (Chandler 2001, quoting from computer historians Marie Anchoy and Kenneth Flamm).
107. This paragraph summarizes and includes quotations from Christensen (1993: 579).
108. See the histories of the formation of Intel, Control Data, Compaq, Amdahl, and the hard disk drive companies in Chandler (2001) and Christensen (1993). In Amdahl's case, the source of frustration was his conviction that IBM could have produced a cheaper mainframe, not that it was failing to develop the technology.
109. Daisy Systems, a pioneer of engineering workstations in the early 1980s, recruited at least 50 engineers from Intel. But by helping companies speed up designs of complex integrated circuits, it probably helped Intel's R&D (Wilson 1985a). The defections from Intel to other chipmakers, from Cisco to other communications device firms, and from IBM to hard drive and other computer component makers, helped create products that were compatible with the parents' products and that used the parents' protocols and thus, at least in some cases, increased demand for the parents' products.
110. Most employers in most industrialized countries require, as a condition of employment, that employees assign to them rights in any patentable inventions or copyrightable works made in the course of their employment. Usually the employer applies for patents and maintains ownership of issued patents even if the employee leaves. These protections do not work, however, if an invention is not patentable, if employers use trade secrets rather than patents to protect their technologies, or if employees fail to disclose inventions to their employers. Hyde (2003) describes cases of Silicon Valley employees failing to disclose inventions and other information when the end of their employment is in sight.
111. Hyde (2003: 68).
112. More so than the Route 128 corridor outside Boston.
113. See Saxenian (1994), Gilson (1999), Hyde (2003), and note 105.

114. This is the main thesis of Chandler (2001: 236). It is also echoed in Aoki (1990: 9) and Fransman (1995: 313–16 and concluding chapter). Both Aoki and Fransman note the importance of lifetime employment and internal job rotations to build long-term learning and organizational competence. However, the failure of US consumer electronics companies, such as RCA, Ford Philco, and GTE Sylvania, to withstand Japanese competition was probably due largely to incompetent management that became distracted from the companies' core business.
115. Including marketing, customer support, and feedback.
116. However, despite their success in drug discovery, only a few biotechs have developed integrated R&D competencies. In other words, many do not conduct clinical trials, most do not have sales forces and, except in the cases of NTBs, manufacturing is usually outsourced.
117. This point is made graphically in Fransman (1995: ch. 9, Fig. 9.1).
118. See Chesbrough (2003) and Cukier (2005, especially 'An open secret').
119. It has been suggested that, as companies engage in patent arms races, established companies might use their large patent arsenals to harass or drive out of business new companies they perceive might become competitors. So far evidence of such behavior targeted particularly against new companies seems scant. More often one hears new companies say that patent protection is essential for their early survival. See text above as well as Cukier (2005).
120. The high technology sectors of Silicon Valley are in order of number of employees: software, semiconductors and related equipment, computer and communications hardware, innovation services, biomedical, electronic components, corporate offices, and creative services. Overall Silicon Valley employment in these sectors declined 3.2% over the twelve months ending in June 2004, while average salaries in these sectors rose 8.2% over the twelve months ending in June 2003. The balance between firm creations and deaths and entries and departures from Silicon Valley, was a net gain of 12,600 companies in 2002, the largest net gain since 1992. VC investment in Silicon Valley was US\$7.1 billion in 2004, higher than for any year except 1999, 2000, and 2001. In 2004, thirteen publicly traded companies reported revenue increases of at least 20% per year over each of the previous four years, a higher number than any year since 2001. Corporate R&D spending as a percentage of sales was 12% in 2003 compared with 14% in 2001 and 2002, but this was still a higher rate of R&D investment than any year prior to 2000 (when it was also 12%), and four times the national average of 3% (Joint Venture: Silicon Valley Network 2005).
121. High housing costs, problems assimilating immigrants, mediocre performance by school children, falling local government revenues, and (perhaps surprisingly) lower rates of residential broadband access than other high technology US regions (Joint Venture: Silicon Valley Network 2005).
122. Begley (2002) summarizes the apparently widespread frustration among US engineers, who feel they are treated as commodities, in part because of large

numbers of young foreign-born engineers (who presumably can change jobs more easily) and who hold down salary increases for senior employees. Many engineers interviewed for the Begley article said they discourage their children from entering the profession. Whatever the merits of their other claims, there is little evidence that foreign scientists and engineers bid down wages, or that they cause significant unemployment. Foreign-born scientists and engineers tend to have higher incomes than US-born scientists and engineers. See Hyde (2003: 345), Dahms and Trow (2005), and Anderson (1996).

123. Of course, employee mobility and competition from ventures may be less important reasons for the demise of large corporate basic research laboratories than competition from other companies and antitrust actions, that reduce profits and force stricter cost accounting, pressure from shareholders, etc.
124. One might reply that the hurdles such persons face obtaining senior positions in Japanese companies or permanent jobs in Japan, and Japan's reluctance to accept skilled professionals and their families as immigrants, are the root causes of Japan's inability to attract and retain more skilled immigrants.
125. Saxenian (1999) and Hyde (2003) for 1990 data. Wulf (2005) for 2000 US-wide data. For comparison, twenty years earlier in 1980, 24% of Ph.D. scientists and engineers were foreign-born. Because Silicon Valley is known to attract a large number of foreign scientists and engineers, the percentage of foreign-born scientists and engineers in the Valley in 2005 is probably higher than the US national average.
126. These allow US companies to employ foreign workers in specialty fields such as science, engineering, medicine, nursing, law, and accounting for up to six years. The annual limit of new visas was 65,000 until 1999 when it was raised to 115,000 and then to 195,000 in 2001. However, under sunset provisions, it reverted to 65,000 in 2004. (Dahms and Trow, 2005).
127. This is probably true nationally, because Chinese and Indian S&E professional immigrants are more concentrated in California than any other state (Saxenian 1999: 12) and a high proportion of California's S&T employment is in venture companies. However, I know of no data on whether, within any particular high technology region, the ratio of immigrants among S&E professionals in new S&T companies is greater than the ratio in established S&T companies. (Generally, on S&E immigrants in Silicon Valley, see Saxenian 1999; Hyde 2003.)
128. Data on immigrants in Japan is classified according to type of job, not level of education. The relevant categories are 'researchers' and 'technical personnel'. The former applies to foreign scientists, engineers, and technicians in universities and GRIs, the latter to those in other organizations. (Students, trainees, physicians, nurses and other medical personnel are excluded, as are permanent residents.) In 2004, the total number of foreigners in these two categories combined was 25,758 (2,548 researchers and 23,210 technical personnel). Compared to the total number in 2000 (19,465) this suggests a net annual increase of about 1,600 persons (Ministry of Justice and Ministry of Foreign

Affairs). Assuming that the Japan's total S&E labor force as a percentage of its total population (127 million in 2004–6) is approximately the same as that of the USA (3.8%), suggests that Japan's total S&E labor force is around five million. Thus foreign nationals probably account for about 0.5% of Japan's S&E labor force.

129. See Saxenian and Hsn (2001). However, Japanese-born engineers account for only 4% of the foreign-born Silicon Valley engineers, which probably is one reason Japanese regional innovation centers have not grown in parallel with Silicon Valley, the way centers such as Bangalore, India, Hsinchu, and Taiwan, have.
130. Rather than being triggered by concern that the visa applicant will engage in terrorist activities, this stricter scrutiny usually is aimed at preventing transfers abroad of technologies with military applications. Strict scrutiny is triggered if consular officials think a visa applicant's background or likely study/work in the USA will involve access to one of a long list of *sensitive* technologies listed on the Government's Technology Alert List (TAL). However, following the Sept. 11 terrorist attacks the TAL was substantially expanded to include, example, almost all fields related to infectious diseases, environmental planning, and landscape architecture. Also consular offices were instructed shortly after Sept. 11 to be more vigilant concerning sensitive areas of study. In 2003, it often took over 60 or even 120 days for consular offices simply to receive a recommendation whether to issue the visas. F-1 visas issued for full-time students fell 20% (from 293,357) in 2001 to 2002 and 8% from 2002 to 2003.

As for professional foreign nationals recruited by US companies to work in special technical fields, between 2001 and 2002, H-1B visa recipients (a large proportion of whom are foreign scientists and engineers) fell 27% from 161,643 to 118,352. Between 2002 and 2003, they fell an additional 9% to 107,196. Reductions in H-1B visas issued to Indians and Chinese, who make up approximately half of foreign-born engineers in Silicon Valley (Saxenian 1999: 11–12), are even higher than these overall averages. In October 2004, with the reversion of the H-1B visa ceiling to 65,000, H-1B immigrants fell sharply again (Paral and Johnson 2004; Dahms and Trow 2005).

131. In 2000, 55,000 US citizens and permanent residents received bachelors degrees in engineering, off from a high of 71,000 in 1985 and lower than any number since 1977. In 2000, 18,000 US citizens and permanent residents received doctoral degrees in science and engineering, off from a high of 21,000 in 1995 and lower than any number since 1993 (National Science Board 2004).
132. See Flanigan (2005) reporting on the decision of Conexant (the 1999 spin-off of Rockwell International's semiconductor operations, that makes microchips for modems connecting home computers and other devices to the internet) to outsource two-thirds of its semiconductor design and other high technology engineering work to its subsidiary in India, because too few American engineers are graduating each year and Indian graduates are staying home and finding work in India due to post-9/11 visa restrictions.

133. e.g. see Markoff (2005) and Rai (2005).
134. Hyde (2003).
135. See Chapter 4.
136. Hyde (2003: 228).
137. Although their knowledge may be valuable, for various reasons (lack of information during the job search process, salary expectations that are out of line with what potential new employers are willing to pay, preconceptions by potential new employers about what constitutes a desirable mix of ages, personalities, etc.) companies may not hire them, or by the time they are able to hire them (following an economic upturn) they have found other work unrelated to their former field.
138. Health Insurance Portability and Accountability Act of 1996 (Public Law 104-191) §701.
139. In 2005, the out of pocket cost for health insurance coverage for a healthy family of four living in the Washington, DC, area (principal breadwinner about age 50 with no significant risk factors) was US\$5,000–6,000 annually. Even at this rate, deductibles and co-payments (the costs of various procedures that the family had to pay for out of pocket) were high, almost US\$2000, mostly for routine visits—not for any major ailments. This insurance would not have covered medical conditions (e.g. diabetes, circulatory diseases, and so on) existing at the time insurance was purchased for a period of twelve to eighteen months following the purchase (enrollment) date.
140. Most other industrialized nations have a nationwide health insurance system that provides, if not for public funding of self-employed persons and employees of small businesses and their families, then for pooling of health insurance payments from such persons so that risk can be spread among a large number of persons. Except for persons over 60 who are covered by Medicare or those who are quite poor and eligible for Medicaid, the USA lacks such a nationwide insurance system, relying on employers to provide health insurance, but not requiring (at least on a national level) that they do so.
141. Wilson (1985*b*).
142. Hyde (2003: 63) quoting the vice-president of one of Silicon Valley's best known companies.
143. Employment in high technology manufacturing industries declined by 15% compared with 9% for manufacturing industries as a whole (Hecker 2005).
144. Hecker (2005). The three IT-related high technology manufacturing industries are *computer and peripheral equipment manufacturing*, *communications equipment manufacturing*, and *semiconductor and other electronic component manufacturing*, and these experienced average annual increases in output per hour of work of 25%, 10.5% and 21%, respectively, between 1987 and 2002.
145. Between 1987 and 2002, average annual output per hour in pharmaceutical manufacturing increased only 1%, while over the decade up to 2002, employment increased by 30%.
146. In Hecker's analysis, most biotechs were classified either to *pharmaceutical and medicine manufacturing* or to *scientific R&D services*.

147. 70% of US venture capital disbursements in 2002 were in IT-related companies. 24% were in biotech and other fields of health and medicine (National Science Board (2004, appendix table 6-15)). The distribution of angel investments shows a similar pattern, with perhaps a slightly higher percentage for companies in non-IT engineering fields (energy, instruments, etc.). (Online reports from the Center for Venture Research and the Angel Capital Association.)
148. e.g. Qualcomm developed the strongest portfolio of essential patents covering 3G wireless technology (Goodman and Myers, 2005). Of course it would not be feasible for a venture company to finance an extremely expensive project, e.g. a space station as a platform to develop microgravity manufacturing processes. However, if some other organization could finance a space station, a venture company might be able to quickly develop such processes and pay a reasonable use fee to the space station operators.
149. The system will have to be flexible enough to ensure that people return to a particular field when downturns are over, or, shift to other S&T fields (or related management) if downturns in a particular field will be prolonged. The Japanese system has been to keep persons within the same company even when the company no longer needs their expertise. The US system has been to rely on these persons to find new employment on their own. So the Japanese system is good at preserving its S&T labor force but not at redeploying it to areas of greater need. The US system is better at redeployment to areas of greater need, but it runs a greater risk of losing persons permanently from its S&T labor force in times of prolonged downturn.
150. See Chapter 2, note 16 and accompanying text.
151. Kneller (2003) summarized in Chapter 2.
152. Of course, if biotechs did not exist, US pharmaceutical companies would carry out some of the drug discovery work currently done by biotechs. However, the discussion in Part I of this chapter suggests that the output of innovative drugs would probably be less.
153. i.e. observing closely innovations made in overseas companies and then trying to improve on those products while manufacturing at cost competitive.
154. In 1977, there were over 1,300 companies manufacturing machine tools in the USA. Their average employment was 62. Only 10 plants had more than 1,000 employees. The average size of a Japanese machine tool company was even smaller, 21, and only 6 had more than 1,000 employees (Carlson 1990).
155. Apple did not market its first microcomputer until 1976 or 1977, Commodore and Tandy not until 1977. IBM did not begin marketing the PC until about 1982 (Chandler 2001).
156. In 2004, the leading producers of MTs were, in order, Japan, Germany, Italy, mainland China, Taiwan, and the USA (2005 World Machine Tool Output and Consumption Survey).

