Exporting U.S. High Tech, Facts & Fiction About the Globalization of Industrial R&D

Sean S. Costigan
Benedicte Callan

Council on Foreign Relations, January 1, 1998

Foreword

The explosion of information technologies makes us dream of a world where people can work away from the office or factory floor and where the generation of knowledge is as important as the manufacture of products. But this same technological explosion raises the specter that the United States, so long the research center for thousands of innovative firms, may not remain the place where companies choose to develop their best ideas and roll out their newest products. If people can be footloose, so can research and development (R & D).

This Council on Foreign Relations Study Group Report shows, through a series of case studies, that while R & D globalization is in fact occurring, the pace is moderate, and, so far, the U.S. economy has benefited from the increasing mobility of industrial R & D activities. In particular, the report finds the fear that newly industrializing economies will easily exploit their educated workforce and become world-class research locales is premature. To be sure, many countries are trying to become information-intensive. In less than two decades, for example, Korea succeeded in becoming the third largest semiconductor manufacturer in the world. This burst into a high-tech industry is exceptional, however. In most other industries and countries, infrastructural limits and research constraints will make the creation of high-technology industries a long-term process.

Nevertheless, this report, which will be included in a forthcoming edited volume, reminds us that American complacency would be a mistake. The United States needs to ensure that it remains an attractive research locale. Attention to our tax, regulation, and education policies should be a top priority. Internationally, the United States should encourage other countries to contribute to the global basic research base. Finally, the United States must learn how to learn from others. The convergence in technical capabilities among nations was to be expected. As our trade partners become increasingly sophisticated, we must look outward for knowledge, not just for new markets. Useful ideas will percolate in unusual places. Far from being a process to be resisted, the globalization of industrial R & D can benefit us if we learn to learn.

Gary C. Hufbauer

Maurice R. Greenberg Chair, Director of Studies

Executive Summary

One of the great strengths of the U.S. economy is its capacity for innovation. Relatively young companies like Microsoft, Genentech, Intel, and Netscape bring

verve to the American industrial landscape. The products they introduce transform the way we do business and the way we live. Older companies, like AT & T, Ford, and IBM, prove that they can adapt new technologies to stay vital. Old or young, it is the commitment to research and development (R & D) that has allowed these companies to come up with novel ideas, products, and processes. The American ability to foster high-technology industries is the envy of both advanced and industrializing countries alike.

As business globalizes, however, the possibility that research and development can be sourced internationally becomes more evident. So far the knowledge-intensive industries are dominated by Europe, Japan, and the United States. Advanced countries hope that the future international division of labor will continue to favor the location of high-technology industries and services within their borders. Indeed, until recently multinational corporations (MNCs) overwhelmingly kept their research laboratories at home. But over the last quarter century a myriad of important changes have altered the funding and location of industrial R & D. Foreign direct investment with an R & D component has increased, international strategic alliances are much more frequent, R & D expenditures among the advanced countries are more evenly distributed, and trade in intellectual property and in the goods and services that embody high technology have grown. Indeed, the explosion of information technologies makes it increasingly feasible to locate all manner of research and development in far-flung locales. In short, industrial research has become more geographically spread out and more dependent on the innovation systems of multiple countries.

Extrapolating from these trends, some analysts worry that the American innovation system could "hollow out." In particular, developing countries like Korea, Israel, and India are making important investments in high-technology sectors. What stops them from becoming the new Japans? Is technology transfer between countries accelerating? Is the technological superiority of the developed world more precarious than in the past?

This Council on Foreign Relations Study Group Report finds that these concerns--voiced about industries as disparate as software, biotechnology, industrial chemicals, and medical devices--are often overstated. In case-by-case studies of the R & D globalization trends we found:

- R & D globalization is occurring at a moderate pace. Most industrial R & D is still performed in the company's home country.
- Although R & D globalization is expected to continue steadily, we should recognize that it is a normal corollary of the entrance of multinational corporations into new markets. It is also a by-product of the fact that as foreign economies grow, they seek to improve their own technology-based industries, thus improving the chances for alliances with American technology-intensive firms.
- There is no single driving factor pushing firms to source R & D abroad. Consequently, the pace, extent, and nature of R & D globalization varies considerably across industries. Some industries, such as those that experience labor shortages or high regulatory hurdles at home, will outsource aspects of their research and development work more quickly and more extensively than other industries.

- Despite a few interesting countries--Korea and India most notably--developing countries are often left out of the R & D globalization process. Multinational corporations are primarily expanding their research and development activities to other first world countries. MNCs hesitate to locate their laboratories in lesser-developed countries (LDCs)--first, because LDCs perform very little research of their own; and second, because infrastructural problems, such as the frequent lack of strong intellectual property protection, make them unattractive research locales.
- The industrial R & D globalization process is not leading to a homogenization of industries across countries. Nations are instead building particular technical or sectoral strengths.
- The U.S. economy appears to have benefited greatly from the globalization of R & D, as a recipient of foreign direct investment, as an educator of the world's technical elite, and as a host country for foreign scientists and engineers.

