Chapter One

Introduction

THE IMPORTANCE OF TECHNOLOGICAL INNOVATION

technological innovation The act of introducing a new device, method, or material for application to commercial or practical objectives.

In many industries **technological innovation** is now the most important driver of competitive success. Firms in a wide range of industries rely on products developed within the past five years for almost one-third (or more) of their sales and profits.[1] For example, at Johnson & Johnson, products developed within the last five years account for over 30 percent of sales, and sales from products developed within the past five years at 3M have hit as high as 45 percent in recent years.

The increasing importance of innovation is due in part to the globalization of markets. Foreign competition has put pressure on firms to continuously innovate in order to produce differentiated products and services. Introducing new products helps firms protect their margins, while investing in process innovation helps firms lower their costs. Advances in information technology also have played a role in speeding the pace of innovation. Computer-aided design and computer-aided manufacturing have made it easier and faster for firms to design and produce new products, while flexible manufacturing technologies have made shorter production runs economical and have reduced the importance of production economies of scale.[2] These technologies help firms develop and produce more product variants that closely meet the needs of narrowly defined customer groups, thus achieving differentiation from competitors. For example, in 2012, Toyota offered 16 different passenger vehicle lines under the Toyota brand (e.g., Camry, Prius, Highlander, and Tundra). Within each of the vehicle lines, Toyota also offered several different models (e.g., Camry L, Camry LE, Camry SE) with different features and at different price points. In total, Toyota offered 64 car models ranging in price from $14,115 (for the Yaris three-door liftback) to $77,995 (for the Land Cruiser), and seating anywhere from three passengers (e.g., Tacoma Regular Cab truck) to eight passengers (Sienna Minivan). On top of this, Toyota also produced a range of luxury vehicles under its Lexus brand. Similarly, Samsung offered over 100 models of cell phones, and Sony produced over 50 models of MP3 portable audio players. Both companies also offered a variety of color choices and accessories that could be purchased to further tailor the product to the consumer's tastes. Samsung and Sony's and utilize information obtained externally.[30] Absorptive capacity refers to the firm's ability to understand and use new information (absorptive capacity is discussed in more detail in Chapter Four).

Universities and Government-Funded Research

Another important source of innovation comes from public research institutions such as universities, government laboratories, and incubators. A significant share of companies report that research from public and nonprofit institutions enabled them to develop innovations that they would not have otherwise developed.[31]

ex. set al a seperate unit in a company

Universities

Many universities encourage their faculty to engage in research that may lead to useful innovations. Typically the intellectual property policies of a university embrace both patentable and unpatentable innovations, and the university retains sole discretion over the rights to commercialize the innovation. If an invention is successfully commercialized, the university typically shares the income with the individual inventor(s).[32] To increase the degree to which university research leads to commercial innovation, many universities have established **technology transfer offices**.

technology transfer offices
Offices designed to facilitate the transfer of technology developed in a research environment to an environment where it can be commercially applied.

In the United States, the creation of university technology transfer offices accelerated rapidly after the Bayh-Dole Act was passed in 1980. This act allowed universities to collect royalties on inventions funded with taxpayer dollars. Before this, the federal government was entitled to all rights from federally funded inventions.[33] While the revenues from the university technology transfer activities are still quite small in comparison to university research budgets, their importance is growing rapidly. Universities also contribute significantly to innovation through the publication of research results that are incorporated into the development efforts of other organizations and individuals.

Government-Funded Research

science parks
Regional districts, typically set up by government, to foster R&D collaboration between government, universities, and private firms.

incubators
Institutions designed to nurture the development of new businesses that might otherwise lack access to adequate funding or advice.