*Advantage New Companies*

339

157. Around 2000, over 60% of the value of US MT purchases were imports, but about 30% of US production was exported, a rare phenomenon for a 'mature' industry (Kalafsky and McPherson 2002).
158. As the median number of employees for all US firms in 2000 was around sixty, the smaller firms all had fewer than this number of employees. These small firms tended to be clustered in the states bordering the Great Lakes and to depend on customers who were themselves old rust belt manufacturers—at risk of moving to other regions and thus further depleting the small MT companies' customer base (Kalafsky and McPherson 2002).
159. UNOVA, a data automation and communications company descended from the conglomerate, Litton, had acquired Cincinnati Machine (formerly Cincinnati Milacron, one of the largest independent US MT companies), Lamb Technicon and Landis Grinding as well as a host of other MT companies. Together, as UNOVA's Industrial Automation Systems (IAS) unit, they made UNOVA the largest US MT producer from the late 1990s until about 2004. However between 2004 and 2005 UNOVA divested its entire IAS unit, the Cincinnati and Lamb components going to an investment firm and the Landis operations to a French industrial engineering consortium, Groupe Fives-Lille. Ingersoll Milling Machine Co. was America's second largest MT maker in the late 1990s. It went bankrupt in 2003. The larger part of its assets were acquired by the Camozzi Group of Italy. A smaller part was resuscitated as Ingersoll Production Systems by the Chinese MT company, Dalian. In a similar vein, Thyssen, Germany's largest MT maker bought Giddings & Lewis in 1997, saving G&L from dismemberment at the hands of the American company Harnischfeger that was interested only in G&L's service parts business (2005 Machine Tool Scoreboard and various media reports).
160. 40% of US MT production was exported in 2004 (2005 World Machine Tool Output and Consumption Survey). See also Kalafsky and McPherson (2002) and Uchitelle (2005).
161. Uchitelle (2005). Haas was founded in 1983 and is among the youngest of the major US MT companies. It eschewed layoffs because they go against its corporate culture, and probably also because it wants to have skilled employees on hand when orders are high. While increasing exports, it is also increasing automation in order to keep labor costs in check.
162. See Appendix 3, Table 7A3.1 for a ranking of the largest Japanese and US companies. Of the 90 members of the Japan Machine Tool Builders Association, one of the most important industry trade groups, only 9 had more than 500 employees. The median number of employees was about 100, equivalent to the US median of 60 in 2000. Germany has vied with Japan for leadership in this industry, and its MT firms also tend to be independent SMEs, an exception being Siemens which was the sales leader in 2004, mainly, like Fanuc, on the strength of sales of numerical controls and measuring systems.
163. See Tom Beard (2005), 'World Machine Tool Review' (Special Report, Jan. 9). *Modern Machine Shop*, [www.mmsonline.com](http://www.mmsonline.com)

164. Unless noted, this account is based on Friedman (1988).
165. According to Friedman (1988), this was the case with Mori Seki (no. 7 in the world in 2005) and Matsuura (2004 sales about US\$100 million and 301 employees).
166. Carlson (1990). Modular innovation in the US arose in part from various companies making IBM compatible computer peripherals and by the advent of standard computer operating systems such as DOS/Windows and Unix (Christensen and Raynor 2003: 137–41; and Chesbrough 2003).
167. Friedman (1988) citing studies by Kiyonari and Koike.
168. Friedman (1988) and Whittaker (1997) are the source for most of this paragraph. This particular example is from Whittaker.
169. This is the main thesis of Friedman (1988).
170. See Asanuma (1992), Dyer (1996), and Odagiri (1992) under Chapter 6, References.
171. Friedman (1988) would probably argue it is the only policy that offered significant benefit. Loans by the much larger Japan Development Bank (JDB) and government research subsidies did not account for a large proportion of capital investment (pp. 86–91).  

Research by Calomiris and Himmelberg have analyzed lending to MT firms by not only the JDB, but also the Export–Import Bank and the private, development-oriented Industrial Bank of Japan and the Long-Term Credit Bank. They conclude that JDB and Ex-Im Bank loans may have helped to promote private investment, but in general their conclusions agree with Friedman’s—these large-scale government loan programs provided at best marginal benefit to MT firms.

Tariffs on MT imports also cannot account for the flowering of the Japanese MT industry in the 1970s and 1980s. These were instituted in the late 1950s. Many were rolled back in the 1960s. By the 1970s, rates were equivalent to those in the USA. In 1983, all tariffs were removed.
172. Needs not being met by the main US MT manufacturers.
173. For example, the nonbiomedical, nonsoftware companies that had IPOs 2000–4 listed in Chapter 5, Appendix 1, Table 5A1.1; also the companies engaged in patent infringement or unfair competition suits (see notes 264 in this chapter and 58 in Chapter 4).
174. See Whittaker (1997, Chapters 7 and 8). See JSBRI (2003, Chapter 4 references) for rates of SME entry and exit in manufacturing.
175. The importance of a capable, interventionist bureaucracy was stressed by Johnson (1983). Fransman (1995) described the virtues of managed competition, often mediated by a government monopoly-corporation, such as NTT, that has advanced research resources to share with Japanese companies and is a guaranteed purchaser of their products. For counterarguments to the competent industrial policy thesis, see, e.g. Callon (1995), who questions the effectiveness of MITI-inspired R&D consortia once Japanese companies were beyond the catch-up phase. See also Friedman (1988), who describes how

the machine tool industry prospered despite repeated government efforts to exert greater control over that industry—efforts that probably would have been counterproductive had they succeeded.

As an example of recent Japanese research on this issue, Takahashi (2007) concludes, on the basis of interviews with former officials of MITI and the Ministry of Post and Telecommunications, that while ministry guidance was of some value in the catch up phase, it failed to anticipate key changes in the IT industry and it hindered Japanese telecommunication companies once they had attained globally competitive capabilities in the 1980s.

176. This appears to be the definition adopted by Mariko Sakakibara (1997: 449), who has published analyses of data from 1959 to 1992 covering most government consortia. Sakakibara defines her sample as follows: ‘government-sponsored R&D consortia in the sample include all significant company-to-company cooperative R&D projects formed with a degree of government involvement’.

However, to my knowledge, projects are not classified by funding agencies as to whether they are *consortium* projects. In other words, with the exception of some large-scale projects such as VLSI, New Sunshine, and PERI that are clearly consortium projects, decisions as to which projects to classify as consortium projects probably have to be made on a case-by-case basis. Thus, how to define *consortium projects* becomes important. A review of all NEDO projects funded in 2005 shows a wide range of projects, that may or may not be considered to be consortium research depending on the precise definition. There are subprojects within projects. The subprojects may involve a single university or company, but the larger project involves several companies and universities. There are projects involving local government-affiliated companies and private companies. There are (sub)projects that involve only one company but a group of universities or GRIs. There are projects involving an industry association (often METI sponsored) such as the Japan Bioindustry Association or the Japan Fine Ceramics Center whose members include a large number of private companies. Finally, there are projects or subprojects involving a single company which subcontracts to universities and/or other companies. As indicated below, subprojects that involve two or more companies are relatively rare even for NEDO (rarer still for JST-CREST and OPSR projects). However, for high priority frontier fields of R&D where successful research is likely to find commercial applications (e.g. IT, nanotechnology, and some fields of biomedicine), (sub)projects involving two or more companies (usually large companies) are fairly common.

177. See Fransman’s account (1995), and note 85, above.
178. This following account is from Callon (1995) and is corroborated by discussions I have had with persons in the semiconductor industry. The five corporate participants in the project were Hitachi, Fujitsu, NEC, Toshiba, and Mitsubishi. The former three, as long-term main suppliers to NTT, also collaborated closely with NTT’s laboratories during the project.

179. Callon emphasizes that the amount of information shared among the participants was limited because of concerns about leakage of each company's confidential information, although toward the end of the project, sharing of information increased as new technologies evolved, including technologies developed by the project itself.

I have heard the same basic story with respect to the amorphous silicon solar cell consortium. Advances were achieved mainly by cooperation between individual corporate participants and university scientists, not by cooperation between scientists in different corporations.

180. Ironically, in 1980 at a time of high trade tension involving automobiles as well as electronics, and amidst charges by the US government and US semiconductor manufacturers of secrecy and unfair government subsidization of R&D, MITI and NTT decided to open all VLSI consortium patents to any company to license nonexclusively. Since IBM and Texas Instruments had cross licensing agreements with the consortium members, they were able to use almost all the VLSI patents for free (Callon 1995: 168).
181. Callon (1995) and Sakakibara (1997).
182. See [www.nedo.go.jp/nanoshitsu/project/index.html](http://www.nedo.go.jp/nanoshitsu/project/index.html) and note 190, below.
183. These include most of Japan's major chipmakers (Fujitsu, NEC, Toshiba, and Renesas (a joint venture between Hitachi and Mitsubishi)), three main producers of EUV light sources (Komatsu, Ushio, and Gigaphoton (a joint venture between Komatsu and Ushio)), and two of the main manufacturers of optical equipment for lithography, Nikon and Canon. Seven universities are also participants along with AIST.
184. The EUV LLC was initiated in 1997. In addition to Intel, it includes Advanced Micro Devices (AMD), Micron, Motorola, IBM, Infineon (the 1999 spin-off of Siemen's semiconductor operations), and ASML (a Dutch company whose main rivals are Nikon and Canon), and three DOE laboratories, Lawrence Berkeley, Lawrence Livermore, and Sandia. Various European consortia have been initiated, some privately and some under the EU's Eureka/Medea+ Program. In 2005, IBM organized the International Venture for Nanolithography (INVENT) consortium to pursue further development of EUV (and also to develop 193-nanometer immersion technology to enhance the capability of normal or deep ultraviolet lithography). Besides IBM, the INVENT consortium includes the University of Albany and the university's Albany NanoTech R&D center, AMD, Infineon, Micron (all of which use ASML scanners), and ASML itself, as well as Applied Materials, VEECO, and dozens of other metrology, photoresist, and other equipment and materials suppliers.

Apparently no Japanese or Korean companies are included in the EUV LLC or INVENT Consortia (although Tokyo Micron has a separate collaboration with the Albany NanoTech Center). A Japanese industry scientist familiar with these consortia attributed the absence of Japanese companies to METI's concern that Japanese technology would leak to foreign rivals, the inability of Japanese companies to deduct consortium expenses from income subject to

*Advantage New Companies*

343

Japanese tax (whereas they could deduct expenses for Japanese consortia), and linguistic and cultural hurdles.

This scientist also observed that cooperation among the member companies of the Japanese EUVA has been more difficult than in the VLSI project, and also more difficult than among the corporate members of EUV LLC and INVENT. He attributed this to the EUV LLC and INVENT consortia having been formed voluntarily by private initiative without the aim of including (and sharing technology among) all relevant companies. In contrast, as in the case of VLSI, METI sought from the outset to include all major Japanese companies and thus had to force collaboration between companies that were rivals in many of the fields in which they were to be cooperating. Research is constrained by the requirement that it not be likely to help one particular company more than another. At the same time, the scientific and technical uncertainties still facing all EUV lithography development efforts worldwide are greater than those that faced the VLSI consortium members in 1976. The foreign threat in 2005 seems less immediate than in 1975, and the Japanese EUVA companies are reluctant to commit large human and financial resources to projects where the payoffs are uncertain and where the government's top-down push for collaboration is not reinforced by grassroots agreement on important areas on which to cooperate.

Some of the EUVA members are working out cooperative arrangements outside the consortium framework. But, as in the case of the VLSI project, cooperation seems easiest among companies that do not have competing technologies and business goals. Toshiba, which unlike the other members is concentrating on NAND flash memories, seems to be a 'natural' partner and it has agreed with Hitachi and Renesas to prepare to begin joint production of 65 nanometer system chips in 2007. NEC and Matsushita were included in the original negotiations but have backed off from the project. However, NEC and Toshiba are discussing joint R&D on 45 nanometer chips. ('Chipmakers study Joint Production'. *Nikkei Weekly*, Jan. 9, 2006: 14).

185. To my knowledge, the only full accounting of government consortia spending is by Sakakibara (1997). The last year for which she has published these levels is 1992, when consortia spending amounted to approximately 85 billion yen, about 4.2% of the total government S&T budget for that year of 2,023 billion yen (NSF Tokyo Office, annual Japanese S&T budget summaries). 85 billion yen is high compared to consortia spending in the 1960s and 1970s but it is off from a peak of about 100 billion yen in 1988.
186. By limiting my analysis to extramural expenditures, I am trying to exclude funds that are budgeted for ongoing research in GRIs. In other words, I am most interested in consortium research as a percentage of discretionary government R&D funding devoted to specific projects. Thus I also want to exclude from the denominator ongoing large budget projects related to research and exploration in space, deep oceans, and the Antarctic.
187. In order to make these estimates, I assumed the validity of Sakakibara's finding that 4.2% of the total 1992 government S&T budget was devoted to

consortium research (see two notes previous), and also that this percentage is approximately the same circa 2005.