The R & D globalization process is real and it is important. Industrial research, which accounts for three-quarters of all R & D in the United States, is experiencing changes in its location, funding, staffing, and organization. This is a gradual, evolutionary process, and the U.S. government does not need to reform its own policies radically in response. The U.S. government, however, should keep in mind the following considerations as it formulates both domestic science and technology policy and foreign trade policy:

- The United States government should minimize the factors that push U.S. firms to locate research abroad. Very little can or should be done to minimize the factors that pull firms to go abroad in their search for new technologies and their desire to serve foreign markets. The U.S. government, however, should be vigilant about ensuring that domestic policies --concerning taxes and regulation, for example--do not unnecessarily drive R & D abroad.
- The U.S. government should continue to provide adequate funding for basic research. Basic research is the soil in which technological developments with commercial applications grow. Although the possibility exists that other countries will free-ride on U.S. investments, the considerable benefits that accrue to the United States should override these concerns. Indeed, our successes demonstrate the advantages of public investment in R & D and encourage other countries to make similar commitments.
- The U.S. government should encourage Americans to look outward and learn from others. As more countries reach the frontiers of scientific and technical knowledge, we need to canvas discoveries around the globe. A promising strategy is to offer American students in the sciences and engineering fellowships to learn languages and study abroad. At the moment there is a large imbalance in the international exchange of students and technical personnel. If more Americans learn abroad, it will help U.S. firms to absorb and adapt technology from foreign countries.
- The U.S. government should ensure that data about the globalization of research and development is adequately documented, to track important changes in the behavior of firms that could affect future policy decisions.

The Study Group's findings show that industrial research and development is undergoing a slow and steady transformation as the technical capabilities of countries converge. The pace and direction of the process is far from uniform across

industries, making it difficult to discern a "best policy." It is clear however, that the United States needs to shore up its attractiveness as a research locale because other technological poles are actively fostered by foreign governments, in countries as disparate as France and Malaysia, to attract innovative firms from around the globe. To be sure, the United States and its technology-intensive companies are still in an enviable position. The United States is the only country with a net surplus in its trade of intellectual property. But increasingly, the United States is becoming "first-among-equals," a situation to which we are unaccustomed and one that will challenge our public research strategies, universities, defense capabilities, and technology industries.

Introduction

THE UNITED STATES IS a country of innovators. Its higher education system and entrepreneurs are respected worldwide for their contribution to research and development. Yet in many domains, the United States is no longer technologically well ahead of its competitors. American industries are beginning to exploit offshore research and development capabilities, just as they are already globalizing sales and manufacturing. The ultimate effect of this R & D globalization on the U.S. economy and U.S. industry remains uncertain. But extrapolating from three important trends in the international economy--namely the rise of newly industrializing economies; the restructuring of the American system of innovation; and the globalization of sales and production--it seems likely that knowledge-intensive activities, from basic research to technology-based production, are not permanently anchored in American soil.

High-technology companies are interested in newly industrializing economies as markets for their products and as environments for innovation. In the 1980s, Asian countries surprised the United States by producing electronics of a quality and sophistication so high, with prices so low, that many U.S. producers were driven out of their home market. This ability to make and export technology-intensive products arose as Japan and later Korea and Taiwan transformed themselves from developing countries to rich nations. Other countries are poised to follow suit. China, Indonesia, Brazil, and several East European countries have an educated elite, a desire to enter higher-value-added industries, and to varying degrees policies and institutions in place that may enable them to follow in the footsteps of the East Asian nations and become centers of innovation in their own right. Many countries are, in fact, consciously fostering the growth of idea-intensive, high-value-added industries.

The advent of these potential new centers of technological innovation has coincided with a period of self-examination in the American scientific and technological community. These are indeed turbulent times for public and private funding of research and development. With the demise of the Cold War, American citizens have begun to question the level of public expenditure on basic science. Budget constraints have forced a reduction in government support for research. Critics of "corporate welfare" have curbed the use of government funds for applied research and industrial development and asked the private sector to take up the slack. Total U.S. 1996 expenditures for R & D came to $184 billion, with more than 60 percent being funded by the private sector, and, as shown in Figure 1, only 34 percent coming from federal coffers.

Even universities, the pride of the American R & D system, are being forced to rethink their roles in research and graduate education because of funding difficulties and the rising number of doctorates being granted just as the number of professional openings declines. The reforms in the public sector's R & D base are occurring in large part because the Cold War security doctrines that buttressed our innovation system have lost their persuasiveness. Although many people still believe that national pride is a sufficient reason to pursue leadership in basic science, in the face of budget difficulties pride alone is a weak reed.

Figure 1. U.S. R & D Expenditures for 1996.

Source: NSF/SRS, National Patterns of R & D Resources--1996.

(U.S. Government Printing Office: Washington, D.C.), p. 1.

Technological development is now seen primarily as a tool forgenerating rapid economic returns--a perspective that makes it difficult to justify government (rather than private sector) investments in R & D preeminence. In the long run, this more tenuous commitment to scientific excellence and technological development runs the risk of making the United States a less attractive innovative environment for the private sector than it has been in the past.

High-technology companies are also turning to R & D outsourcing beyond the borders of the United States because it is a logical extension of their industrial strategies to build a system of global sales and production. In order to compete against their foreign counterparts, U.S. companies are learning how to coordinate their industrial activities across international borders. Industrial R & D--which can include some basic scientific research as well as product development and design, prototype construction, testing, clinical trials, and the building of pilot plants--simply becomes one piece of a complicated supply structure designed to meet regional market needs, support production and sales, and distribute corporate activities across the world in the most efficient and effective way. Many firms are already building networks of internal laboratories and ties with other firms in far-flung locales.

The rise of new technological powers, the uncertain future of U.S. R & D funding, and the international character of business today are all contributing to the globalization of industrial R & D. Opinions are divided, however, on the actual extent of this globalization--whether it represents a net transfer of R & D that would otherwise be carried out in the United States, and what its effects on the U.S. economy and workforce are likely to be. The growth of the information infrastructure has made the transmission of new ideas to distant parts of the production system rapid and cheap. Some argue that research, to the extent that it can be reduced to abstract and discrete ideas, can be nurtured abroad and communicated wherever needed. Those who worry about globalization express the concern that it will lead to a diffusion of high-technology and service industries away from the United States, with negative

consequences for American workers. Furthermore, they argue that the prestige, if not the wealth, of the United States is predicated on the innovative quality of its industry, which would be threatened by wider distribution of industrial R & D activities. Are these concerns justified?

