23 Growth of Industrial R&D: The Implications, Influences, and Issues

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Why has industrial research and development (R&D) grown to such an extent over the past decade? How does the federal government impact funding by the private sector? What does this influence mean for business and for those formulating federal science and technology (S&T) policy? These are some of the questions discussed in this chapter.

Growth of Industrial R&D

R&D investment by U.S. industry has grown by nearly ten percent for each of the last six years. For the current year, the National Science Foundation (NSF) and the Battelle Memorial Institute estimate industry's total effort at about $214 billion. Over $20 billion of this amount comes from the federal government. Industry funds nearly 70 percent of the total R&D in the United States, and conducts about 77 percent of it. Most of this is devoted to development, with a smaller amount devoted to basic and applied research. Forty years ago the federal government funded 65 percent of U.S. R&D. So the roles of industry and the federal government have now been reversed. This in itself raises some issues related to federal S&T policy.

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The R&D Process

To understand the changes taking place in industrial R&D, we need to understand something about the R&D process itself. Industrial R&D can be pictured as a process with inputs—people, ideas, equipment, and funds—that flow into the R&D "lab." Here, testing, exploration, and knowledge-building take place. Out of the lab flow outputs—patents, knowledge and design for products, processes, and services. Receiving systems such as business units, manufacturing functions, engineering functions, or other operations take the outputs and convert them to outcomes—cost reductions, new businesses, and new and improved products, services, and processes. It is apparent that R&D is an integral part of the business it supports.

At each step we can measure the effectiveness of the R&D effort. We can use a variety of metrics, such as input metrics, in-process metrics, output metrics, and outcome metrics. (Often different constituencies are interested in measuring at different points in the process.) These metrics may be used to help determine the R&D budget for the coming years.

Briefly put, R&D is about creating knowledge. How an organization learns, how tacit knowledge becomes explicit, and how corporate memory can be developed—these are all important to the proper functioning of R&D.

The R&D process is in turn part of the overall, more general innovation process where innovation is taking an idea and turning it into something unique and tangible that has utility. This innovation process is certainly not a linear one. It has many recycle loops, and often the idea must be reworked or put on the shelf for a year or two before being exploited. The product, once commercialized, may not find a market until it is modified or improved. Also, many factors influence the process, such as new company strategies, changes in regulations or governmental S&T policies, changing marketplace forces, new scientific discoveries, and emerging technologies.

Influences on Those Doing R&D

Today major influences act on those doing R&D. Global competition is intense, with a company's competitive position often determined by the strength of its technologies. Many scientific domains are ready to be exploited. Revolutions are taking place in research methods—in computation, analytical methods, bioinformatics, and information management and organic synthesis. Information and technology transfers take place rapidly and reach around the globe as technological competencies are increasing every day in China, Korea, India, and many other parts of the world. The marketplace is also making increased demands on R&D to increase product functionality and quality. Total development costs continue to increase; the more successful research is, the more development work there is to be done. Finally, the critical factor is speed.

Reasons Why R&D Is Growing

There are at least nine reasons why industrial R&D is growing at such a rapid pace.

1. A number of companies compete in businesses where success in R&D can make a major difference. These companies must devote significant resources to R&D.

The top R&D spenders are involved in either life sciences or information technology—eight of the top ten, 19 of the top 25, and 37 of the top 50. Also at the top of the list, Ford and General Motors have heavy development and engineering investments. The top 100 spenders account for nearly two-thirds of all industrial R&D expenses.

The shift of U.S. industrial R&D toward information technology and life sciences (including health care) promises to change the traditional model for industrial R&D. Practices that have proven effective in these industries will influence R&D environments across a range of sectors. Also, the increasing complexity of information technology, boosted by the continuing growth of the Internet, will continue to widen the scope of formal management systems far beyond the boundaries of the core organization.

2. We are seeing the increasing role of technological innovation as a factor of corporate growth. Management challenges will arise depending on whether a technology is emerging or established, and whether the business is emerging or established. Corporate management must be prepared to interact with systems for technological innovation that have evolved well beyond the model of large, well-established companies conducting the bulk of industrial R&D internally.

For example, over the last 25 years or so not only has the service sector come to dominate the U.S. economy but service industries have become more R&D intensive. According to NSF, service sector R&D accounted for less than five percent of the U.S. total in1983; by 1993 it had increased to 26 percent. However, service sector R&D tends to be targeted to different business objectives that relate to different roles in the economy. For example, the manufacturing sector typically adds value by transforming materials into products. By contrast, much of the service sector (finance, communications, transportation, utilities, trade, etc.) creates value and competes by buying products and assembling them into a system or network, efficiently running or operating the system, and providing services for customers who are often members of the general public. Thus the R&D portfolios of service corporations reflect these required core competencies. They typically address:

a) system design (the network of physical products and information),

b) system operation (equivalent to manufacturing processes in manufacturing industries), and

c) service design and delivery, including interaction with individual customers.

They also may draw upon very different scientific disciplines.

Ron Jonash of Arthur D. Little, Inc. has pointed out the correlation between a company's innovation leadership and its performance on Wall Street. Next-generation companies know that innovation is more than simply creating new products and services. It is also about improving top and bottom lines by capturing and exploiting value that exists in the "extended organization." Innovation leadership, however, is difficult. Clayton Christensen of Harvard Business School pointed out that "Great companies can fail precisely because they do everything right—they had their competitive antennae up, listened to customers, and invested in new technologies but still lost market leadership when confronted with disruptive changes in technology and market structure."[1]

Mainstream customers initially reject breakthrough innovations (disruptive technologies) because they cannot use them (because of poor quality, poor functionality, or inadequate performance). This rejection can lead firms with strong customer focus to allow strategically important innovations to languish. An excessive customer focus can prevent firms from creating new markets and finding new customers for the products of the future.