To calculate the denominator for the lower limit percentages, I started with the *allocations to promote science and technology* in the *regular budget* and subtracted out the expenditures for space, deep ocean, and Antarctic research. I had precise amounts for these expenditures for 1994, because I have a detailed official analysis in Japanese of the entire S&T budget for that year. (As background, the S&T budget consists of three components: (a) *regular budget allocations to promote science and technology*, (b) *other regular budget allocations* related to S&T (mainly administrative and infrastructure expenditures, including salaries for full-time employees), and (c) allocations from *special account budgets* of which four are relevant to the S&T budget: one to support national universities, two related to energy and one for industrial investment.) Next, I added 1994 expenditures from the *other regular budget allocations* and the *special accounts* that I thought might be used to fund R&D projects that might have commercial applications, even though indirect and sometime in the future. The three largest add-back items, all from special accounts budgets, were funding for the New Sunshine Project (alternative energy), nuclear power technology, and the Japan Key Technology Center. This adjusted 1994 S&T promotion budget was 569 billion yen, or 24% of the total 1994 S&T budget.  $(4.2 \times 100)/24 = 17.5\%$ , before excluding MEXT-grants-in-aid. However, this percentage is an underestimate, because the denominator overestimates project-specific R&D expenditures, because it contains expenditures for training, infrastructure development, transfer payments to local governments, and the basic, non-project-specific R&D-related expenses of universities and GRIs.

The upper-limit estimates assume that all consortia research projects are a subset of competitive research projects, and that competitive research funding is approximately equivalent to extramural project-specific research expenditures. These assumptions allow using total funding for competitive research as the basis (denominator) against which to compare consortium research expenses. The major competitive research programs in 2002 are listed in Chapter 3 Appendix 1, Table 3A. All competitive programs together accounted for 9.8% of the 2002 total S&T budget, a proportion that has been fairly steady since 1990 according to annual Cabinet Office reports.  $(4.2 \times 100)/9.8 = 43\%$ , before excluding MEXT-grants-in-aid. Are the assumptions underlying this upper-estimate valid? Most of the consortium research projects that I found (see following text) are funded under competitive programs such as JST's CREST or NEDO's Industrial Technology Research Projects. However, I am not sure if former Key Technology Program projects such as New Sunshine and Rite are considered competitive projects. Also it is possible that some other major consortium projects (e.g. EUVA) are not included within competitive funding programs.

188. Available at <http://www.nedo.go.jp/informations/press/index.html>. In 2005, there were over forty such announcements.

189. The projects newly initiated in 2005 all related to the subtheme, 'R&D for the practical use of advanced nano-technology components [Nano sentan buzai jitsuyouka kenkyuu kaihatsu]'. Sixteen teams were funded in 2005.
190. I randomly selected several projects within METI-NEDO's overall Nanotechnology Program launched in 2000, which had about US\$100 million in funding in both 2003 and 2004. (A list of the main themes and subthemes under this program is available at [www.nedo.go.jp/nanoshitsu/project/index.html](http://www.nedo.go.jp/nanoshitsu/project/index.html). However, finding the names of the projects and participants required additional searching under each subtheme.) Under the Nano-material/Process subtheme, the main participants in the 'Fine Macromolecule Technology' project are twenty-three companies, mostly large, fourteen university laboratories and AIST. Also under the same subtheme, the main participants in the 'Development of Nano-carbon Products' project are eight companies (again mostly large), the Japan Fine Ceramics Center (a METI organized industry group), four universities, and AIST. Under the Nano Manufacturing and Measurement subtheme, the main participants in a project to develop conductive ceramic materials amenable to low temperature molding are five companies (all large), four universities, AIST, and a METI organized industry association originally focused on robotic manufacturing. Under the same subtheme, a project to use non-destructive electron beams for nanoscale manufacturing involves six large companies, and three universities. Of the thirty-two NEDO nanotechnology projects highlighted in an English language publication (available at [http://www.nedo.go.jp/kankobutsu/pamphlets/nano/nano\\_eng.pdf](http://www.nedo.go.jp/kankobutsu/pamphlets/nano/nano_eng.pdf)), most are headed by professors at elite universities (or by AIST researchers) and most involve mainly large companies as collaborators.
191. The Key Technology Center was formed in 1985 to invest proceeds from the partial privatization of NTT into socially and industrially relevant fields of S&T and R&D. It has funded some of Japan's largest consortium projects; including the Protein Engineering Research Institute (PERI), the Advanced Telecommunications Research Institute (ATR), the Research Institute for Innovative Technology for the Earth (RITE), and Helix (genome research); some of which continue today as major research centers. In 2003, the Center was disbanded and its operations assumed by the Key Technology Promotion Group within NEDO. Information about recent Group projects are at [www.nedo.go.jp/kibanbu](http://www.nedo.go.jp/kibanbu)
192. MIC is the successor agency to the Ministry of Posts and Telecommunications, and exercises substantial control over the partially privatized NTT and NTT's affiliated laboratories.
193. These consortium-like projects involving at least one large company and one university, or two large companies, account for fifteen of the 135 MIC projects initiated in 2005. One of these was commissioned by MIC to develop home and mobile applications for Internet Protocol version 6. Six others funded R&D proposals solicited under the competitive Program for Strategic Promotion of Information and Communication Technologies. Eight

others were commissioned by MIC in a variety of telecommunications fields. In addition to these fifteen consortium-type projects, sixteen other projects in advanced fields of telecommunications involve a single large company (or in two cases a small company and a large company). An additional forty-seven projects support university/GRI R&D without corporate collaborators (ten involved disaster preparedness and nine were for international collaborations). Finally, 57 projects support R&D by small or regional companies.

194. By *extramural R&D*, I mean research support made available by government agencies to outside organizations (companies, universities, and in some cases GRIs) for specific research projects, usually on a competitive basis.
195. OPSR is roughly MHLW's equivalent of NEDO or JST with respect to R&D support. In 2005, OPSR's R&D support functions were transferred to MHLW's National Institute of Biomedical Innovation. (See Glossary)
196. The remainder were either new bioventures or incorporated consortia created by OPSR (see next note). About half the OPSR projects with corporate participants had more than one corporate participant. Lists of projects and participants are available at [www.pmda.go.jp/kenkyuu/kisoken](http://www.pmda.go.jp/kenkyuu/kisoken). I reviewed the final reports of projects initiated in 1996–9, as well as those of a special series of projects in genomics and proteomics initiated in 2001.
197. The youngest participant was a government-affiliated organization formed in 1989 to promote industry–university–government cooperation in the Tohoku region. The youngest private sector participant, Nihon Medi Physics, was formed in 1973 as a joint venture between Sumitomo Chemical and a US company. The others, all formed before 1954, included pharmaceutical, chemical, medical device/instrument, foodstuffs, electronics and optical companies. See Okada and Kushi (2004) for more information about these consortia.
198. The CREST program funds fairly large-scale projects, usually by teams from several institutions (see Chapter 3). Lists of CREST projects and participants are available at [http://www.jst.go.jp/kisoken/crest/report/heisei16/html/kenkyuu\\_houkoku.htm](http://www.jst.go.jp/kisoken/crest/report/heisei16/html/kenkyuu_houkoku.htm).  
Among the other JST programs, ERATO projects (fewer in number but larger in scale) usually include industry researchers, while PRESTO projects (smaller in scale, usually for less well-known researchers) usually are to single university laboratories.
199. Sakakibara (2001: 1004) also found that most of the participants in the consortia initiated between 1959 and 1992 were large companies, although her published data do not elaborate on this issue, and she provides no data on university participation.
200. Or erstwhile rivals might be assigned separate fields in a project so that their rivalry is limited, as in the case in the broadband optical communication project mentioned in Chapter 6.

201. See Hayashi (2003), Okada and Kushi (2004) and Branstetter and Sakakibara (2002). One problem is lack of an appropriate group with which to compare companies that participate in consortia. The latter study tried to address this by comparing consortia participants with a 'broadly comparable' set of non-participants. This study found a small (approximately 5%) greater number of US patents for participants compared with nonparticipants. Other problems related to the validity of jointly authored publications and patents (especially mere patent applications) as indices of innovation are discussed in Chapter 2. These problems are particularly acute when the consortia participants and the agencies funding the consortia know that their activities will be evaluated on the basis of such indices.
202. I have discussed this issue with about ten persons who are personally familiar with one or more consortia, in addition to the persons whose interviews are reflected in the Chapter 4 case studies and in Kneller (2003). Although most were skeptical about the value of consortia in terms of either the discovery/development of useful products/processes, or the improvement of participants' ability to conduct R&D, they were more likely to say that the consortia were beneficial from the perspective of producing advances of open scientific knowledge.

Not all projects/programs are assessed negatively. VLSI and some of the ERATO projects are widely regarded as successful consortia. As for lesser known consortia, former participants have cited the silicon solar cell project involving several companies and universities (mentioned in Chapter 2) as a success. Another is the Drug Delivery System (DDS) Institute, the first of the fifteen OPSR consortia mentioned above. The DDS Institute consortium operated 1988–95. The participants were Asahi Kasei, Ajinomoto, Eisai, Daiichi, Meiji Seika, Shionogi, and Tanabe. One of the participating companies volunteered that this consortium had advanced its R&D program and resulted in technologies that it aimed to commercialize.

Analysis of patents related to the DDS consortium support these favorable comments. More US patents were issued to this consortium (thirteen) than to any of the 14 other OPSR consortia. At least seven of these thirteen patents had inventors from two or more of the consortia participants, suggesting a fairly high degree of intercompany collaboration. Five of the consortia patents were cited by later patents issued to four member companies doing research on their own. This suggests that at least these four companies (Ajinomoto, Asahi Kasei, Daiichi, and Tanabe) found the consortium research relevant to their continuing in-house drug delivery R&D. A fifth consortia member, Shionogi, does not have patents that cite consortium patents—but one of its researchers is an inventor on consortium patents, and also on ten patents belonging only to Shionogi (many drug delivery related) that span the time before, during, and after the consortium, suggesting that this experienced researcher contributed his expertise to the consortium. Some of the DDS consortia patents have been cited by non-Japanese inventors. *However, none of the other OPSR consortia*

*approach the DDS Institute in terms of favorable comments from participants or a patent record suggesting close cooperation among members and continuing benefits to members, and citations by inventors worldwide.* (However, I have complete (or nearly complete) lists of the patents of only the first eight of the fifteen OPSR consortia, because the latter seven did not end until 1999 or later. Thus some US patents may still be pending while others have had little time to be cited. A partial analysis of registered Japanese patents does not suggest results different from the analysis of US patents.)

203. Sakakibara (1997, 2001). Responses to a 1993 survey of R&D managers in sixty-seven companies participating in eighty-six consortia between 1959 and 1992 indicated that companies generally participate in government consortia to obtain complementary knowledge from other participants and to enter a new field of technology/business. They considered the main benefits to participation to be researcher training, breakthroughs in or accelerated development of a technology and increased awareness of the importance of R&D related to the technology, increased internal funding of R&D, and increased awareness of the subject. Sakakibara, who conducted this survey, believes these responses indicate consortia facilitate diversification. Her findings with respect to movement from low to high growth industries and vertical integration arise from a comparison of the self-identified primary three-digit SIC (standard industrial classification) of 627 manufacturing companies participating in 186 consortia over the 1959–92 period with the three-digit SIC classification that most closely matches the activity of each of the 186 consortia.
204. In the case of ventures and other SME participants, the most commonly mentioned motivation they cite for participation is access to government cofunding to pursue their own core R&D.
205. The history of the Protein Engineering Research Institute (PERI) provides insight into the actual reasons companies participate in consortia and their interactions with each other. PERI was a Key Technology Center consortium established in 1986 to develop technologies related to protein structure, synthesis, and function. With its own building, an annual budget of over US\$10 million, fourteen participating companies and approximately forty-two scientists, it was one of Japan's larger and longer enduring consortia. It probably had a somewhat more basic science orientation than most. In 1992, seventeen of its scientists were from universities (generally entry-level faculty or postdoctoral-level researchers) and twenty-five were from its fourteen member companies: Ajinomoto, Fujitsu, Kaneka, Kirin, *Kyowa Hakko*, *Mitsubishi Kasei*, Nihon Digital Equipment, Nippon Roche, Showa Denko, Suntory, *Takeda*, *Tonen*, *Toray*, and *Toyobo* (*italics* indicate core/founding members, companies that generally had the strongest protein engineering capabilities at the start of the consortium). All of these are established companies with at least 1,500 employees. Originally scheduled to operate until 1996, its operations were essentially extended for ten more years, while its focus was somewhat broadened, under the name Biomolecular Engineering Research Institute (BERI).

*Advantage New Companies*

349

In order to maximize cooperation among the scientists and to provide a foundation for wide improvement in Japan's protein science capabilities, almost all the projects focused on basic research issues. Evaluation of the consortium was to be based primarily on publications in international scientific journals, and company scientists were enjoined from reporting individually the specific contents of their research to their home companies. (How this was enforced in practice is not clear.) By the early 1990s, PERI's output of international journal articles per researcher was fourth among all of Japan's bioscience institutes, and in its first ten years of existence, it contributed half of Japan's input to international databases on three-dimensional protein structures. In addition, Japanese scientists and research managers outside PERI generally felt it was beneficial in raising awareness, particularly within the pharmaceutical industry, of protein engineering as a way to solve various problems.

However, there was widespread concern among the corporate members about losing researchers to a basic research project for two to three years. Some of the companies without much expertise in protein biology/chemistry felt this was outweighed by the training their scientists received. Some of the larger companies, however, felt participation offered little practical benefit aside from building up the R&D capabilities of weaker companies (Protein Engineering in Japan 1992; Coleman 1999).

Three of the core members, Kyowa Hakko, Mitsubishi Kasei, and Takeda, as well as Nippon Roche (via its Swiss parent), probably already had considerable expertise in the application of protein biology and chemistry to pharmaceuticals. For junior members Ajinomoto, Kirin, and Suntory who had recently begun pharmaceutical R&D, participation in PERI probably was a way to acquire expertise to help them diversify into a new field. Kanebo may have been interested in applications of protein chemistry to its main cosmetics business. Kaneka, Showa Denko, Tonen, and Toray are all primarily chemical companies and were probably interested in applications of protein science to industrial processes—i.e. not so much diversifying into new disciplines as adapting new disciplines to their core businesses. Fujitsu and Nihon Digital Equipment were responsible for computational and database aspects of PERI research. Fujitsu was also an important participant in some of the instrumentation projects—such as development of an electron microscope that could operate at near absolute zero thus enabling imaging of protein crystal structures—one of the most highly regarded projects at PERI around 1992.