This Council on Foreign Relations study took as its premise that an industry-by-industry study of the motives for R & D globalization and the mechanisms by which it occurs, as well as an evaluation of the prospects of countries at different stages of development of becoming offshore research locales, is necessary to understand the extent and dynamics of the R & D globalization process. Understanding the factors that drive and limit R & D globalization in a cross section of industries is the necessary first step in determining what actions the U.S. government could take, if any, to influence the process. The second step is evaluating what effect the dispersion of R & D might have on the U.S. economy so as to determine what action the U.S. government should take.

The term "R & D globalization" most commonly refers to the offshore sourcing of research and development activities in multinational corporations (MNCs), through either licensing agreements, R & D alliances, or the establishment of subsidiaries abroad. It is important to distinguish two closely related concepts: (1) the convergence of national technological capabilities, and (2) the transfer of R & D activities from the United States to foreign countries. Convergence refers to the fact that as many countries reach similar levels of economic prosperity and educational attainment, their spending on research and development, and their technological outputs also become more similar. Such national trends make the globalization of R & D by firms both more attractive and more feasible. That said, the globalization of industrial R & D is not synonymous with a transfer of research activities or jobs from one country to another. While this worst-case scenario is possible, the changing geography of R & D sourcing and production has so far occurred in an era of expanding private expenditures on scientific and technological development. R & D globalization, therefore, is not necessarily a zero-sum game.

With these caveats, the study has found that the offshore sourcing of R & D by multinational corporations--through alliances and joint ventures, and the offshore development of new ideas and products through subsidiaries--has the following characteristics:

- It is occurring at a moderate pace, with the majority of industrial R & D still done in the company's home country.
- It is expected to continue steadily and, in most industries, is seen as a natural process.
- It varies considerably across industries in its pace, extent, and nature.
- It is primarily a first-world phenomenon because the developing countries, even the advanced ones, are marginal participants in industrial research. Although on the rise, a relatively small percentage of U.S. R & D is performed in the developing world. (See Figure 2.)
- R & D globalization has primarily benefited the United States economy because the United States has remained an attractive research site for foreign MNCs.

Thus, the present trend of R & D globalization should not be cause for alarm on the part of the U.S. government. But as we shall see in the more detailed review of

individual sectors and country studies, neither should the United States be complacent. The United States is still considered an excellent research locale; however, it will increasingly be only "first-among-equals," an unaccustomed situation that will challenge our public research strategies, universities, and defense capabilities, and require flexibility from our technology-intensive industries.

The Cases Summarized

To canvas the American experience of R & D globalization as widely as possible, the Study Group studied several cases of technology-intensive industries: software, semiconductors, industrial chemicals, medical devices, and pharmaceuticals. These sectors were chosen because the type of research they perform differs along dimensions that we expected would result in distinct globalization patterns.

Type of Research Performed

Software industry R & D is almost entirely developmental, whereas in pharmaceuticals basic research is very important to new product discovery.

Predictability of Research Trajectories

In sectors like semiconductors, the research targets are well specified, whereas in other sectors research trajectories are harder to predict.

Level of Regulation

Highly regulated industries such as biomedical devices and pharmaceuticals are often required to do a significant amount of product development and clinical testing in target markets to gain government approval, making R & D globalization a necessity for entry into foreign markets.

Maturity of Industry

Mature industries, like chemicals and pharmaceuticals, have had longer to globalize their R & D activities than younger industries, like software. But mature industries may also have fewer incentives to continue to source R & D globally, if the sector is no longer research-intensive, or if new products no longer drive competition.

Commodity versus Differentiated End Products

In commodity industries like industrial chemicals, process innovations are most important for competition. In contrast, in the software, medical device, and pharmaceutical sectors, firms need to differentiate their products as well as discover better or cheaper manufacturing methods. In other words, product innovation counts.

All these factors affect company innovation strategies and should influence the way firms react to globalization pressures. We posed the following set of questions to understand each sector's experience with R & D globalization:

- What drives the process of R & D globalization in MNCs?

- To what extent is offshore sourcing of R & D actually occurring?
- What are the limits or constraints on offshore R & D sourcing?
- What means are used--what types of networks are built--to access R & D abroad?

Table 1 summarizes the main findings about the drivers of R & D globalization and the extent of globalization to its further expansion.

Table 1. R & D Globalization Process in Key High-Technology Industries

Observations On R & D Globalization

R & D globalization takes several organizational forms. Although most people think of "R & D globalization" as the establishment or purchase of laboratories abroad, in reality the modes of engagement in international research networks can be much more complicated. Globalization for the pharmaceutical industry entails mergers, international product licensing, and strategic alliances. Software companies have both set up subsidiaries in India and contracted work out to foreign companies. They also use "body shops" to hire foreign programmers for short-term assignments in the United States. Even industries that claim not to engage in global R & D may be indirectly tied into a global R & D network. The semiconductor industry, for example, does not outsource development work, but it depends on research that is dominated by foreign companies, including the R & D for pure refined silicon as well as the development and supply of essential manufacturing tools. Here is a case where the international R & D network is located almost entirely outside the firm.

The globalization of R & D can entail, therefore, one or all of the following:

1. The global exploitation of technologies through patents and licenses;
2. The global sourcing of R & D through alliances and joint ventures with foreign companies or universities;
3. The global production of R & D through overseas subsidiaries.