Governments of many countries actively invest in research through their own laboratories, the formation of **science parks** and **incubators**, and grants for other public or private research entities. For example, the U.S. Small Business Administration manages two programs that enable innovative small businesses to receive funding from federal agencies such as the Department of Defense, the Department of Energy, the Department of Health and Human Services, and others. The first is the Small Business Innovation Research (SBIR) program. Under the SBIR program, agencies award grants of up to $850,000 to small businesses to help them develop and commercialize a new innovation. The second is the Small Business Technology Transfer (STTR) program, which awards grants of up to $850,000 to facilitate a partnership between a small business and a nonprofit research institution—its objective is to more fully leverage the innovation that takes place in research laboratories by connecting research scientists with entrepreneurs.

The U.S. government was the main provider of research and development funds in the United States in the 1950s and 1960s, accounting for as much as 66.5 percent in 1964. Its share has fallen significantly since then, and in 2009, U.S. government spending accounted for only 31 percent of the nation's R&D spending. However, the decline in the government share of spending is largely due to the rapid increase in industry R&D funding rather than a real decline in the absolute amount spent

FIGURE 2.5
U.S. Spending on R&D by Source, 1953-2009[34]

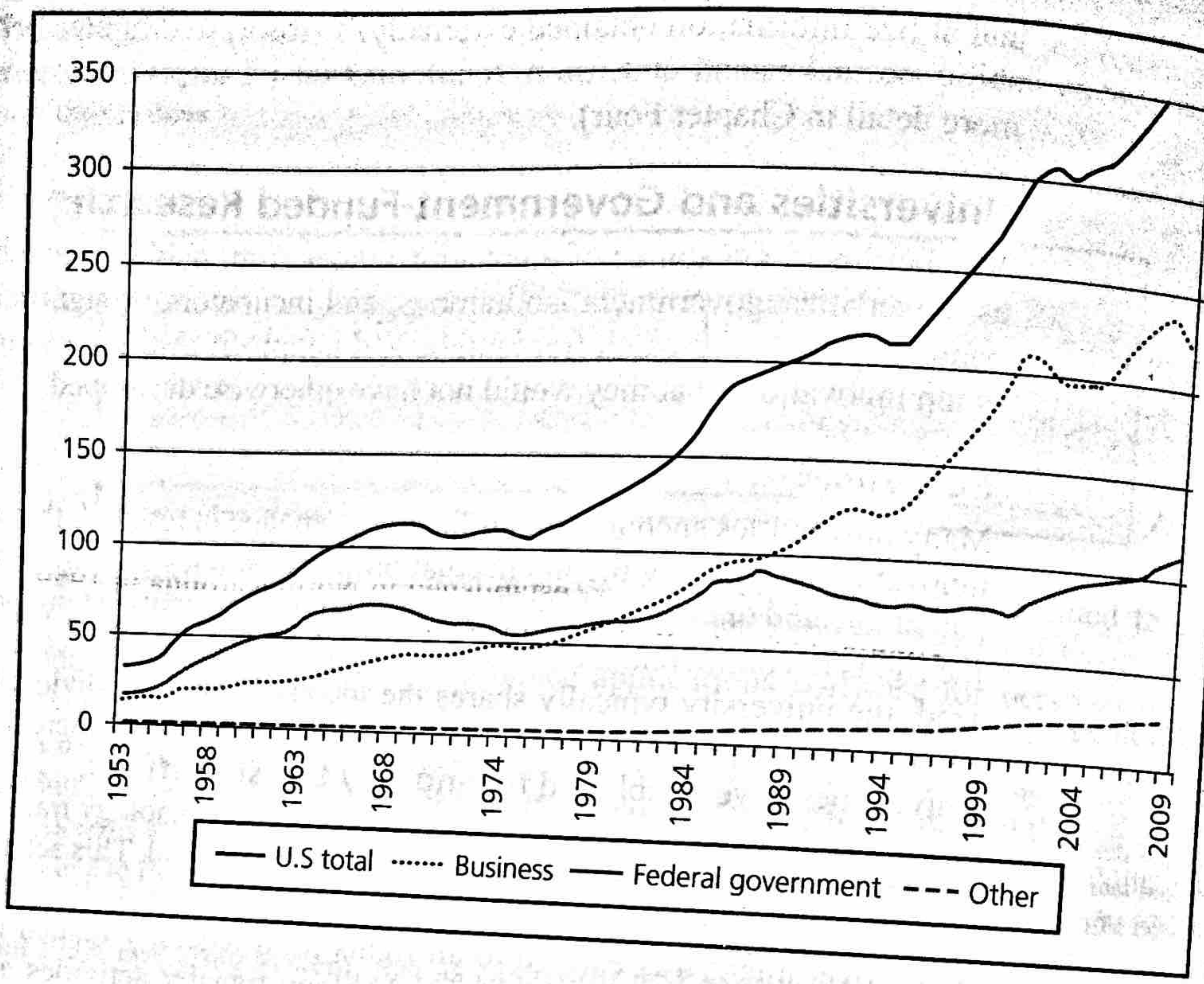
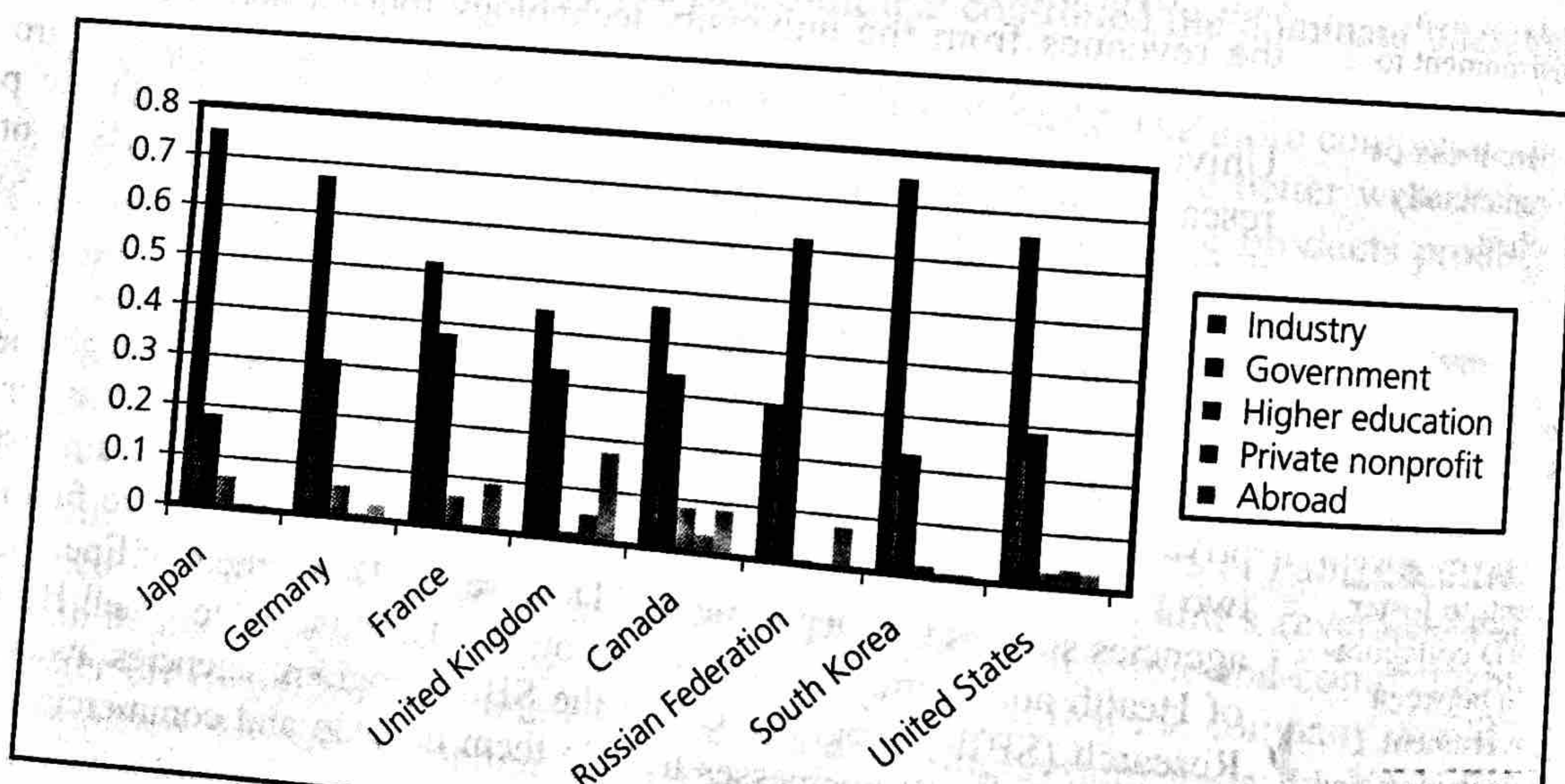