206. OPSR's DDS consortium included only established companies. To my knowledge, none of the ventures developing DDS benefited from the research of the OPSR consortium, although some have received other forms of government support.
207. Typically, the consortium is supposed to own or co-own patents arising from consortium research. Members typically have a license to use the patented

inventions for their own purposes. Licenses to outside companies usually require consortium approval.

208. My contention that rarely does any company emerge that pushes forward consortium research on its own does not apply to established companies, such as those involved in the VLSI, EUVA, and photovoltaic cells consortia, that already have strong business reasons to pursue R&D in these fields. Beyond this qualification, I base my assertion on anecdotal accounts, such as those mentioned in the text above, and the apparent dearth of new products or vigorous new companies that trace back to consortium R&D. One exception that proves the general rule may be a gene therapy vector that constitutes the core technology of a venture company that was originally formed as an OPCR consortium to develop this and other gene therapy technologies. Another may be the DDS discoveries referred to above. However, to my knowledge, most of the DDS consortium-linked discoveries are being pursued by large pharmaceutical companies that have long been interested in improved drug delivery systems. Although the DDS consortium (in particular the government funding) may have advanced the pace or range of discoveries in this area, this is a field the large companies could have pursued (and indeed are pursuing) either on their own or with other companies in privately initiated collaborations.
209. This is the consistent response from the ventures I have spoken to. See also the Chapter 4 case studies of Big Crystal, Fine Molded Plastics and Internal Search Engine. A secondary incentive mentioned by some ventures is access to university research. Cooperation with other companies is usually not mentioned as a benefit of participation, except in so far as they contribute instrumentation or support services that are useful to the venture.
- Of course this raises the question whether government funding for ventures creates overdependence and diverts them from goals that offer the best chance for long-term commercial strength. I know of examples where this is probably the case, yet I also know of examples where government funding seems to have provided a necessary bridge to attracting more substantial private funding.
210. For example, see the Chapter 4 case study of Molecular Visualizer which decided not to participate in consortia out of concern that large companies would absorb its know-how and technology. Note also the importance most of the companies featured in the Chapter 4 case studies attached to patent protection.
211. But note that Big Crystal (Chapter 4) participates in consortia even though IP must be shared.
212. At least this seems to be the case in elite universities with strong S&T departments. In lesser known universities, a relatively small percentage of S&T faculty may participate in consortia or joint research with large companies.
213. See the observation in Chapter 4, that outside biomedicine and software, the technology and business potential of most startups from the University of Tokyo, Keio University, and AIST seem to have limited technical scope and business potential.

214. One of the early informal collaborators, a large well-known electronics company, applied for a patent on one of the founder's inventions, without even naming him or any of his university colleagues as an inventor. The application was later challenged but the opportunity for the startup to receive IP rights to this technology was lost.
215. At the end of 2005, about a year after its founding, the startup had seven employees. It hopes to increase the number to twelve by mid-2006. But attracting qualified Ph.D. level researchers and capable managers is one of its biggest challenges.
216. See Sakakibara (1997) and remainder of this chapter.
217. Here I am referring to the benefits that would likely be achieved beyond simply making government funds available to individual companies or leaving companies to work out collaborative R&D on their own.

This raises the question of the benefits of government organized consortia in the USA and other countries. I am not aware of many studies that try to assess concrete, practical benefits of government organized consortia. SEMATECH, one of the best known US consortia, was formed in 1987 with the mission to rebuild a strong infrastructure for domestic semiconductor manufacturing equipment. Improving communication and institutional linkages between semiconductor manufacturers (which tend to be large companies such as Intel and Motorola) and the more numerous manufacturers of the various types of semiconductor manufacturing equipment (which tend to be smaller companies) appears to have been SEMATECH's main achievement. One vehicle for coordination was the development and periodic updating of a National Technology Roadmap for Semiconductors, which defines agreed-on industry goals and the technical developments necessary to achieve those goals. SEMATECH also helped improve buyer-seller transaction processes. It established a process to certify whether semiconductor manufacturing equipment met industry-agreed-on standards, and thus eliminated expensive duplicative testing. It also established a standard auditing process for equipment manufacturers (Corey 1997: 1). Thus it seems SEMATECH's main achievements lie more in improving the institutional framework for cooperation than in specific technical advances. Japanese consortia generally are more applied, in the sense of aiming for specific technical advances, and deal with topics closer to commercial applications.

218. As described in Chapter 3.
219. The Japanese term for these value adding corporate workplaces is *gemba*.
220. The former pattern, transfers from central/basic research to development laboratories, is described by Westney and Sakakibara (1986a, 1986b) in the case of three major computer companies. Each company had a central (primarily basic) research laboratory that was the initial posting for many new engineering graduates. After 6-7 years, they were transferred to laboratories of the various manufacturing divisions where they worked on scale-up and commercialization of projects they began in the central research laboratory, providing important continuity for each project.

In the latter pattern, described by Kuzunoki and Numagami (1998) in the case of a large chemical/materials company, product development is the job transfer nexus linking research, process development, and manufacturing.

In contrast, US engineers tend to have much more control over their careers, but to spend all their time in a research laboratory, to have less contact with production staff, and often to view production staff with disdain (Westney and Sakakibara 1986a & b; Lynn, Piehler, and Kieler 1993).

Absent from these accounts of typical job rotations for engineers are posts that involve customer contacts. An executive from a major IT company remarked that while Japanese engineers come to understand their companies well, they rarely have contacts with customers. Most have no experience trying to understand needs outside their companies or how things are done in other companies.

221. Chuma (2001) documents differences in the degree of active feedback between R&D and production staff in US, Japanese, and German machine tool companies (with the German practices generally being closer to the Japanese).

222. Based on Aoki (1990), Westney and Sakakibara (1986a, 1986b) and Kuzunoki and Numagami (1998). This summary is specific for engineers and R&D managers, but similar management policies apply to other scientific and technical personnel in large corporations. In the case of blue-collar workers, rotations are usually decided by shop floor or factory supervisors rather than the central personnel office.

Aoki stresses the importance of frequent and easy communication among teams (or among individuals in different teams) to solve problems, what he calls Japanese style *horizontal* coordination as opposed to Western style *hierarchical* coordination. Others (e.g. Doeringer, Evans-Klock, and Terkla 1998) confirm these contrasting styles in the context of Japanese manufacturing transplants in the USA compared with new plants of indigenous US companies in the same industries.

223. Kneller (2003) documents the low proportion of Ph.D. new hires by pharmaceutical companies. Discussions with large companies in other industries as well as graduate students and professors indicate that most leading manufacturing companies still hire MS or BS graduates for their R&D laboratories. One university professor who has collaborations with many of Japan's leading electronic companies observed that today, as opposed to ten or twenty years ago, large companies do not regard university Ph.D. training negatively—at least in laboratories oriented toward fundamental research. However, neither do they regard a Ph.D. favorably. Students who obtain Ph.Ds. and then take jobs in industry usually are those who were undecided between a career in academia or industry and ended up choosing industry, often because of the scarcity of academic positions.

224. This factor is stressed by Aoki (1990). With the introduction of merit pay systems in many companies, this uniformity may be breaking down.

*Advantage New Companies*

353

225. This example is from Westney and Sakakibara (1986*b*). The quoted maxims are from Westney and Sakakibara (1986*a*, 1986*b*). Recent communication with one of the authors suggests that these policies are probably still in effect in most companies, although follow-up studies are needed to confirm this.
226. Young Japanese engineers are generally free of administrative personnel matters and thus have more time to devote to research than their US counterparts who have to submit personnel evaluations even though they may have only two or three subordinates. The fact that Japanese engineers in central laboratories spend about 53% of their time directly on R&D compared with 39% for US engineers may be another strength of the Japanese innovation management system. (Westney and Sakakibara 1986*b*). See also Doeringer, Evans-Klock, and Terkla (1998) with respect to merit pay and promotions for workers (primarily blue-collar) in Japanese manufacturing transplants in the USA.
227. This is changing, but probably gradually, as manufacturing companies begin to adopt merit pay systems (see note 275 below and accompanying text).
228. Some companies offer an option to receive (a portion of) pension payments as an annuity (either until death or over a fixed number of years following retirement) in lieu of a single lump sum payment on retirement.  
Persons who have reached up to manager's (buchou) status can usually keep working in management positions longer. As Japan's population ages, persons below this rank are also being offered opportunities to work past 60, but usually in different jobs and with salaries reduced 40–50% (Michio Sugai, 'Boomers get Option to Retire Older', *Nikkei Weekly*, March 21, 2005: 21).
229. Defined contribution pension plans (401-k type plans), although becoming more common, probably still constitute a small percentage of total pension payments by large manufacturing companies.
230. Perhaps this is changing. The *Nikkei Weekly* (May 1, 2006) reported that 'Toray Industries group intends to bring on some 300 midcareer and other workers—the most among manufacturers—to accelerate development of materials used for digital electronics and aircraft', and that 'Mitsubishi Electric plans to take on 160 mid-career engineers and other workers, up 45.5% amid brisk sales of machine tools'. It is not clear, however, to what extent these mid-career hires involve R&D personnel from non-affiliated companies. Recent discussions with R&D personnel in major manufacturing companies suggest that mid-career hires of R&D personnel from unaffiliated companies are still rare.
231. I have confirmed this is the case through interviews with officials in the personnel department of one major electronics company, through published media reports about another, and through discussions with R&D employees and with an academic researcher studying a third company. These sources suggest that such reforms have been adopted by most of the major electronics companies. I am not sure about the extent of similar reforms in other industries.

232. They must make this choice at the time of employment. If they choose to manage pension funds on their own, they receive company contributions toward their pensions as supplements to their semiannual cash bonuses.
233. Interview in April 2006 with personnel officials in a major electronics company.
234. These plans are in effect *defined benefit plans* where the benefits accrue linearly. They are not *defined contribution (401-k type) plans* (although their effect may be somewhat similar) because the employer company manages its pension funds and because biannual benefits are fixed as a proportion of salary. Unlike US companies that have switched to defined contribution plans, the Japanese companies still assume the market risks associated with guaranteeing a particular level of benefits to their employees.
235. The company that described its pension reforms indicated that it did not believe that employees hired since April 1999 were leaving at higher rates than young employees in years prior to 1999.
236. Aoki (1990: 22). The extent to which these attitudes still persist is an important question. Despite the pension reforms, my sense is that reorientation of research teams to seeking out and absorbing outside technologies has not proceeded to a large extent except that more corporate researchers are being sent to universities. In other words, there is more emphasis on absorbing early stage academic discoveries, but much less on partnering with independent new companies. The former requires a much smaller readjustment of corporate research styles and focus than does the latter.
237. Lynn, Piehler, and Kieler (1993).
238. See the cases in Chapter 4 and also the case of the OPCR protein science consortium presented earlier in this chapter. See also Kneller (2003) summarizing discussions with large pharmaceutical companies.
- One of Japan's largest pharmaceutical companies boasted that with twenty persons engaged in finding and maintaining collaborations it had entered the first rank of companies engaged in partnering (Osigo and Matsuzaki 2006). However, these efforts are mainly directed toward overseas partnerships. Also, US and European pharmaceutical companies generally have many more employees engaged in seeking out and managing alliance partnerships. Roche, for example, has approximately 100, according to a 2005 discussion with Roche officials responsible for alliances.
239. Recalling the importance of manufacturing keiretsu noted in Chapter 6, Japanese automobile companies sit atop a high technology chain consisting of many large and small high technology companies, and directly and indirectly account for 60–70% of sales by Japan's machine tool industry ('Auto industry sits atop tech chain'. *Nikkei Weekly*, Jan. 16, 2006: 14). These include not only close long-term cooperation with small to mid-size subcontractors but also with other large industrial companies. Recalling the close

*Advantage New Companies*

355

cooperation and demand articulation between suppliers and users described in Chapter 2 (and also by Kodama 1991), Laage-Hellman (1997) describes successful long-term cooperation between Nippon Steel and several auto manufacturers. He also describes a successful collaboration between Toshiba and Cummins to develop ceramic diesel engine components. Myers (1999) provides an in-depth history of the successful collaboration between IBM and Toshiba in the 1980s to jointly develop and manufacture flat-panel displays for notebook computers. Both companies felt they learned from each other and that the project benefited from complementary strengths.

Not all collaborations are smooth. Recall from Chapter 6 the formation of Epilda and the squabbles between its parents.

As for collaborations with overseas ventures, the comments I have heard from US and European biotechs engaged in collaborations with Japanese pharmaceutical companies are generally positive and depict stable, long-term relationships. In the field of siRNA, a number of Japan's largest pharmaceutical companies have collaborations with a single US biotech company dating to the 1990s. But at least four Japanese biotechs whose core business is drug target identification using siRNA have had a hard time obtaining customers from among Japan's pharmaceutical companies. Might their relative late-comer status be a factor? Or might they be better off as one or two united companies? Absolutely. But I suspect that there is a chicken-and-egg dynamic, where one component is the tendency of large Japanese companies to ignore domestic ventures.

240. e.g. who will assume new posts related to the collaboration or whether there are persons in house who might do the same work as the collaborator is proposing.
241. e.g. the need to work through various levels of the corporate bureaucracy to develop a consensus how to handle relations with the outside partner.
242. Such a startup, founded by a professor in a major national university, actually exists.
243. See the case of Big Crystal in Chapter 4.
244. As if to confirm what I had long suspected, in early 2006 the head of merger and acquisitions in a major Japanese bank who tracks the interest of Japanese pharmaceutical companies in equity investments in biotechs observed that the pharmaceutical companies usually do not want a controlling influence over the overseas companies in which they invest. However, they would usually expect to control any Japanese venture in which they invest. The pharmaceutical company that invested in Gene Angiogenesis and the parent of Internal Search Engine (Chapter 4) are exceptions that prove the general rule.
245. See the spin-off cases in Chapter 6 and the case of Phoenix Wireless in Chapter 4.