R & D Globalization Is Still Limited

In none of the industries the group studied is the extent of offshore sourcing of R & D extensive, a finding congruent with the assessment that industrial research is largely done in a firm's home country. Individual companies often do set up foreign laboratories or make alliances with foreign firms that include R & D goals, but patent data suggests that most innovations occur in the home country. In the industries we studied, the United States remains the primary research locale for U.S. firms.

R & D Globalization Is Expected to Continue

Still, trends indicate greater use of foreign R & D sources in many U.S. industries. The most dramatic case is that of the medical device industry. A strict regulatory regime and the specter of legal liability have driven medical device firms to conduct their development work and initial clinical trials abroad. There is no reason to believe, given the present U.S. regulatory climate, that this pattern will change. For a very different reason--a shortage of programmers in the United States caused by very rapid industry growth--software companies predict they too will increasingly

rely on foreign development houses for their rote programming needs. In both cases, the work being "farmed-out" is product de-velopment, and the primary causes for external sourcing can be found within the United States.

The pharmaceutical industry, on the other hand, wants to tap into local research talent by setting up laboratories abroad and allying with foreign firms. The recent mega-pharmaceutical company mergers, the search for new products outside the firm, and need to access foreign markets quickly has led to a proliferation of alliances and a globalization of research strategies.

Most other industries predict that they too will continue to globalize their R & D sourcing, although perhaps not so rapidly. It is interesting to look at the industrial chemicals sector, where for a variety of reasons relatively little new product research is performed. Process R & D is moved offshore to new production sites in order to satisfy technology transfer agreements reached with developing countries as a condition of market access. The motivations are largely political, since there is little inherent advantage in performing this type of research abroad. Even the U.S. semiconductor industry, which does not frequently contract R & D work to foreign suppliers, will experience some globalization of development work. Exorbitant research and factory construction costs--the price tag for a new fabrication plant is on the order of $1 billion--are forcing semiconductor firms to engage in joint ventures to minimize expenses, many of which include R & D agreements with foreign companies.

No Simple Policy Prescriptions

The extensive catalogue of reasons why firms plug into an international research network suggests that R & D globalization will not be amenable to simple policy prescriptions. Companies act to exploit regional know-how and centers of excellence, to customize manufacturing operations, to facilitate market entry and satisfy technology transfer requirements, and, more rarely, to access abundant skilled labor abroad. These are the major pull factors that make globalizing R & D attractive, but there are also a few push factors that drive firms from the U.S. market. These factors include stringent government regulations, high litigation costs, corporate disincentives to research, tax policies, firm mismanagement, and the antitrust breakup of large labs. In no case studied was a poor U.S. research base or a lack of U.S. competitiveness a factor driving R & D abroad.

Nevertheless, the U.S. government should be concerned about maintaining an attractive research environment, which means it should be vigilant in minimizing domestic push factors. Pull factors, however, are not necessarily a bad thing. In most industries R & D globalization is an essential part of building international business. Government intervention would not be welcome and might have unintended consequences.

Not an Open-Ended Process

The globalization of R & D is not an automatic and open-ended process. Individual companies actively have to choose to exploit, source, or produce R & D globally. They may encounter problems along the way, which means that not all products or technologies will be developed easily abroad. The limitations encountered in our case studies most frequently had to do with conditions in host countries. For software, a

skilled, English-speaking labor force abroad and good telecommunications infrastructure are prerequisites for outsourcing. For pharmaceuticals and chemicals, weak intellectual property protection limits the types of research that can be performed in many developing countries.

The closer R & D is to basic science, the more the host country's system of innovation and the make-up of its labor force become critical determinants. It is significant that Microsoft's new research laboratory--an attempt to keep the company at the forefront of international developments in computer science--is being built in Cambridge, England, not Bangalore, India. Similarly, American pharmaceutical companies locate their important "global" laboratories mostly in Europe, and the Europeans do so in the United States. Despite cutbacks in federal research expenditures, the United States retains an enviable R & D culture, which means it has disproportionately benefited from investments by European and Japanese firms in offshore laboratories.

The extent to which R & D globalization will proceed remains to be seen. It is occurring for different reasons in different industries and takes different organizational forms. Thus R & D globalization will not yield a homogenization of research capacities across all countries. But as new nations raise their production capacities and standards of living, multinational corporations will want to tap into their markets and access the innovative ideas of their populations. Below, we summarize the outlook in four industrial sectors.

Software

A manpower shortage in the United States, the rapidly growing need for programmers in software and related industries, and the availability of relatively inexpensive programmers abroad has pushed firms to outsource their software development needs. But the outsourcing trend is limited by the number of skilled programmers abroad who speak English well and can provide quality work in the time frame required by U.S. industry. Other factors that also impede the formation of software service industries abroad are the absence of a modern IT (Information Technology) infrastructure, a scarcity of venture capital, censorship, and weak intellectual property protection.

Biomedical devices

Offshore sourcing of R & D is driven by factors normally associated with globalization of production, such as the need to be closer to market and customers, the need to access excellent medical research centers, and local expertise. Peculiar to this sector, however, are complex and unpredictable regulatory requirements, restrictive reimbursement policies for breakthrough technologies under investigation, and the prohibitive costs of litigation in medical liability cases. These latter factors limit the type of products that can feasibly be developed in the United States. By encouraging firms to relocate clinical trials to non-U.S. centers, they may also contribute to the erosion of the U.S. leadership position in the medical device industry and related portions of the academic medical infrastructure.