FIGURE 2.6
Percent of R&D Funds by Source and Country, Selected Years (2004–2006)[35]



by the government. U.S. government funding for R&D in 2009 was at its highest ever—$113 billion (see Figure 2.5). By contrast, about $225 billion was spent by industry on R&D.

In the United States, industry spending on R&D dwarfs that spent by government (as shown in Figure 2.6). However, the ratio of R&D funding provided by industry compared to government funding varies significantly by country, as also shown in Figure 2.6.

One way governments support the research and development efforts in both the public and private sectors is through the formation of science parks and incubators. Since the 1950s, national governments have actively invested in developing science parks to foster collaboration between national and local government institutions, universities, and private firms. These science parks often include institutions designed to nurture the development of new businesses that might otherwise lack access to adequate funding and technical advice. Such institutions are often termed *incubators.* Incubators help overcome the market failure that can result when a new technology has the potential for important societal benefits, but its potential for direct returns is highly uncertain.[36]

Notable examples of science parks with incubators include:

- Stanford Research Park, established near Stanford University in 1951.
- Research Triangle Park, established in North Carolina in 1959.
- Sophia Antipolis Park, established in Southern France in 1969.
- Cambridge Science Park, established in Cambridge, England, in 1972.

These parks create fertile hotbeds for new start-ups and a focal point for the collaboration activities of established firms. Their proximity to university laboratories and other research centers ensures ready access to scientific expertise. Such centers also help university researchers implement their scientific discoveries in commercial applications.[37] Such parks often give rise to technology clusters that have long-lasting and self-reinforcing advantages (discussed later in the chapter).

Private Nonprofit Organizations

Private nonprofit organizations, such as private research institutes, nonprofit hospitals, private foundations, professional or technical societies, academic and industrial consortia, and trade associations, also contribute to innovation activity in a variety of complex ways. Many nonprofit organizations perform their own research and development activities, some fund the research and development activities of other organizations but do not do it themselves, and some nonprofit organizations do both in-house research and development and fund the development efforts of others.

INNOVATION IN COLLABORATIVE NETWORKS

As the previous sections indicate, there is a growing recognition of the importance of collaborative research and development networks for successful innovation.[38] Such collaborations include (but are not limited to) joint ventures, licensing and second-sourcing agreements, research associations, government-sponsored joint research programs, value-added networks for technical and scientific interchange, and informal networks.[39] Collaborative research is especially important in high-technology sectors, where it is unlikely that a single individual or organization will possess all of the resources and capabilities necessary to develop and implement a significant innovation.[40]

multiple producers. Managers could then use these curves to assess whether a technology appears to be approaching its limits or to identify new technologies that might be emerging on s-curves that will intersect the firm's technology s-curve. Managers could then switch s-curves by acquiring or developing the new technology. However, as a prescriptive tool, the s-curve model has several serious limitations.