246. *Organizational relationship management overload* may also be a barrier to collaboration in with ventures. As noted in Chapter 2, Japanese companies emphasize a smooth technical and business interface between collaborating companies and they devote much energy to making these relationships work. It may be that the number of relationships they can handle is limited. Thus, venture companies that pop up with new technologies have a high threshold to overcome to be taken seriously by large Japanese companies, because being taken seriously has traditionally entailed the commitment of substantial resources.
247. Appendix 7.4, Figures 7A4.1 and 7A4.2 show age-specific mid-career departure rates for firms with at least 1000 employees (large firms) and those with 30–99 employees (small firms), respectively. Graphs for other firm size groups, as well as graphs for specific manufacturing industries, are not shown. In the latter cases, exceptions to the pattern shown in Figure 7A4.1 for firms with at least 1,000 employees are (a) plastic products manufacturing, which had higher mid-career retirement rates in 1995 than during any year 2000–4 (this industry is unusual in that total employment in large firms increased from 1995–2004) and (b) metal products manufacturing, where mid-career departures seem to oscillate in a high-low pattern year by year. I limited my analysis to male employees because female employment is much less than male employment (see Fig. 7A4.4), and because a large proportion of women leave the work force in their 20s and 30s to raise families.
248. Press reports in 2005 mentioned sizable layoffs by Matsushita, Sankyo, and Sony. Discussions with R&D scientists and managers in major electronics companies indicate that shedding of workers was widespread in all electronics companies, and that even as late as 2005 most still wanted to reduce payrolls. Nevertheless, even in Sankyo and Sony, reductions in their Japanese workforces were achieved mainly through transfers to subsidiaries, early retirement, etc., not by layoffs.
249. According to an executive familiar with several of the seller and buyer companies.
250. This company tried (apparently more or less successfully) to ensure that its good engineers kept working. In contrast, when IBM instituted its second Career Path in 1987 as a means to ease out unwanted senior personnel (by offering a two years terminal leave of absence with full salary and US\$10,000 for educational expenses) the persons whom the company hoped would stay left while those whom it hoped would take advantage of the program chose to remain.
251. According to a person familiar with the industry, about 30% of the 1990 workforce in large electronics companies were contract workers from outside corporations, but by 2005 most companies had raised (or were trying to raise) this to about 40%.

252. On this last point, see: 'New Lives for Corporate Dropouts,' *Nikkei Weekly*, March 6, 2006, 7.
253. The largest percentage declines in female manufacturing employment were in the largest and smallest firms, while the largest absolute decline was in the smallest firms (see Appendix 7.4, Figure 7A4.4).
254. Also known as Keidanren.
255. Also Chairman of the Board of Toyota.
256. Keynote address to the 2006 Keidanren Employer–Employee Forum by Chairman Okuda, held on January 12, 2006 in Tokyo. *Italics* indicate speaker's emphasis as indicated on the Japanese transcript available at [www.keidanren.or.jp](http://www.keidanren.or.jp). Masahiko Aoki, Professor Emeritus at Stanford and one of the most respected economists concerning Japan's economic system, echoed the same perspective in an English language interview (*Nikkei Weekly*, Jan. 9, 2006, 5):

...I think the lifetime employment and seniority systems have been at the heart of Japanese institutions. Under those systems, people have been able to secure stability in their livelihoods in exchange for considering an occupation at one place as their vocation and working there diligently. Because the systems are solid, it will take about a generation for them to collapse. After that, lifetime employment elements and a flexible labor mobility will likely coexist.

257. About 5% consider work in such a venture desirable, and over half consider such work unacceptable. Rates are similar for MS and Ph.D. students.
- However, in a university that has been the training ground for government and big business elites, such interest might be lower than in most other universities.
258. See, e.g. JPD-SED (2005), reporting results of a survey of new company recruits participating in two-day training courses held by a government-affiliated organization, suggesting that about 26–38% of new recruits expect to spend their entire career in one company, compared with 16–22% of new recruits in 1999. (The lower estimates within each range are for respondents who had been on the job for half a year, while the higher estimates are for respondents who had just joined corporations.)
- Household-based interview surveys by the Japan Institute for Labor Policy and Training (Nihon ryoudou kenkyuu kikou, available at [www.jil.go.jp](http://www.jil.go.jp)) show that overall 77% of regular employees (and 79% of part-time employees) supported lifetime employment compared with 72% in 1999. Among men in their 20s, the support rate was 64% in both years (rates for women in their 20s were slightly higher). Overall 43% of employees hoped to work in the same company all their life in 2004 compared with 40.5% in 1999. Only 26% expected to work for more than one company compared with 24% in 1999. Only 13% expected to start their own business compared with 15% in 1999.

259. See new Section 21(4) of the Law to Prevent Unfair Competition [Fusei Kyousou Yobou Hou]. This section authorizes criminal as well as civil penalties against persons who disclose trade secrets of their former employers to their new employers, if they do so with the purpose of gaining profit or aiding competitors of their former employer. Criminal penalties can include up to five years' imprisonment. The new employer can also face criminal and civil penalties, including injunctions. Prior to 2005 it was less clear that criminal penalties would apply, except in cases of acquisition of trade secrets by theft, fraud, or assault. The fact that criminal penalties now can apply even to acquisition of trade secrets in the normal course of work might expose to liability employees who move to ventures where they will continue work begun with their former employers.
260. Prior to 2005, plaintiff companies would have had to publicly disclose in court the trade secrets that were allegedly misappropriated by departing employees. See: Examples of Regulations Governing so-called In Camera Proceedings [Iwayuru in-ka-me-ra shinri ni kansure kitei no rei] at [http://www.soumu.go.jp/gyoukan/kanri/jyohokokai/pdf/050125\\_sanko2.pdf](http://www.soumu.go.jp/gyoukan/kanri/jyohokokai/pdf/050125_sanko2.pdf)
261. And also in nondisclosure agreements that many employees are expected to sign when they leave employment.
262. Indeed, it might make sense for Japanese courts to consider carefully the likely proximate damages that would occur to the former employer's investments in deciding whether to enjoin an employee from moving to another company. In other words, following Hyde's suggestion (2003), a rational condition for upholding unfair competition (including trade secret) suits by employers against departing employees might be that the employer show that the change of jobs would likely result in significant harm to a specific project the employer is undertaking.
263. A 2003 METI White Paper referred to four district level court decisions between 1970 and 1998 that upheld covenants not to compete for periods ranging from one to five years (Trade Secret Management Guidelines [Eigyō Himitsu Kanri Shishin] issued January 30, 2003).
264. I have searched for IP-related decisions by the Tokyo District Court under key words such as unfair competition and trade secrets. Of approximately 300 cases, a research assistant scanned over 100 and identified 2 that addressed this issue indirectly.

In addition, I was granted access to the lists and disposition of all cases brought before the Tokyo District Court dealing with patent or unfair competition issues from 1994 through 2004, no matter whether they resulted in a final court ruling. Selecting all such actions brought in 1994, 1999, and 2004 (844 in total), I selected a 30% random sample (145) and then, on the basis of the type of action (infringement, injunction, etc.), the main technology at issue (an item in the database) and publicly available information on the plaintiffs and defendants, I tried to determine which cases in the sample might have involved unfair competition charges against R&D employees who had

*Advantage New Companies*

359

moved to high technology ventures. I identified only one such case (out of 145). In other words, the number of such cases indeed is probably quite small.

Japanese patent attorneys, whom I have queried do not know of specific court cases dealing with this issue.

265. The threat was reportedly made by the main VC backer of a venture company in response to suggestions that the venture's lead manager might be recruited to form another startup.
266. The challenges in balancing work and family obligations are intense in most modern societies. However, these challenges are particularly severe in Japan and are felt most intensely by women (See, e.g. Tolbert 2000; Otake 2006). For women with minimal family obligations, career opportunities in 2005 are greater and closer to men's than they were prior to 1985. Nevertheless, most Japanese organizations have evolved less than those in the USA to allow both men and women to accommodate the needs of family as well as work. For professionals, obligations to be present at work (or at meetings or social events with work colleagues) in the evening and weekends are frequent. Also flexible work patterns to accommodate care for young children that allow the mother (and/or father) to remain professionally involved in the work of her organization and subsequently to resume a full-time career (with promotion potential nearly equal to that of colleagues that did not have to care for children) are rare. In my interviews with the eight largest Japanese pharmaceutical companies in 2002, only one said it hoped that its female researchers would remain employed after marriage, or return to work after taking time off to care for young children and had policies in effect to encourage their return (Kneller 2003). It is common for a married professional woman either to have no children or to have one child and then no more, saying that she does not want to impose further on her work colleagues the inconvenience of her having to take time from work to care for a child.
267. I am surprised at the amount of time children even in elementary grades four to six spend cramming to prepare for examinations to reach preferred schools in the next rung of the educational ladder. Probably about 20% of students in these grades in Tokyo (roughly half the students who will attend some sort of university or junior college after high school) are involved in cramming programs that, for most serious students, leave little unstructured time to explore and develop their own interests. The way these programs impart knowledge (in cram schools or using self-study books) aims at accumulating a lot of factual knowledge, without opportunities to develop skills in self-expression (written or oral) and critical analysis, and also without opportunities to observe nature and to develop interests and skills in experimentation. This phenomenon is also present in other large Japanese cities. Parents say that a generation ago, children spent less time cramming. Cramming to enter elite secondary schools is motivated by parents' belief (largely self-fulfilling) that public junior high schools do not provide a good education that enables their children to be competitive in entrance examinations for senior high schools and universities,

and that bullying and other disruptive behavior pervades public junior high schools. Also by entering an elite private secondary school, students are usually spared an otherwise mandatory round of cramming and test taking to enter senior high school (10th–12th grades)—even public senior high schools admitting students only by examination set by the individual schools. Tokyo metropolitan area statistics show the percentage of sixth graders taking entrance exams for private junior high schools rising from 15% to 17% from 2003 to 2006, but percentages within Tokyo itself are higher (*Asahi Daily* (English edition, combined with the *International Herald Tribune*), Feb. 11–12, 2006, 35).

The public elementary schools, which occasionally organize field trips and have some inquiry-based science classes, scale back homework and the other demands on their students, knowing that a large proportion of students are heavily burdened with cram school assignments. *In other words, the public elementary schools are ceding responsibility for educating children to the cram schools whose avowed goal is to impart knowledge necessary to pass junior high school, high school and university entrance exams.* Of course children from families that value education do not spend sixteen hours per day with their noses in books. A few take part in organized sports (but much less than in the USA). Some take music lessons, although it is disheartening to hear parents frequently say that it is important for their children to take music or art lessons in order to be admitted to elite junior high schools. There is widespread fatigue, angst, and cynicism among children, and many take long breaks to watch television and play computer games. But nevertheless, for children whose parents hope they will attend good universities and have professional careers, from the latter years of elementary school on, most time is structured, and the need to prepare for entrance exams to keep climbing the academic ladder is ever present.

I say this largely out of personal experience observing our eldest daughter progress through the Japanese public elementary school system and conversations with her classmates and parents. (And, yes, we have sent our daughter to two different cram schools over the past four years, and she still attends a cram school to keep up her Japanese.) In fifth grade, we switched her to an international English-language school in Tokyo. We found the level of mathematics, in terms of concepts, equivalent to that taught in the most competitive cram schools (quite high compared to what I studied in US public schools in the 1960s). Moreover, the level of mathematics and Japanese language taught in the cram schools is generally several months ahead of that in the public schools. However, reinforcement of mathematical concepts and problem solving speed is higher among the public school students who attend cram schools compared to my daughter's international school. Both the public and international schools give students time for hands on experimentation and discovery in science classes—the public school devoting more time to science instruction generally, the international school going more deeply into particular topics. But the single glaring

contrast between the curricula of the two school systems is the amount of time spent in the international school to develop *skills of self-expression and critical analysis*—in writing, in oral and computer-based presentations, even in drawing—and also the degree to which students are encouraged to do projects or to explore subjects that interest them. The Japanese public school tries to do this to some degree through occasional student projects. However, there is *absolutely none of this in the two cram schools* my daughter has attended, which are both large with dense neighborhood branches nationwide and where students often direct more of their energy than the public schools.

268. i.e. high examination scores and admission to elite schools.
269. For persons interested in R&D careers, they reach this point usually on graduation from a good university.
270. Conversations with friends from well-to-do neighborhoods around Washington, DC suggest convergence towards the Japanese model.
271. See Trends in International Science and Mathematics Study (TIMSS) scores for 2003, where Japanese eighth graders ranked fifth in both mathematics and science while US eighth graders ranked fourteenth in mathematics and eighth–ninth in science (tied with Australia). (Some major developed countries such as France, Germany, and England do not appear in these rankings.) See also the OECD's Program for International Student Assessment (PISA), which compares reading, mathematics and science abilities among students in most OECD countries. These rank Japanese 15-year-olds among the top four while US 15-year-olds score close to the OECD average (data available from the US National Center for Education Statistics).
272. See Westney and Sakakibara (1986*a*, 1986*b*).
273. So far, my discussions have mainly been with University of Tokyo students and faculty. One professor who works closely with many electronics manufacturers put the matter this way.
- It would be difficult for me to try to assign my students to various companies. If I recommended one of my best students go to Company A, Companies B and C might feel I was not treating them fairly. It is better for me to leave the initiative with my students, and to let this be a matter between the students and the companies.
- The situation may be different in less prestigious universities, where professors have to go to bat for their students in order for them to find good jobs in top-tier companies.
274. This is not a question I have so far raised directly with many entrepreneurs and corporate officials, so reality may differ from what I have surmised in the text above. The Chapter 4 case studies of Chip Detect and Internal Search Engine nevertheless seem consistent and show variations in the possible responses of parent companies. In Chip Detect's case, relations with the parent remain distant, although the terms of separation were favorable for Chip Detect. In Internal Search Engine's case, the separation was amicable and both sides

continue to make the relationship mutually advantageous. However, Chip Detect's technology is closer to its parent's core business than is Internal Search Engine's, and more key employees left the parent in the former than the latter's case. Also Internal Search Engine's parent is unique in encouraging its employees to form independent spin-offs. Therefore, not surprisingly, whether departures occur amicably or are regarded as betrayal depends on the number and importance of the employees who leave and how close their work is to the parent's core business.