Semiconductors

While U.S., Japanese, and European multinational manufacturers have gradually increased spending outside their home base, all still perform more than 90 percent of their R & D domestically. Starting some 30 years ago, the major semiconductor manufacturers established laboratories abroad, but their research capacity remained rooted in the advanced industrialized countries. More recently, South Korea has established a significant R & D capacity in semiconductors. Since building semiconductor plants requires huge capital investment, strategic alliances that include development agreements have proliferated. Nevertheless, the semiconductor industry has seen more convergence in R & D capacity than globalization of R & D networks. To this day, American semiconductor manufacturers do little contractual outsourcing of R & D to foreign suppliers.

Industrial Chemicals

The chemical industry, being much more mature than the other industries considered here, is less reliant on new product R & D for competitiveness. Although production has globalized, the effect on R & D locales is more subtle, in part because product research has been cut back in many firms. Thirty years ago, U.S. firms established laboratories in Europe, and lately European companies have been buying major R & D-intensive U.S. firms for their know-how. But this has not resulted in a large transfer of research overseas. One reason is that developing countries are often less attractive sites because their weak intellectual property rights make R & D investments very risky. Thus the globalization of R & D in industrial chemicals is not expected to accelerate substantially.

The Developing Countries

AN IMPORTANT CONCERN OF the United States is the extent to which developing economies are becoming effective competitors and producers in certain high-technology fields. So far, R & D globalization has been driven primarily by a convergence in technical capabilities among the advanced countries in Europe and North America as well as in Japan. But Korea's jump into the semiconductor industry and India's explosion of software service providers suggests that other developing countries may follow suit. In 1993 in Korea, 45 percent of merchandise trade was in high-technology goods, while in China during the same year high technology accounted for 35 percent. In both countries, technology product trade has grown by 200 percent since 1985. As an offshoot of this vigorous technological development, patent applications in Asia are also rapidly growing. From 1986 to 1995, applications for patents increased by 250 percent in China and by more than 500 percent in Korea, Taiwan, and the ASEAN countries. As countries like China, Russia, Brazil, and Poland become more technologically sophisticated, one wonders, first, whether the transfer of R & D activities to such countries is possible and, second, whether they will become trade competitors in technology-intensive fields. Is a transfer of R & D.

Figure 3. Population in millions and Gross Domestic Product (GDP in U.S.$ millions) for Selected Emerging Markets.

Source: World Resources, 1996--97 (Oxford: World Resources Institute, 1996).

Activities likely? What are the economic or political prerequisites? What types of technologies could we see moving offshore?

Developing countries with promise are not numerous, but the interest they generate in the West is real and unlikely to diminish given the size and growth rates of the emerging markets. (See Figure 3.) Below, we explore the experience of several key emerging markets in creating an industrial R & D base.

An overview of developing countries with aspirations to enter higher-value-added industries reveals the many difficulties they face in building a technological base. So far, the globalization of industrial research and development remains primarily a process reinforcing the links among the advanced industrialized countries. Although it may be theoretically possible for developing countries to take advantage of the ability of MNCs to locate their R & D labs globally, the jump from national demands for technology transfer from MNCs to creating a strong national research base is daunting.

Developing countries like Korea or India, which have managed to create a homegrown R & D-intensive industry or have attracted investments in industrial R & D from abroad, are not the norm. The list of requirements for a lesser-developed country to create a domestic research base is long. They include:

- An educated, flexible workforce;
- Access to capital;
- A high-quality university or public research system;
- An intellectual property system to protect innovation;
- A predictable and reasonable regulatory system;
- A large end market, either domestic or international;
- International connections for access to foreign technologies and knowledge.

For most LDCs, these are tall orders. Countries that have succeeded usually have had active government commitment to fostering higher-value-added industries, but such industrial policies must be skillfully managed. Nevertheless, Japan and Korea have already navigated these waters, and China presents itself as a credible candidate for developing a technology-intensive industry base. A small elite of developing countries will join the ranks of the advanced countries as homes to selected technology-intensive industries.

South Korea

Beginning in the 1960s, South Korea embarked on a series of reforms intended to reduce its technological dependence and enable it to enter into competition with the industrial nations. By the 1980s these reforms helped to build a strong industrial base in a wide range of products, from automobiles and televisions to satellites and cellular phones. By 1995 Korea had become the world's third largest supplier of semiconductors. The government of South Korea played an important hands-on role in this process by enacting laws to promote the creation of a viable electronics industry. The government's choice to push semiconductor production was fortuitous since it was possible to predict the product's development trajectory (i.e., the technical hurdles and time frame were well understood). This factor made central planning of research targets possible. South Korea's timing was equally good, as the passage of the U.S.-Japan Semiconductor Trade Agreement unwittingly handicapped Japanese competitors and gave Korean manufacturers an opportunity to enter U.S. markets in the late 1980s. South Korea is continuing to enter other technology-

intensive sectors successfully with a strategy of direct government involvement in planning that facilitates close company cooperation in research.

India

The government of India has invested heavily in the city of Bangalore in an effort to bring about industrial and military self-sufficiency, creating in the process a strong software industry and a viable space science industry. Bangalore is widely envied by industrializing countries for its entry into the software engineering market and has attracted investments from such corporations as Motorola and Texas Instruments. Few developing countries have the characteristics of India, which benefits from a Western legal system and widespread use of English as the language of government. In creating a software-service industry, the Indian government was directly involved in building the necessary infrastructure with policies that fostered an educated labor force, funded research activities, created a predictable regulatory environment, developed telecommunications infrastructure without censorship, and supported exports. Software service exports for 1996 totaled $750 million. It is worth noting, however, that for developing countries, including India, market controls have proven to be impediments in the rapidly changing software industry.