Limitations of S-Curve Model as a Prescriptive Tool

First, it is rare that the true limits of a technology are known in advance, and there is often considerable disagreement among firms about what a technology's limits will be. Second, the shape of a technology's s-curve is not set in stone. Unexpected changes in the market, component technologies, or complementary technologies can shorten or extend the life cycle of a technology. Furthermore, firms can influence the shape of the s-curve through their development activities. For example, firms can sometimes stretch the s-curve through implementing new development approaches or revamping the architecture design of the technology.[15]

Christensen provides an example of this from the disk-drive industry. A disk drive's capacity is determined by its size multiplied by its areal recording density; thus, density has become the most pervasive measure of disk-drive performance. In 1979, IBM had reached what it perceived as a density limit of ferrite-oxide–based disk drives. It abandoned its ferrite-oxide–based disk drives and moved to developing thin-film technology, which had greater potential for increasing density. Hitachi and Fujitsu continued to ride the ferrite-oxide s-curve, ultimately achieving densities that were eight times greater than the density that IBM had perceived to be a limit.

Finally, whether switching to a new technology will benefit a firm depends on a number of factors, including (*a*) the advantages offered by the new technology, (*b*) the new technology's fit with the firm's current abilities (and thus the amount of effort that would be required to switch, and the time it would take to develop new competencies), (*c*) the new technology's fit with the firm's position in complementary resources (e.g., a firm may lack key complementary resources, or may earn a significant portion of its revenues from selling products compatible with the incumbent technology), and (*d*) the expected rate of diffusion of the new technology. Thus, a firm that follows an s-curve model too closely could end up switching technologies earlier or later than it should.

TECHNOLOGY CYCLES

The s-curve model above suggests that technological change is cyclical: Each new s-curve ushers in an initial period of turbulence, followed by rapid improvement, then diminishing returns, and ultimately is displaced by a new technological discontinuity.[16] The emergence of a new technological discontinuity can overturn the existing competitive structure of an industry, creating new leaders and new losers. Schumpeter called this process *creative destruction,* and argued that it was the key driver of progress in a capitalist society.[17]

Several studies have tried to identify and characterize the stages of the technology cycle in order to better understand why some technologies succeed and others fail, and whether established firms or new firms are more likely to be successful in introducing or adopting a new technology.[18] One technology evolution model that rose to standards and facilitate exchange both within and across national borders. Where government regulation imposes a single standard on an industry, the technology design embodied in that standard necessarily dominates the other technology options available to the industry. The consumer welfare impact of dominant designs is explored further in the Theory in Action section.

The Result: Winner-Take-All Markets

All these forces can encourage the market toward natural monopolies. While some alternative platforms may survive by focusing on niche markets, the majority of the market may be dominated by a single (or few) design(s). A firm that is able to lock in its technology as the dominant design of a market usually earns huge rewards and may dominate the product category through several product generations. When a firm's technology is chosen as a dominant design, not only does the firm have the potential to earn near-monopoly rents in the short run, but the firm also is in a good position to shape the evolution of the industry, greatly influencing what future generations of products will look like. However, if the firm supports a technology that is not chosen as the dominant design, it may be forced to adopt the dominant technology, effectively forfeiting the capital, learning, and brand equity invested in its original technology. Even worse, a firm may find itself locked out of the market if it is unable to adopt the dominant technology. Such standards battles are high-stakes games—resulting in big winners and big losers.

path dependency
When end results depend greatly on the events that took place leading up to the outcome. It is often impossible to reproduce the results that occur in such a situation.

Increasing returns to adoption also imply that technology trajectories are characterized by **path dependency**, meaning that relatively small historical events may have a great impact on the final outcome. Though the technology's quality and technical advantage undoubtedly influence its fate, other factors, unrelated to the technical superiority or inferiority, may also play important roles.[11] For instance, timing may be crucial; early technology offerings may become so entrenched that subsequent technologies, even if considered to be technically superior, may be unable to gain a foothold in the market. How and by whom the technology is sponsored may also impact adoption. If, for example, a large and powerful firm aggressively sponsors a technology (perhaps even pressuring suppliers or distributors to support the technology), that technology may gain a controlling share of the market, locking out alternative technologies.