Those who leave are also sensitive about the notion of *betrayal*. A senior manager in a major electronics company used just this term to describe his initial reaction to overtures that he join a US venture, and also the frequency with which employees moved between US ventures. His new boss, the founder of the venture that recruited him, tried to assuage his guilt and surprise by saying, 'Just think of all these ventures [in this field of technology] as one company.'

275. Because most Japanese merit pay systems have been in effect only a few years, it probably is too early to judge their effectiveness in improving productivity within companies, much less in providing a signal to some employees that they should leave in mid career. (To my understanding, the latter is not a goal of most merit pay systems.) A 2004 survey of both company officials and employees found general agreement that introduction of merit pay increased work effort and output, as well as cooperation among co-workers. But employees also felt that their extra effort was not rewarded in their salaries and bonuses, evaluations often were not fair, and the evaluation criteria did not match work goals (JILPT 2004).
276. Lincoln and Gerlach (2004: 329).
277. For example,
- sustained, widespread interest among university researchers in forming bioventures,
  - the ability of patents to prevent encroachment into their core business by large companies that may have a large presence in university laboratories,
  - the relative success of bioventures in pursuing niche technologies with commercial potential that are not being pursued by pharmaceutical or other large companies,
  - the existence of specialized biomedical VC companies that are able to help ventures grow not only by financial investments, and
  - access to university discoveries not enjoyed by ventures in other S&E fields.
278. The decline of large basic-research-oriented corporate laboratories such as Bell and PARC and Sarnoff, and the shift to contract research in the central laboratories of large Japanese corporations, all are indications that most corporate research now is application oriented. Fundamental research that will give rise to the next generation of technologies is now almost the exclusive purview of universities and GRIs.

279. Chesbrough (2003) and IBM's Emerging Business Opportunities Program (which supports ventures and other SMEs developing hardware and software related to IBM's business) indicate that the flow of technology from ventures to large US corporations is substantial and quite important, even outside biomedicine. This is substantiated by discussions with officials of IBM, Johnson & Johnson (with respect to medical devices) and other companies, as well as data on university licensing presented in Part II above. Cohen, Nelson, and Walsh (2000) show that large corporations also benefit directly from published university research.
280. See notes 85, 178–179 and 202 above, as well as Chapter 2.
281. i.e. research to bridge the gap between basic research findings and development aimed specifically at commercialization. Examples of translational research might include development of a working prototype, research into methods to scale up production, and in the case of drugs, studies with live animals showing proof of concept.
282. This is probably a valid assumption in view of the sharp rise in industry-sponsored joint research as well as the rise in government-sponsored commissioned research, which includes government-sponsored consortium research.
283. See references cited under notes 3–5. What about the lower level engineers, scientists, programmers, technicians, and secretaries in ventures, those who do not have great say in management and may not even have large stock options? To what extent does a venture's success depend on motivating all its employees? Assuming that such motivation is important (but that stock options are not distributed equally) how do ventures sustain a sense of shared commitment in the face of potential job cuts during economic downturns or in the event of mergers/acquisitions? These are questions about which surprisingly little seems to be written—yet the answers bear on the lives and careers of many Americans, as well as the sustainability of what appears to be a unique, and so far successful, innovation system.
284. The ever present danger of earthquakes may have contributed to the preference for individual homes. However, apartment buildings are now built to withstand sizable quakes and most families still say they prefer a house of their own.
285. Perhaps characteristic Japanese qualities such as politeness, reluctance to confront others, and reticence except among close associates are, at their most basic level, means to maintain social harmony while at the same time preserving and respecting a core sphere of individual privacy. However, these same qualities may not be well suited for ventures which thrive on rapid communication and ability to make deals rapidly, sometimes with previously unknown entities.

In this regard, see Yamagishi, Cook, and Watabe (1998) and other works by Yamagishi suggesting that general trust (the tendency to trust another person regardless of whether he or she is bound by the same stable social relations, i.e. is a member of the same family or work group) is lower in Japan than America, and this is due largely to the closed nature of key social groups in Japan, particularly work-related groups.

286. Or, in the case of universities, let them have expression in semi-autonomous fiefdoms (*kouzas*) subject to only weak departmental and university-wide coordination.
287. See also Whittaker (1997) and Friedman (1988).
288. e.g. Sony and a few of the machine tool companies.
289. At least on the shop floor and within work units.
290. Aoki (1990). The typical western corporation Professor Aoki has in mind is one that relies on hierarchical authority and explicit written instructions and procedures (the opposite of tacit knowledge) for control and coordination. Whether this is an accurate characterization of successful US manufacturing corporations today may merit clarification.
291. Musha (2006).
292. This is, of course, a risky prediction offered not as much out of confidence that it will come to pass, but to catalyze further discussion. One reason it may be proved wrong is that large Japanese manufacturers may devise a uniquely effective system of close cooperation with universities. This would go beyond simply appropriating the bulk of university IP, to involve students and professors helping companies to make strategic decisions as to which new technologies to pursue, even though commercialization may be far in the future. In other words, universities would not only play a role akin to that of Bell Labs, PARC or Sarnoff Research Center, but they would also help companies to conduct strategically targeted translational research to demonstrate the commercial feasibility of some of their key discoveries. Some companies are establishing research centers in major universities, which suggests small steps in this direction.

Nevertheless, I do not think this is a scenario that many professors, corporate managers, or government officials consider feasible or desirable. Fundamental culture and goals are too distinct between universities and corporate laboratories. The resources that both sides would have to commit to carry out such a transformation of university research would be too great, and universities would be loath to lose so completely their neutrality vis-à-vis competing companies. Nevertheless, there are some concrete steps in this direction, such as the contractual right, noted in Chapter 3, of companies sponsoring joint research to censor academic publications—a right which researchers indicate is frequently exercised, although usually in the form of requests for changes. If it did, come about in some sort of creeping manner (perhaps in response to reduction of government support for university R&D, or, conversely the government increasing funding for such centers in an explicit attempt to aid Japanese industry), it would be to the detriment of Japanese science. It would also be a further blow to startups, whose access to university discoveries and the energy of university researchers would be even more curtailed. This scenario may be less far fetched, however, in the case of other countries where university R&D is more dependent on corporate joint research funding, e.g. China and Korea.

*Advantage New Companies*

365

293. 'Biotech, then and now' (interview with George Rathmann), *Business Week Online*, Sept. 19, 2005.
294. VC investment in the USA was US\$21.7 billion and US\$21.6 billion in 2005 and 2004, respectively, compared with US\$18.9 billion in 2003 and US\$104.8 billion in 2000, the recent nadirs and peaks (National Venture Capital Association (NVCA) at [www.nvca.org](http://www.nvca.org)).
295. In 2003, 21% of total industry R&D in the USA was conducted by companies with less than 500 employees, compared with 6% in 1984 (Global Insight 2004).
296. OECD (2004*b*). Between 1999 and 2002, 0.4% of US GDP was accounted for by VC investment in high technology sectors, compared with 0.64% for Israel and about 0.36% for Canada, the next closest country. At the other end of the spectrum of OECD countries, high-tech VC investments accounted for about 0.01% of Japan's GDP, 0.05% of Italy's, 0.06% of Australia's, 0.08% of Germany's, 0.09% of Denmark's, 0.11% of France's, 0.12% of Finland's, 0.14% of the Netherlands's, 0.17% of Korea's, 0.21% of the UK's, and 0.26% of Sweden's. (Sweden is the fourth ranked country after Canada.) (Data for Australia, Japan, and Korea are from 1998–2001.) The percentage for Japan has probably increased since 2001 (see Chapter 5).
297. Most ventures tell me they try to match salaries in large industry leaders to within 5–10%, but they cannot match on pensions and other benefits, except through stock options.
298. See Thelen and Kume (2003), n. 19, with respect to Germany.
299. See Jaeger and Stevens (1999) which shows, e.g., that about 52% of US male heads of households in 1996 had been employed in the same organization less than ten years compared with about 42% in 1982. Higher education was associated with greater likelihood of job change. Kambourov and Manovskii (2004) also found that mobility between and within US industries increased for all age and education groups between 1968 and 1993, which they attributed partly to 'the increasing variability of occupational demand shocks over time'.
300. See OECD (2004*a* & *b*) and n. 296. The OECD has established a scale to measure employment protection legislation (EPL) that takes into account protections against individual dismissal, protections against collective layoffs, and regulations on temporary employment. The USA scores lowest on this scale, followed by the UK, Canada, New Zealand, Ireland, Australia, Switzerland, Hungary, Japan, and so forth. According to this scale, EPL protection in Japan is about two to three times stronger than in the USA, while in Italy, Germany, Belgium, Norway, Sweden and France, it is about four times stronger than in the USA.

The Pearson correlation coefficient for a simple comparison of percentage of GDP invested in high-tech VCs and strength of EPL is  $-0.52$ . Japan's level of VC investment is lower than expected on the basis of its moderate level of EPL, while Sweden's level of VC investment is higher than expected on the basis of its high EPL. Remove Japan and the correlation coefficient becomes

−0.55, remove Sweden and it becomes −0.61, remove both and it becomes −0.65.

Of course, there are other determinants of high technology entrepreneurship than the level of employment protection. (In the case of Japan, these are discussed above.) Nevertheless, this simple analysis suggests a causal relationship between the ease with which companies can dismiss employees and the attractiveness of that environment for startups.

301. Casper (2000).
302. Leave Development to Us (Chapter 4) is one of the earliest ventures founded on this strategy, but subsequently others have been formed.
303. Thelen and Kume (2003).
304. See, e.g. Begley (2002) and Hyde (2003). The senior Japanese R&D manager with experience in both Japanese and US IT companies (see n. 274 above) expressed shock at how scientists and executives in a US company reported to work one morning to find notices that they had to clean out their offices by the end of the day and would be given only two weeks' severance pay.
305. See Hyde (2003) and notes 3–5.
306. Factors that make such pressures higher than in large Japanese or German companies may include pressures to return value to stockholders and the importance of stock incentives in executive compensation packages.
307. The varieties of capitalism literature draw a number of contrasts between liberal market economies (LMEs, of which the USA is the archetypal example, but which also include the UK, Canada, Australia, and New Zealand) and coordinated market economies (CMEs, among which Germany is probably the archetype, but among which Japan and Korea are often included, along with many other countries of Continental, especially northern, Europe). These include:
  - Organization of production by arm's-length market transactions vs. coordination among the principal actors (employers' associations, unions, and government),
  - financing and control via equity investors vs. loans or equity investments by banks or other corporations,
  - at-will hiring and firing of employees vs. legal or cultural restrictions on the same,
  - low vs. high levels of in-house or employer-funded training, and
  - technology transfer via labor mobility vs. inter-company associations.

(Hall and Soskice 2001)

Because these distinctions are inter-related and based on established social and institutional norms, shifting from one type of system to the other is not easy. (See also Whitley 2000.)
308. Hall and Soskice (2001: 42–3) present graphical data showing that the relative innovativeness by industry of US companies (as measured by the proportion of European patents they hold) is almost a mirror image of the relative innovativeness of German companies. For example, a higher than average proportion

of total European patents in biotechnology, pharmaceuticals, medical engineering, optics, semiconductors, and IT were issued to US companies, while for all these same industries except pharmaceuticals, the proportion issued to German companies was less than expected. But on the other hand, in transportation, agricultural machines, mechanical elements, engines, and thermal processes, the proportion of European patents issued to German companies was higher than average, while the proportion issued to US companies was lower than average. Without much explanation, Hall and Soskice assert that the former group of industries is characterized by radical innovation while the latter group is characterized by incremental innovation.

309. See previous note.
310. This may be the primary rationale for not only a liberal market type of capitalism but also for strong protection, easy to use patent and a system of ownership of university IP that encourages university, faculty and student entrepreneurship. Shift from a liberal to a coordinated market economy, weaken IP protection, shift to a Japanese style of university–industry cooperation, and large companies will survive, but innovation by new companies would be crippled.
311. This is especially so if inventions are assumed to be radical or incremental primarily on the basis of the industry in which they arise (i.e. if industrial classification becomes a surrogate for innovativeness). For example, was the introduction of computerized numerical controllers (pioneered largely by Fanuc) in the machine tool industry radical or incremental? Hall and Soskice (2001: 39) indicate the machine tool industry is characterized by incremental innovation, but that particular innovation (and some of those that it enabled) would probably best be characterized as radical. Streb's (2003) history of the German chemical cartel, I.G. Farben, and its core progeny, BASF, Bayer and Agfa, describes how these leading companies (in an industry, polymers, that seems to fit neatly into neither classification) produced a mixture of incremental and radical innovations, with radical innovations being more prevalent in its interwar and early postwar years as opposed to the late postwar years.
- In addition, attributing leadership to the USA on the basis of patent numbers in industries supposedly characterized by radical innovation should be done with great caution in view of the tendency for some companies in these industries to amass large patent portfolios to be used as strategic arsenals in negotiations with other companies (see Part II above).
312. Preferably on a patent-by-patent or product-by-product, rather than an industry-by-industry, basis.
313. I have shown this in the case of pharmaceuticals. Goodman and Myers (2005) have shown this in the case of *essential* third generation mobile telecommunication patents, although the dominance of new companies is attributed almost entirely to Qualcomm, with Nokia, Ericsson, Motorola, and NTT DoCoMo trailing by significant margins. (Nortel, Lucent, and IBM did not declare their patents to the *International Third Generation Partnership Projects* to establish standards to aid component parts manufacturers and to ensure a degree of systems interoperability. Thus their contributions are not assessed.)