Russia

Generating considerable interest among Western investors, Russia is frequently cited as a promising software industry locale because of its large population of programmers and scientists. What domestic software production has arisen is in the areas of financial software products for stock exchanges, banks, and the government. In addition, the market for Russian word processing software is dominated by a Russian software company. Although Russia does stand a chance of creating a strong software industry, that positive outcome has been impeded in part by high rates of software piracy (estimated at 90 percent). The continual illegal copying of software has made Russia an unfavorable market for foreign investment. To date, Russia has been only moderately successful in forming a local software industry.

Argentina

Argentina has an important generic pharmaceutical industry and promising national preconditions for biomedical research, yet no competitive research-based industry has emerged or is likely to emerge in the near future. While Argentina has a large number of scientists, a well-educated workforce, and a generic drug industry, it has not been able to maneuver these advantages into a research-based pharmaceutical industry because of a lack of government commitment, a split between academic and industrial scientists, and a weak intellectual property system. In particular, the lack of protection for pharmaceutical products has impeded the creation of a legitimate industry by allowing Argentinian drug companies to copy European and American products. It seems unlikely that Argentina will bridge the gap that separates its academic research from industry. Until it does, few research-based firms will take hold. The necessary capital investments for pharmaceutical research are huge, and the trajectory of products highly unpredictable. These features effectively make pharmaceutical R & D out of the reach for Argentina and most developing countries.

China

Currently one of the world's largest economies, China will continue to maintain its high real growth rate throughout the coming decade. China's industrial thrust has been in the consumer electronics industry, principally because of its large labor pool and consumer demand. China also represents a substantial and growing market for American high-technology products, with over $3 billion worth of U.S. technology exports going there in 1994 By virtue of its size and economic strength, China is likely to create a large industrial infrastructure conducive to localized R & D. But China's desire to expand its industrial base has as many paths to failure as to success, and thus it is not clear that China will become an R & D powerhouse.

The Data On R & D Globalization

ALTHOUGH MOST INDUSTRIES cannot give an exact estimate of how much R & D they do abroad, the available data and anecdotal reports indicate that the world is indeed experiencing changes in the geographic character of industrial R & D. More accurate measurements of industrial research activities would help to identify better what these trends mean for the U.S. economy.

The R & D measurement problem has several sources. First, in manufacturing industries where development work is tightly linked to production and in small companies which do not have formal R & D departments, companies understate how much of their activity is in fact research. Second, reports of R & D expenditures are skewed in all companies because they are derived from tax statistics. Third, comparability across countries is made very difficult by the substantial differences in national R & D taxation categories. Fourth, our best measures are of R & D expenditures rather than of innovative outputs. To assess the real level of innovative activity in a country we use patents, licenses, royalties, and research publications as proxies. These unfortunately miss important outputs such as incremental innovations and changes in production technologies. In developing countries, such incremental improvements are probably the most important aspect of innovation.

Finally, in a study such as this, we are fundamentally interested in the effect that R & D transfers have on the home and host countries. It is hard to assess the impact of increasing technology flows on national economies, however, given that 80 percent of the U.S. trade in intellectual property is actually intrafirm payments between affiliates of a single multinational corporation. In other words, of the $33 billion worth of intellectual property trade conducted by the United States in 1995, about $21 billion was between U.S. parents and their affiliates, and $4 billion between foreign parents and their U.S. affiliates. The predominance of intrafirm transfers reflects the desire to control the use and dissemination of intellectual property, and it calls into question the extent of spillovers to the home or host country.

- A repeated theme in Study Group discussions, therefore, was the need for better data in order to understand the extent of R & D globalization, its structure, and its effects on national economies. The areas where better data could significantly inform U.S. policy formulation include:
- Longitudinal data on industry R & D investments and outputs,
- Cross country comparability of R & D statistics,
- Comparative sectoral data on the extent of R & D globalization,
- Data on the type of R & D networks used--Foreign direct investment, buyout of laboratories, joint ventures and strategic technology alliances, participation in research associations, licensing.

Conclusions And Recommendations

DESPITE THE SHORTCOMINGS of the data, our study shed light on a number of issues with respect to the globalization of industrial R & D.

Global R & D investment continues to grow, and growth rates in the rest of the developed world generally exceed those in the United States. As the world's economy has grown, not unexpectedly the investment in R & D has grown. The world's R & D funding increased between 1987 and 1995 by almost 50 percent in constant dollars. In the United States, the increase was slightly less--about 37 percent--so that the United States' share of world R & D expenditures dropped from about 47 to 43 percent.

The United States has been a net beneficiary of foreign direct investment in research. The percentage of R & D that American MNCs conduct offshore has risen only slightly over the past decade and still hovers in the range of 10 percent. Indeed, the inward transfer of R & D activity--R & D conducted by foreign MNCs in the United States--has actually risen more sharply, so that R & D growth outside the United States does not appear to have resulted from a net transfer of investment from the United States to the rest of the world.

R & D linkages across national borders have been largely limited to developed nations. Based on the aggregate figures, it appears that the transfer of R & D operations between countries has thus far been almost entirely an interchange between developed nations. In the opinion of most members of the Study Group, that is not likely to change in the next decade or so. The combination of infrastructure, human resources, and capital necessary to establish a significant R & D activity is beyond the capacity of countries in the developing world, even of the newly industrialized countries.

Korea (where government funding for R & D is rising at about 25 percent per year--from a small base, to be sure) may be an exception, but even Korea's success in semiconductors may be the exception that proves the rule. India's success in software appears to be a similar exception. First, software development--particularly of the kind being carried out in India--stretches the boundaries of what may legitimately be viewed as R & D and comes close to being a service industry with very short-term goals and low capital investment. Indeed, the creation of a software industry in India has turned out to be a low-cost solution to the growth of a computer-based economy in the United States and in other parts of the developed world.