The influence of a dominant design can also extend beyond its own technology cycle. As the dominant design is adopted and refined, it influences the knowledge that is accumulated by producers and customers, and it shapes the problem-solving techniques used in the industry. Firms will tend to use and build on their existing knowledge base rather than enter unfamiliar areas.[12] This can result in a very "sticky" technological paradigm that directs future technological inquiry in the area.[13] Thus, a dominant design is likely to influence the nature of the technological discontinuity that will eventually replace it.

Such winner-take-all markets demonstrate very different competitive dynamics than markets in which many competitors can coexist relatively peacefully. These markets also require very different firm strategies to achieve success. Technologically superior products do not always win—the firms that win are usually the ones that know how to manage the multiple dimensions of value that shape design selection.

2. **Threat of potential entrants.** The threat of potential entrants is influenced by both the degree to which the industry is likely to attract new entrants (i.e., is it profitable, growing, or otherwise alluring?) and the height of **entry barriers**. Entry barriers can include such factors as large start-up costs, brand loyalty, difficulty in gaining access to suppliers or distributors, government regulation, threat of retaliation by existing competitors, and many others. While profitability and growth may attract new entrants, entry barriers will deter them. For example, while high projected growth in the smart phone market attracts potential entrants to this market, the challenge of competing against large, well-established, and efficient competitors such as Nokia and Ericsson deters many entrants. To effectively compete against these companies requires that an entrant be able to manufacture, advertise, and distribute on a large scale, suggesting significant start-up costs for an entrant to achieve a competitive position. However, some of these capabilities could be obtained through partnerships with other firms, such as having contract manufacturers handle production and having mobile phone service providers handle distribution, thereby lowering start-up costs.

entry barriers
Conditions that make it difficult or expensive for new firms to enter an industry (government regulation, large start-up costs, etc.).

3. **Bargaining power of suppliers.** The degree to which the firm relies on one or a few suppliers will influence its ability to negotiate good terms. If there are few suppliers or suppliers are highly differentiated, the firm may have little choice in its buying decision, and thus have little leverage over the supplier to negotiate prices, delivery schedules, or other terms. On the other hand, if suppliers are very abundant and/or are not highly differentiated, the firm may be able to force the suppliers to bid against one another for the sale. The amount the firm purchases from the supplier is also relevant. If the firm's purchases constitute the bulk of a supplier's sales, the supplier will be heavily reliant upon the firm and the supplier will have little bargaining power. Likewise, if the supplier's sales constitute a large portion of the firm's purchases, the firm will be heavily reliant upon the supplier and the supplier will have more bargaining power. For example, manufacturers that sell to Walmart often have little bargaining power because Walmart's enormous volume often makes its purchases a significant portion of a manufacturer's yearly sales. Walmart's suppliers typically have little bargaining power. When Intel sells to personal computer manufacturers, on the other hand, it typically wields considerable supplier bargaining power. When computer manufacturers consider potential suppliers for microprocessors, they often have little choice but to go with Intel—many consumers demand that their systems include Intel microprocessors, and the majority of personal computer hardware and software has been optimized for the Intel architecture. If the firm faces **switching costs** that make it difficult or expensive to change suppliers, this will also increase the supplier's bargaining power. Finally, if the firm can backward **vertically integrate** (i.e., produce its own supplies), this will lessen supplier bargaining power, and if the supplier can threaten to forward vertically integrate into the firm's business, this will increase the supplier's bargaining power.

switching costs
Factors that make it difficult or expensive to change suppliers or buyers, such as investments in specialized assets to work with a particular supplier or buyer.

vertical integration
Getting into the business of one's suppliers (backward vertical integration) or one's buyers (forward vertical integration). For example, a firm that begins producing its own supplies has practiced backward vertical integration, and a firm that buys its distributor has practiced forward vertical integration.

4. **Bargaining power of buyers.** Many of the same factors that influence the bargaining power of suppliers have an analogous role with the bargaining power of buyers. The degree to which the firm is reliant on a few customers will increase the customer's bargaining power, and vice versa. If the firm's product is highly differentiated,