Others who develop "disruptive technologies" that are simpler and less costly work on improving their functionality, performance, and quality. They build sales in a new, related market and eventually invade the established market of the "great company." Christensen gives some rules for avoiding the attack of disruptive technologies, discussing when not to listen to customers, when to invest in developing lower-performance products that promise lower margins, and when to pursue small markets at the expense of seemingly larger and more lucrative ones.

3. With newer techniques, processes, and practices, R&D has become more productive. Also, because of teaming up, forming alliances, and linking skills with others, success is more certain. Strategic R&D or technology planning may also be more effective. In a recent collaborative effort between the Industrial Research Institute and the Society for Competitive Intelligence Professionals, we learned how competitive technology intelligence can aid the R&D manager not only in understanding and combating threats, but also in finding opportunities. We learned how scientometrics (the study of scientific literature through co-citation analysis) can help us understand the current structure of a number of scientific disciplines. We can see where the work is "hot," where it is headed, and who is doing the critical work. We learned how SmithKline Beecham restructured their R&D portfolio and therapeutic area targets, and how they found R&D partners as they learned about the promise of genomics and identified the leaders in the field.

Relative to such partnerships, George Whitesides of Harvard University identified three distinct models or modes of collaboration among universities, government, industry, and, in some industries, venture capitalists and medical schools. In biotechnology, the universities conduct basic research and venture capitalists find ways to test the prototypes in small start-ups. Medical schools act as "test beds," and then industry acquires the start-ups (in many cases). In microelectronics, collaborative efforts can take place involving all three parties—government, industry, and universities. In the chemical industry, the effort has been far less fluid, far less collaborative, and far less effective. Some industries may need to develop the partnership models from the efforts in biotechnology.

4. Today we have more scientific discoveries that provide opportunities for developing new businesses, new products, and new services. For many businesses, the scientific advances being made today in the material, biological, and information sciences all have important roles to play. Businesses may have a special interest in catalysis, modeling and simulation, or bioprocessing, but they may also see interesting things happening where the sciences overlap or interact, such as with bioengineered materials, biocomputation, or "smart" materials.

It is therefore very important for any industrial R&D organization to maintain close contact with the science base, whether the work is in academia or a government laboratory. The importance of maintaining federal funding for basic research is more than apparent. Business leaders know that funding for basic research is one of the drivers for future R&D as well as a healthy economy.

5. During the past five years, the economy has been strong. Companies have been growing and more funds have been available to fund R&D, both from inside companies and from those supplying venture capital.

6. With more research, and more research results, we see more opportunities for development efforts, which are considerably more costly.

7. The scope of R&D has broadened. R&D is becoming global. For example, General Electric has established the Jack Welch Laboratory in India, and DuPont has been working with science institutes in China for over 15 years. Here some team-based projects continue for 24 hours a day since the work is done around the world.

8. The scope of R&D effort has expanded in another way and given us ever more opportunities. For some, R&D itself has become a thriving business. Technologies are traded, licensed, sold, or donated. On the Internet, Yet2.com acts as the NASDAQ of technologies, and Millennium Pharmaceuticals, Inc., sells research in progress.

9. Finally, industrial R&D is growing because of the availability of talented researchers. We can develop better ways in which we manage research and development, but in the end our success will depend on the talent of our scientists. Our talented researchers must have the skill base; the technical edge to walk with credibility; the ability to use modern computational skills, modeling, and information technology; the knowledge to take an idea and turn it into something of substance; and the ability to collaborate and work in teams. We will continue to rely on public support for developing these talented scientists and engineers upon which the R&D enterprise relies.

Federal Impact on Private Sector Funding

The increasing level of private support for R&D can be impacted—both positively and negatively—by actions of the federal government. These actions include enacting environmental, safety, and health regulations; developing new tax and trade policies; making immigration policies; developing stronger protection for intellectual property; giving awards (such as the National Medal of Technology); establishing partnerships with government laboratories; developing programs such as the Advanced Technology Program; supporting the education of scientists; and promoting scientific literacy throughout our society.

Implications for Federal Science and Technology Policy

From an understanding of the current state of R&D in the nation, we can see several implications for federal science and technology policy:

- Publicly funded R&D must be able to compete for ever-scarcer public funds in the federal budget. To do this, potential outcomes of R&D must be strongly linked to top national priorities.

- Federal support is critical for basic scientific research and the future of our economy.

- We must ensure that the nation's leaders understand the promise of science and technology, not only in general, but also in specific cases.

- Where public funds are limited, the federal government may want to create additional incentives for industrial R&D to meet some of the economic and social needs of the nation.

Conclusion

Since industry funds over two-thirds of the nation's R&D, one must ask to what extent federal S&T policy can enlist industrial R&D resources to work on meeting national goals. These goals include researching climate change, ensuring food security, maintaining a strong R&D infrastructure, conserving water and energy resources, building technologies for a sustainable future, and developing technologies for national security.

Companies have incentives to do R&D that supports and grows their businesses. There may, however, be ways to create incentives for them to do applied research in the national interest. We should explore these ways.

Endnote

1. Christensen, Clayton M. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Harvard Business School Publishing, 1997.