The globalization of R & D activities appears to follow, rather than lead, the opening of production or marketing activities in a host country. When companies have moved R & D from home base to host countries, in most instances the activities have followed, rather than led, the establishment of production facilities. This pattern is instructive in that it indicates the kind of R & D moved is likely to be that necessary for close support of production operations or for fine tuning of products to local markets. Such "intermediate" R & D will always be necessary and is more an indication of success in establishing foreign markets than of loss of leadership. In fact, in a number of instances the establishment of R & D facilities in a host country was a political condition for market entry. This kind of R & D is less likely to lead to

new products that could be adopted or marketed broadly. Nor is it likely to bring about global changes in an industry or sector.

Again, there are exceptions that may not alter these major conclusions but are nevertheless worrisome. In some circumstances, U.S. tax and/or regulatory policies may be a driving force for moving R & D offshore. This could have far-reaching consequences such as reducing the U.S. market share in certain industries or delaying access by the American public to--or even depriving them of--the benefits of certain technological developments. The biomedical device case discussed on page 21 of this study represents one such situation.

The globalization of R & D is an irreversible phenomenon that should be viewed as a positive development that can feed technology-based economic growth in the United States as well as in the rest of the world. Although we have not experienced a wholesale movement of R & D from the United States to other countries--nor are we likely to--the quality of R & D and the amount of investment in it outside our borders will continue to grow as other economies expand and as countries seek to improve their own technology-based industries. This trend is evident not only in the recent data on direct support of R & D globally and such well-publicized plans as those of Japan to double R & D investments in the next five years but also in the data on patenting activity. U.S. patents issued to foreign corporations continue to grow and now represent about half the patents granted each year. The Study Group viewed this not as a threat but as a reality unlikely to be altered by any policy change, and as an opportunity for both the United States and the world to capitalize on the potential of technology to improve the human condition.

The globalization of R & D, with specialized expertise differing from country to country, has stimulated the development of international research networks. An important point made in the study is that the globalization of R & D has not been accompanied by a homogenization of R & D efforts. Countries and geographical regions have retained a concentration of expertise in particular research areas. In turn, this has led to the creation of research networks. Information and communication technologies have made these networks feasible, and there is ample evidence that they are arising both within corporations and between corporations, under a number of different business arrangements.

Taken together, these observations led the Study Group to conclude that the appropriate strategic response for the United States is to work toward a continuing healthy growth of R & D globally and to ensuring that the United States becomes more adept at capitalizing on developments wherever they may occur.

With respect to the former, the group concluded that the intermediate stages of R & D are properly the responsibility of the private sector and that market forces are likely to ensure that its funding will continue. The evidence of growing research networks and patterns of acquisition and partnership are clear and encouraging. Adequate funding for basic research--the ideas and understanding that feed the engine of technological development--is more problematical. The end of the Cold War and U.S. federal budget pressures have reduced support for U.S. basic research. A recent National Research Council analysis shows that federal support has dropped 5 percent in real terms in the past three years and by 10 percent if medical research is excluded. Projections for the future are equally dire. Although basic research is not entirely a U.S. responsibility and the changing economic circumstances of the world

suggest that the burden of support should be shared, the expectation that "others will do it" and the fear of free ridership may lead to global under-investment in basic research. Moreover, an adequate level of basic research activity is a necessary factor for absorbing and capitalizing on R & D carried out elsewere.

The group perceived that the greatest U.S. weakness lies in the area of learning from others. The dominant position that the United States enjoyed at an earlier time in essentially every area of R & D has made it inward looking with respect to new ideas and new technologies. Moreover, effective technology transfer is largely a matter of the exchange of scientists and engineers. The United States' very open educational system has always hosted a great number of students from other countries, many of whom return to their native lands. But that same system has done little to orient American students to other cultures or to prepare them to function in other languages. Hence there are many fewer American students or technical personnel going abroad. That imbalance has been particularly noteworthy in the case of Japan.

These elements--strong support for basic research and the creation of organizational, regulatory, and stimulatory structures that improve the ability of American industry to absorb and adapt technologies created elsewhere--should be the focus of American attention and effort. It is also important to review U.S. tax and regulatory policies that compare unfavorably with those of our competitors and may be driving R & D offshore. These policies may be spurred by other good considerations, but the loss of R & D, particularly where it is not caused by technical opportunity or market considerations, should be appropriately weighed.

Sources

- Abelson, Philip H. "The Changing Frontiers of Science and Technology." Science 273 (July 26, 1996): 445-7.
- Barr, Avron, and Shirley Tessler. "Software R & D Strategies of Developing Countries." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, January 9, 1997.
- Barr, Avron, and Shirley Tessler. "The Globalization of Software R & D: The Search for Talent." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, December 12, 1996.
- Citron, Paul. "Forces Affecting the Location and Relocation of R & D and Manufacturing in the Medical Device Industry." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, December 12, 1996.
- Correa, Carlos M. "Research and Development in Pharmaceuticals: The Argentine Case." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, January 9, 1997.
- The Economist. "Paradox Lost," September 28, 1996.
- Fusfeld, Herbert I. Industry's Future: Changing Patterns of Industrial Research. Washington, D.C.: American Chemical Society, 1994.
- Hane, Gerald. "The Globalization of Innovation and U.S. Innovation and Trade Policies." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, March 13, 1997.
- Hagedoorn, John. "Strategic Technology Partnering during the 1980s: Trends, Networks, and Corporate Patterns in Non-Core Technologies." Research Policy 24 (1995): 207-31.