314. In early 2006, the Christian Democrats and the Social Democrats agreed that the trial period for newly hired employees, during which they could be dismissed relatively easily, should be extended from six to twenty-four months. Similar draft legislation in France sparked riots in early 2006 leading to suspension of the reform efforts.
315. For descriptions of employer–employee relations in Germany, see Hall and Soskice (2001) and Thelen and Kume (2003).
316. Prior to this law, profits from such sales were taxed at around 40%. Dougherty Carter (2005). ‘Less “Germany Inc.”—more outward’, *International Herald Tribune (New York Times)*, Sept. 3–4, 9.
317. Vogel (2003).
318. At least, however, there are the beginnings of political debate in Germany concerning job security. See Survey of Germany: ‘Waiting for a Wunder and Squaring the Circle’, *Economist*, February 9, 2006.
319. In other words, joint and commissioned research contracts between companies and universities must contain an irrevocable override of article 73 of Japan’s Patent Law, lest coinventing companies be able to do as they wish, for free, with university coinventions, while denying universities the option of licensing to third parties.
320. In particular, when the only information at issue is in the moving person’s head, courts should probably require the plaintiff company to show a high likelihood of specific, substantial injury meaning that (a) it would have to halt a particular project from which it expected to gain significant revenue or (b) if it continued with the project, sales revenue would likely be substantially reduced. These criteria are similar to those proposed by Hyde (2003). Courts should require that trade secrets covered under no-compete clauses and the LPUC be specifically and narrowly defined by companies, and not simply cover almost every facet of the work of researchers and R&D managers.
321. For example, occasional windfall profits for universities should not be viewed as a sign the system of university–industry technology transfer is failing, in view of the importance of universities and biotechs in discovering and developing innovative drugs. However, teaching and research should remain the paramount missions of universities. Conflicts of interest must be managed so as to ensure these goals are upheld and that the safety of research subjects is not jeopardized. The basic principle underlying NIH guidelines on licensing of research tools and genome inventions, *that publicly funded inventions should be licensed nonexclusively unless exclusive licenses are necessary to promote their development* (e.g. by venture companies) should probably be applied to most publicly funded university inventions. Fortunately, it appears that many leading universities are complying with the spirit of these guidelines trying to promote wide access to university discoveries, while at the same time providing venture companies with the exclusive rights they need if it appears that the ventures are the best candidates to develop the inventions (Pressman, Cook-Deegan, McCormack et al. 2006).
322. See Jaffe and Lerner (2004).

## REFERENCES

- Acs, Zoltan J. and Audretsch, David B. (1987). 'Innovation, Market Structure, and Firm Size', *Review of Economics and Statistics*, 69(no. 4, Nov.): 567–74.
- (1988). 'Innovation in Large and Small Firms: An Empirical Analysis', *American Economic Review*, 78(no. 4, Sept.): 678–90.
- (1991). 'Innovation And Technological Change: An Overview' (ch. 1), and 'R&D, Firm Size and Innovative Activity' (ch. 3), in Acs and Audretsch (eds.), *Innovation and Technological Change: An International Comparison*. Ann Arbor, MI: University of Michigan Press, pp. 1–23, 39–59.
- Anderson, Stuart (1996). 'Foreign-born Engineers and Scientists Don't Undercut Wages: They Earn More', online report from the Cato Institute, Washington, DC at [www.cato.org](http://www.cato.org)
- Aoki, Masahiko (1990). 'Toward an Economic Model of the Japanese Firm', *Journal of Economic Literature*, 28(March): 1–27.
- Arora, Ashish and Merges, Robert P. (2004). 'Specialized Supply Firms, Property Rights and Firm Boundaries', *Industrial and Corporate Change*, 13(3): 451–75.
- Association of University Technology Managers (AUTM). 'Licensing Surveys and Survey Summaries for Designated Years', available through [www.autm.org](http://www.autm.org)
- Baba, Yasunori, Yarime, Masaru, Shichijo, Naohiro, and Nagahara, Yuichi (2004). 'The Role of University–Industry Collaboration in New Materials Innovation: Evolving Networks of Joint Patent Applications', paper presented at the International Schumpeter Society Conference 'Innovation, Industrial Dynamics and Structural Transformation: Schumpeterian Legacies', Milan, June 9–12.
- Barley, Stephen R. and Kunda, Gideon (2004). *Gurus, Hired Guns, and Warm Bodies: Itinerant Experts in a Knowledge Economy*. Princeton, New Jersey: Princeton U. Press.
- Barnett, Jonathan M. (2003). 'Private Protection of Patentable Goods', Research Paper 28, Fordham University School of Law, available <http://ssrn.com/abstract=434585>
- Begley, Sharon (2002). 'Angry Engineers Blame Shortage on Low Pay, Layoffs and Age Bias', *Wall Street Journal*, July 5, A9.
- Block, Z. and Ornat, R. (1987). 'Compensating Corporate Venture Managers', *Journal of Business Venturing*, 2: 41–51.
- Branchflower, David and Oswald, Andrew (1992). 'Entrepreneurship, Happiness and Supernormal Returns: Evidence from Britain and the US', NBER Working Paper No. 4228. Washington, DC: National Bureau of Economic Research.
- (1998). 'What Makes an Entrepreneur?', *Journal of Labor Economics*, 16: 26–60.
- Branchflower, David and Oswald, Andrew and Stutzer, Alois (2001). 'Latent Entrepreneurship Across Nations', *European Economic Review*, 45(May): 680–91.
- Branstetter, Lee G. and Sakakibara, Mariko (2002). 'When Do Research Consortia Work Well and Why? Evidence from Japanese Panel Data', *American Economic Review*, 92(1): 143–59.
- Callon, Scott (1995). *Divided Sun: MITI and the Breakdown of Japanese High-Tech Industrial Policy, 1975–1993*. Stanford, CA: Stanford University Press.

- Calomiris, Charles W. and Himmelberg, Charles P. (March 1995). 'Government Credit Policy and Industrial Performance' (Japanese Machine Tool Producers, 1963–91), World Bank Policy Research Working Paper No. 1434.
- Carlson, Bo (1990). 'Small-Scale Industry at a Crossroads: U.S. Machine Tools in Global Perspective', in Acs and Audretsch (eds.), *The Economics of Small Firms*. Dordrecht, Netherlands: Kluwer, pp. 171–95.
- Casper, Steven (2000). 'Institutional Adaptiveness, Technology Policy, and the Diffusion of New Business Models: The Case of German Biotechnology', *Organization Studies*, 21(5): 887–914.
- Chandler, Alfred D. (1990). *Scale and Scope: The Dynamics of Industrial Capitalism*. Cambridge, MA: Belknap (Harvard University Press).
- (2001). *Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries*. New York: Free Press.
- Chesbrough, Henry W. (1999). 'The Organizational Impact of Technological Change: a Comparative Theory of National Institutional Factors', *Industrial and Corporate Change*, 8(3): 447–85.
- (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, MA: Harvard Business School Press.
- Christensen, Clayton M. (1993). 'The Rigid Disk Drive Industry: A History of Commercial and Technological Turbulence', *Business History Review*, 67: 531–88.
- and Raynor, Michael E. (2003). *The Innovator's Solution*. Boston, MA: Harvard Business School Press.
- Chuma, Hiroyuki (2001). 'Sources of Machine-Tool Industry Leadership in the 1990s: Overlooked Intrafirm Factors', Discussion Paper No. 837. Yale University Economic Growth Center.
- Cockburn, Iain and Henderson, Rebecca (1997). 'Public–Private Interaction and the Productivity of Pharmaceutical Research', Working Paper No. 6018. National Bureau of Economic Research.
- Cohen, Wesley M. and Klepper, Steven (1991). 'Firm Size Versus Diversity in the Achievement of Technological Advance', in Acs and Audretsch (eds.), *Innovation and Technological Change: An International Comparison*. Ann Arbor, MI: University of Michigan Press, pp. 183–203.
- Nelson, Richard R., and Walsh, John P. (2000). 'Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)', NBER Working Paper No. 7552. Cambridge, MA: National Bureau of Economic Research.
- Coleman, Samuel (1999). *Japanese Science: From the Inside*. London: Routledge.
- Corey, E. Raymond (1997). *Technology Fountainheads: The Management Challenge of R&D Consortia*. Boston, MA: Harvard Business School Press.
- Crabtree, Penni. 2006. New drug price tag: \$1.2 billion—Biotechs criticized for rising treatment costs. San Diego Union-Tribune. 10 Nov. 2006.
- Cukier, Kenneth (2005). 'Survey: Patents and Technology', *The Economist*, Oct. 20.
- Dahms, A. Stephen and Trow, Stephen C. (May 2005). 'US Biotechnology Companies and Foreign Nationals: The Changing Dynamics of Access to H-1B Visas', *Nature Biotechnology*, 23(5): 629–30.

- Dibner, Mark D. (1988). *Biotechnology Guide U.S.A.*, 1st edn. New York: Stockton Press.
- (1995). *Biotechnology Guide U.S.A.*, 3rd edn. Research Triangle Park: Institute for Biotechnology Information.
- (ed.). (1999). *Biotechnology Guide U.S.A.* 5th edn. London: Macmillan Reference.
- Doeringer, Peter B., Evans-Klock, Christine, and Terkla, David G. (January 1998). 'Hybrids or Hodgepodges? Workplace Practices of Japanese and Domestic Startups in the United States', *Industrial and Labor Relations Review*, 51(2): 171–86.
- Etzkowitz, Henry (2002). *MIT and the Rise of Entrepreneurial Science*. London: Routledge.
- Feldman, Maryann, Feller, Irwin, Bercovitz, Janet, and Burton, Richard (2002). 'Equity and the Technology Transfer Strategies of American Research Universities', *Management Science*, 49(1): 105–21.
- FitzRoy, Felix R. and Kraft, Kornelius (1991). 'Firm Size, Growth and Innovation: Some Evidence from West Germany', in Acs and Audretsch (eds.), *Innovation and Technological Change: An International Comparison*. Ann Arbor, MI: University of Michigan Press, pp. 152–9.
- Flanigan, James (2005). 'Why High-Tech Jobs Fly Off to India: Foreign Brainpower Lets Research-Oriented U.S. Firm Cut Costs', *International Herald Tribune (New York Times)*, Nov. 18, 13.
- Florida, Richard L. and Kenney, Martin (1988). 'Venture Capital-Financed Innovation and Technological Change in the USA', *Research Policy*, 17: 119–37.
- Fransman, Martin (1995). *Japan's Computer and Communications Industry: The Evolution of Industrial Giants and Global Competitiveness*. Oxford: Oxford University Press.
- Friedman, David (1988). *The Misunderstood Miracle: Industrial Development and Political Change in Japan*. Ithaca, NY: Cornell University Press.
- Ganguli, Ishani (2006). 'Complement', *The Scientist*, 20(7): 34.
- Gans, Joshu S., Hsu, David H., and Stern, Scott (2000). 'When Does Start-up Innovation Spur the Gale of Creative Destruction', NBER Working Paper No. 7851. Cambridge, MA: National Bureau of Economic Research.
- Gilson, Ronald J. (1999). 'The Legal Infrastructure of High Technology Industrial Districts: Silicon Valley, Route 128, and Covenants Not to Compete', *New York University Law Review*, 74(June): 575–627.
- Global Insight (2004). 'Venture Impact 2004: Venture Capital Benefits to the U.S.', *Economy* (available at [www.nvca.org](http://www.nvca.org)).
- Goodman, David J. and Myers, Robert A. (2005). 3G Cellular Standards and Patents. Proceedings of IEEE WirelessCom 2005, June 13–16. Available at <http://www.frlicense.com/wireless2005-b.pdf>
- Gorman, Robert A. and Ginsburg, Jane C. (1993). *Copyright for the Nineties: Cases and Materials*. Charlottesville, VA: Michie.
- Hall, Bronwyn H. and Ziedonis, Rosemarie Ham (2003). 'The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979–1995', *RAND Journal of Economics*, 32(1): 101–28.