- Hodges, David A., M. Borrus, and A. L. Nguyen. "International R & D Sourcing in the Semiconductor Industry." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, December 12, 1996.
- Kyong, S. H. "Korea's Entry into the Semiconductor Industry: How Korea Succeeded in Building a Native R & D Capacity." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, January 9, 1997.
- Lerner, J., and R. Roy, "Numbers, Origins, Economic Value, and Quality of Technically Trained Immigrants into the United States." Scientometrics 6:4 (1984): 243-59.
- Mowery, David C. "Technological Innovation in a Multipolar System: Analysis and Implications for U.S. Policy." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, February 21, 1997.
- National Academy of Engineering. Prospering in a Global Economy: Foreign Participation in U.S. Research and Development--Asset or Liability? Washington, D.C.: National Academy Press, 1996.
- National Research Council. Conflict and Cooperation in National Competition for High-Technology Industry. Washington, D.C.: National Academy Press, 1996.
- National Science Foundation. Science & Engineering Indicators-1996. Washington, D.C.: Government Printing Office, 1996.
- North, David S. Soothing the Establishment. Lanham, Md.: University Press of America, 1995.Organization for Economic Co-Operation and Development. Main Science and Technology Indicators. Paris: Organization for Economic Co-Operation and Development, 1996.
- Pearce, Robert D., and Satwinder Singh. Globalizing Research and Development. New York: St. Martin's Press, 1992.
- Ratchford, J. Thomas. "International Convergence and the Industrial R & D Enterprise." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, February 24, 1997.
- Reid, Proctor P., and Alan Schriesheim, eds. Foreign Participation in U.S. Research and Development: Asset or Liability? Washington, D.C.: National Academy of Sciences, 1996.
- Reul Shinnar. "Globalization of Research in the Chemical Industry." Paper presented to the Council on Foreign Relations Study Group on the Globalization of Industrial R & D, December 12, 1996.
- U.S. Congress. Office of Technology Assessment. Multinationals and the U.S. Technology Base. OTA-ITE-612. Washington, D.C.: Government Printing Office, 1994.

Study Group Members

Chair

Rodney Nichols, New York Academy of Sciences

Co-directors

Benedicte Callan, Fellow for Political Economy, Council on Foreign Relations

Kenneth H. Keller, Senior Fellow, Council on Foreign Relations

Research Associate

Sean S. Costigan, Council on Foreign Relations

Speakers

Avron Barr, Stanford University

Paul Citron, Medtronic Inc.

Carlos Correa, University of Buenos Aires

Gerald Hane, Office of Science and Technology Policy

David Hodges, University of California, Berkeley

Gary C. Hufbauer, Institute for International Economics

S. H. Kyong, National Computerization Agency of Korea

David Mowery, University of California, Berkeley

J. Thomas Ratchford, George Mason University

Reuel Shinnar, City University of New York

Joseph E. Stiglitz, Council of Economic Advisers

Shirley Tessler, Stanford University

Participants

Paul Almeida, Georgetown University

Vincent W. Ansanelli III

Kenneth Balick, Nomura Securities International

Michael Besso, Elf Atochem

Richard Celeste, Celeste & Sabety Ltd.

David B. H. Denoon, New York University

Patrick DeSouza, Council on Foreign Relations

Rafael Docavo-Malvezzi, Council on Foreign Relations

Marsha Echols, Howard Law School

Richard Florida, Carnegie-Mellon University

Wendy Frieman, Science Applications International

Joachim Gfoeller, Jr., Gfoeller and Co.

James Glaze, Semiconductor Industry Association

Bill Green

Craig Hackett, Council on Foreign Relations

Giselle P. Hantz, Debevoise and Plimpton

Martha Caldwell Harris, U.S. Department of State

Stanley Heginbotham, New York Academy of Sciences

Shafiqul Islam, BRN Associates

Jerome Jacobson, Economic Studies Inc.

Merit E. Janow, Columbia University

Antonie Knoppers

Thomas H. Lipscomb, Infosafe Systems

Harpreet K. Mann, Council on Foreign Relations

Ann Markusen, Council on Foreign Relations

James C. McGroddy

William Curtis Messner, International Affairs Education Series

M. Ishaq Nadiri, New York University

Michael F. Oppenheimer, Multinational Strategies, Inc.

Richard Petree, Institute for East-West Studies

Proctor P. Reid, National Academy of Engineering

Paul M. Sacks, Multinational Strategies, Inc.

Barbara C. Samuels, II, Samuels Associates

Eugene Sekulow, NYNEX Corporation

Anne G. K. Solomon, U.S. Department of State

Robert Spinrad, Xerox Corporation

Fred Tipson, AT & T

James Wei, Princeton University

Harry Woolf, Institute for Advanced Study

Participants In Study Group Session In Minneapolis

April 9, 1997

Speakers

David Mowery, University of California, Berkeley

Benedicte Callan, Fellow for Political Economy, Council on Foreign Relations

Presider

Kenneth H. Keller, Senior Fellow, Council on Foreign Relations

Participants

Susan Albright, Minneapolis Star Tribune

James Boyd, Minneapolis Star Tribune

Sean S. Costigan, Council on Foreign Relations

Charles Denny, ADC Telecommunications, Inc. (retired)

Gerald P. Dinneen, National Academy of Engineering

Barbara Frey, Minnesota Advocates for Human Rights

Milda Hedblom, Center for Strategic and International Studies

Geri Joseph

Erwin A. Kelen, Kelen Ventures

Richard Krueger, Minnesota High Technology Council

David B. Laird, Minnesota Private Colleges Council

Michael McPherson, Macalester College

Michael F. Metcalf, University of Minnesota

Douglas Petty

Edson Spencer, Spencer Associates

Leonard Weisberg, Honeywell Inc. (retired)

Robert White