- Hall, Peter A. and Soskice, David (2001). 'An Introduction to Varieties of Capitalism', in Hall and Soskice (eds.), *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage*. Oxford: Oxford University Press.
- Hara, Takuji (2003). *Innovation in the Pharmaceutical Industry: The Process of Drug Discovery and Development*. Cheltenham, UK: Elgar.
- Hayashi, Takayuki (2003). 'Effect of R&D Programmes on the Formation of University–Industry–Government Networks: Comparative Analysis of Japanese R&D Programmes', *Research Policy*, 32: 1421–42.
- Hecker, Daniel (2005). 'High Technology Employment: A NAICS-Based Update', *Monthly Labor Review* (July): 57–72.
- Hutchinson, Jamie (2002). 'Plasma Display Panels: The Colorful History of an Illinois Technology', *Electrical and Computer Engineering Alumni News*, University of Illinois at Urbana-Champaign 36 (no. 1). Available at <http://www.ece.uiuc.edu/pubs/plasma/plasma1.html>
- Hyde, Alan (2003). *Working in Silicon Valley*. Armonk, NY: M.E. Sharpe.
- Jaeger, David A. and Stevens, Ann Huff (1999). 'Is Job Stability in the United States Falling?' Discussion Paper Series No. 35. IZA, Bonn, Germany: Institute for the Study of Labor Law.
- Jaffe, Adam B. and Lerner, Josh (2004). *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do About It*. Princeton, NJ: Princeton University Press.
- Japan Institute for Labour Policy and Training (JILPT) (2004). 'Survey of Employee Work Motivations and Employment Management' [Roudousha no hataraku iyoku to koyou kanri no arikata ni kansuru chousa], available at [www.jil.go.jp](http://www.jil.go.jp)
- Japan Productivity Center for Socio-Economic Development (JPC-SED) (2005). 'Survey of Attitude Changes after Half a Year Among FY 2005 New Company Employees' (Summary), [2005 Nendo shinniiu sha-in hantoshikan no ishiki henka chousa].
- Jensen, Richard and Thursby, Marie (2001). 'Proofs and Prototypes for Sale: The Licensing of University Inventions', *American Economic Review*, March: 240–59.
- Johnson, Chalmers (1983). *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925–75*. Stanford, CA: Stanford University Press.
- Kalafsky, Ronald V. and MacPherson, Alan D. (2002). 'The Competitive Characteristics of U.S. Manufacturers in the Machine Tool Industry', *Small Business Economics*, 19: 355–69.
- Kambourov, Gueorgui and Manovskii, Iourii (2004). 'Rising Occupational and Industry Mobility in the United States: 1963–1993'. Discussion Paper Series No. 1110. IZA, Bonn, Germany: Institute for the Study of Labor Law.
- Kneller, Robert W. (2003). 'Autarkic Drug Discovery in Japanese Pharmaceutical Companies: Insights into National Differences in Industrial Innovation', *Research Policy*, 32: 1805–27.
- (2005a). 'Correspondence: The Origin of New Drugs', *Nature Biotechnology*, 23(5) (May): 529–30.

- (2005b). 'Correspondence: The National Origins of New Drugs', *Nature Biotechnology*, 23(6): 655–6.
- Kodama, Fumio (1991). *Emerging Patterns of Innovation: Sources of Japan's Technological Edge*. Boston, MA: Harvard Business School Press.
- Kortum, Samuel and Lerner, Josh (1999). 'What Is Behind the Recent Surge in Patenting?' *Research Policy*, 28: 1–22.
- Kuzunoki, Ken and Numagami, Tsuyoshi (August 1998). 'Interfunctional Transfers of Engineers in Japan; Empirical Findings and Implications for Cross-Functional Integration', *IEEE Transactions on Engineering Management*, 45(3): 250–62.
- Laage-Hellman, Jens (1997). *Business Networks in Japan: Supplier–Customer Interaction in Product Development*. London: Routledge.
- Leaf, Clifford (2005). 'Law of Unintended Consequences', *Fortune*, Sept. 7.
- Lerner, Josh (1995). 'Patenting in the Shadow of Competitors', *Journal of Law and Economics*, 38(Oct.): 463–95.
- Lincoln, James R. and Gerlach, Michael L. (2004). *Japan's Network Economy: Structure, Persistence, and Change*. Cambridge, MA: Cambridge University Press.
- Lynn, Leonard H., Piehler, Henry R., and Kieler, Mark (1993). 'Engineering Careers, Job Rotation, and Gatekeepers in Japan and the United States', *Journal of Engineering and Technology Management*, 10: 53–72.
- Markoff, John (2005). 'Silicon Valley Loves—and Fears—China: Venture Capitalists See Boomerang Risk', *International Herald Tribune (New York Times)*, Nov. 5–6, 1.
- McKelvey, Maureen (1996). *Evolutionary Innovations: The Business of Biotechnology*. Oxford: Oxford University Press.
- Merges, Robert P. (1995). 'Intellectual Property and the Costs of Commercial Exchange: A Review Essay', *Michigan Law Review*, 93(May): 1570–615.
- (2004). 'A New Dynamism in the Public Domain', *University of Chicago Law Review*, 71: 183–203.
- Murray, Fiona (2002). 'Innovation as Co-Evolution of Scientific and Technological Networks: Exploring Tissue Engineering', *Research Policy*, 31: 1389–403.
- Musha, Ryoji (2006, Vice Chairman Deutsche Securities). Interview in 'Weighing in on the Japanese Economy', *International Herald Tribune (New York Times)*, May 27–8, 16.
- Myers, Robert A. (1999). 'The IBM Origins of Display Technologies, Incorporated', Discussion Paper MITJP 99-01 of the MIT Japan Program, Science, Technology, Management. Cambridge, MA: Center for International Studies, Massachusetts Institute of Technology.
- National Science Board (2004). *Scientific and Engineering Indicators 2004* (two volumes). Arlington, VA: National Science Foundation.
- Organization for Economic Cooperation and Development (OECD) (2004a). *OECD Employment Outlook 2004*, ch. 2: Employment Protection Regulation and Labour Market Performance. Paris: OECD.
- (2004b). 'Venture Capital: Trends and Policy Recommendations'. Report Prepared by Baygan, Günseli of the OECD Secretariat, available at <http://www.oecd.org/dataoecd/4/11/28881195.pdf>

- Okada, Yosuke and Kushi, Takahito (2004). 'Government-Sponsored Consortium Research in Japan. A Case Study of the OPSR Program', OPIR Research Paper Series No. 22. Available at [http://www.jpma.or.jp/opir/research/paper\\_22.pdf](http://www.jpma.or.jp/opir/research/paper_22.pdf)
- O'Neil, Maryadele J. (ed.) (2006). *The Merck Index: an Encyclopedia of Chemicals, Drugs and Biologicals, 14th Edition*. Whitehouse Station, New Jersey: Merck Research Laboratories.
- Osigo, Yoshinori and Matsuzaki, Yusuke (2006). '\_\_\_ Aims to Be All-Around Player', *Nikkei Weekly*, March 6, 12.
- Otake, Tomoko (2006). 'Women in Japan: Equality Still Has a Long Way to Go', *Japan Times*, March 12.
- Paral, Rob and Johnson, Benjamin (2004). 'Maintaining a Competitive Edge: The Role of the Foreign-Born and U.S. Immigration Policies in Science and Engineering', *Immigration Policy in Focus* (Immigration Policy Center) (August): 1–15.
- Pavitt, Keith, Robson, Michael, and Townsend, Joe (1987). 'Size Distribution of Innovating Firms in the UK: 1945–1983', *Journal of Industrial Economics*, 55(March): 291–316.
- Pressman, Lori, Burgess, Richard, Cook-Deegan, Robert M., McCormack, Stephen J., Nami-Wolk, Io, Soucy, Melissa, and Walters, Leroy (2006). 'The Licensing of DNA Patents by US Academic Institutions', *Nature Biotechnology*, 24: 31–9.
- 'Protein Engineering in Japan: Report of a U.S. Protein Engineering Study Team on its Visit to Japan' (1992). US Government limited circulation report.
- Rader, Ronald A. (2006). *Biopharmaceutical Products in the U.S. and European Market, 5th edition*. Rockville, Maryland: Bioplan Associates.
- Rai, Saritha (2005). 'India Gains in Role of Designing Chips', *International Herald Tribune (New York Times)*, Nov. 19–20, 13.
- Rathmann, George B. (1991). 'Biotechnology Startups', in Vivian Moses, Ronald E. Cape (eds. of 1st edn. 1991) and Derek G. Springham (ed. of 2nd edn. 1999), *Biotechnology: The Science and the Business*. Amsterdam: Harwood Academic, pp. 47–58.
- Roessner, David, Bozeman, Barry, Feller, Irwin, Hill, Christopher, and Newman, Nils (1997). 'The Role of NSF's Support of Engineering in Enabling Technological Innovation', Final Report Prepared for the National Science Foundation by SRI International. Arlington, VA: SRI International.
- Rosenberg, Nathan (1998). 'Technological Change in Chemicals: The Role of University–Industry Relations', In Ashish Arora, Ralph Landau, and Nathan Rosenberg (eds.), *Chemicals and Long-Term Economic Growth: Insights from the Chemical Industry*. New York: John Wiley & Sons, pp. 193–230.
- Rothwell, Roy and Dodgson, Mark (1994). 'Innovation and Size of Firm', in M. Dodgson and R. Rothwell (eds.), *Handbook of Industrial Innovation*. Cheltenham, UK: Elgar.
- Sakakibara, Mariko (1997). 'Evaluating Government-Sponsored R&D Consortia in Japan: Who Benefits and How?', *Research Policy*, 26: 447–73.
- \_\_\_\_ (2001). 'Cooperative Research and Development: Who Participates and In Which Industries Do Projects Take Place?', *Research Policy*, 30: 993–1018.

- Saxenian, AnnaLee (1994). *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
- (1999). *Silicon Valley's New Immigrant Entrepreneurs*. San Francisco, CA: Public Policy Institute of California.
- and Hsu Jinn-Yuh (2001). 'The Silicon Valley–Hsinchu Connection: Technical Communities and Industrial Upgrading', *Industrial and Corporate Change* 10(no. 4): 893–920.
- Scherer, F. M. (1991). 'Changing Perspectives on the Firm Size Problem', in Zoltan J. Acs and Joseph Schumpeter (eds.), 1942. *Capitalism, Socialism and Democracy*. New York: Harper Perennial.
- Shane, Scott (2001). 'Technological Opportunities and New Firm Creation', *Management Science*, 47:(Feb.): 205–20.
- (2004). *Academic Entrepreneurship: Academic Spinoffs and Wealth Creation*. Cheltenham, UK: Elgar.
- Silicon Valley Network (2005). *Index of Silicon Valley* (at [www.jointventure.org](http://www.jointventure.org)).
- Streb, Jochen (2003). 'Shaping the National System of Inter-Industry Knowledge Exchange: Vertical Integration, Licensing and Repeated Knowledge Transfer in the German Plastics Industry', *Research Policy*, 32: 1125–40.
- Takahashi, Hiroshi (2007). *Jouhou tsuushin kakumei: inobaeshion ni taisuru seifu no yakuwari* [The politics of the telecommunications revolution: the role of government in innovation]. (Doctoral dissertation in Japanese submitted to RCAST, University of Tokyo, and approved in Feb.)
- Thelen, Kathleen and Kume, Ikuo (2003). 'The Future of Nationally Embedded Capitalism: Industrial Relations in Germany and Japan', in Kozo Yamakura and Wolfgang Streeck (eds.), *The End of Diversity? Prospects for German and Japanese Capitalism*. Ithaca, NY: Cornell University Press.
- Thursby, Jerry and Thursby, Marie (2003). 'Industry/University Licensing: Characteristics, Concerns and Issues from the Perspective of the Buyer', *Journal of Technology Transfer*, 28: 207–13.
- Tolbert, Kathryn (2000). 'Women Opt for Jobs Instead of Children', *Japan Times*, Aug. 22, 3 (reprinted from the *Washington Post*).
- Uchitelle, Louis (2005). 'If You Can Make It Here', *New York Times*, Sept. 4, sec. 3 p. 1.
- Vogel, Steven K. (2003). 'The Re-Organization of Organized Capitalism: How the German and Japanese Models are Shaping Their Own Transformations', in Kozo Yamakura and Wolfgang Streeck (eds.), *The End of Diversity? Prospects for German and Japanese Capitalism*. Ithaca, NY: Cornell University Press.
- Westney, D. Eleanor and Sakakibara, Kiyonori (1986a). 'The Role of Japan-Based R&D in Global Technology Strategy', in Mel Horwitch (ed.), *Technology and the Modern Corporation*. New York: Pergamon. 217–32.
- (1986b). 'Designing the Designers: Computer R&D in the United States and Japan', *Technology Review*, April: 24–69.
- Whitley, Richard (2000). *Divergent Capitalisms: The Social Structuring and Change of Business Systems*. Oxford: Oxford University Press.

- Whittaker, D. H. (1997). *Small Firms in the Japanese Economy*. Cambridge, MA: Cambridge University Press.
- Willoughby, Kelvin W. (1997). *New York's Evolving Bioscience Industries: Managing Knowledge, Production and Services for Economic Development*. New York: Center for Biotechnology & New York Biotechnology Association.
- \_\_\_\_ (1998). 'Utah's Bioscience Technology Industry Complex: A Census and Analysis of the Biotechnology, Medical Technology and Life-systems Technology Industries in the State of Utah'. Salt Lake City: Utah Life Science Association & State of Utah Division of Business and Economic Development.
- \_\_\_\_ (2005a). 'Intellectual Property Management in Entrepreneurial Technology Firms in the United States', Presentation at RCAST, University of Tokyo, 25 August 2005. Also additional analyses related to these data conducted July, 2005.
- \_\_\_\_ (2005b). 'How Do Entrepreneurial Technology Firms Really Get Financed and What Difference Does it Make?', Paper for the U.S. Association for Small Business and Entrepreneurship, Technology Entrepreneurship Division, Annual Conference, Tucson, AZ, January 12–15, 2006.
- Wilson, John W. (1985a). *The New Venturers: Inside the High Stakes World of Venturing*. Reading, MA: Addison-Wesley.
- \_\_\_\_ (1985b). 'America's High-Tech Crisis: Why Silicon Valley Is Losing Its Edge', *Business Week*, March 11.
- Wulf, William A. (President of the National Academy of Engineering) (2005). The importance of foreign-born scientists and engineers to the security of the United States. Statement before the Subcommittee on Immigration, Border Security, and Claims of the Committee on the Judiciary of the US House of Representatives (Sept. 15).
- Yamagishi, Toshio, Cook, Karen S., and Watabe, Motoki (1998). 'Uncertainty, Trust, and Commitment Formation in the United States and Japan', *American Journal of Sociology*, 104(1): 165–94.
- Zucker, Lynne G. and Darby, Michael R. (1997). 'Present at the Biotechnology Revolution: Transformation of Technological Identity for a Large Incumbent Pharmaceutical Firm', *Research Policy*, 26: 429–46.