

# Impact of Technology Transfer

*The interchange of technical knowledge among nations importantly affects the pattern of world trade, often creates balance-of-payment problems, and influences economic growth rates*

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Because of the differences among nations in technological capabilities, there is a continual process of international diffusion of technology. Knowledge can be transmitted in various ways — by emigration of engineers and skilled workers, by export of goods and services, by licensing, and by direct investment, among others. OECD data are available concerning national receipts and payments for patents, manufacturing licenses and technological know-how between parent firms and their subsidiaries as well as between independent firms. Taken at face value, these data seem to indicate that billions of dollars in payments are involved, that the United States is the single most important supplier of technology to other major Western nations, and that a large proportion of these payments represents transactions between American parent firms and foreign subsidiaries. Although many experts regard these figures as extremely unreliable, it seems clear that technology transfer in the modern world economy is a very big business.

Moreover, technology transfer is an activity with very important economic impacts and implications. It has a major impact on the pattern of world trade and the balance-of-payments problems of individual countries, and it has a very important influence on the rate of economic growth in various countries. In this paper, I shall try to describe briefly what economists think they know about these impacts of technology transfer. In addition, I shall discuss certain aspects of the transfer process, including the role of the multinational firm, and comment on some relevant questions of public policy.

To begin with, it is important to point out that, according to the available studies, technology is currently being transferred across national boundaries more rapidly than used to be the case. During the nineteenth century, 20 to 30 years often elapsed before a new product developed in one country was produced in

another country. For example, it was about 20 years after their introduction in the United States that the rotary printing press or typewriter were first produced in Britain. At present, however, the imitation lag is much shorter — in many industries such as electronics, only a few years, on the average. For example, John Tilton's study of the international diffusion of semiconductors during the 1950's and 1960's shows that the average lag between the time when a major semiconductor device was first produced and the time when it was first produced outside the innovating country was about 2 years. Or consider the stainless steel razor blades introduced by Wilkinson, a British firm; within a year, American firms had competing products on the markets. This reduction in the imitation lag is important, because it means that an innovating country will export an innovation for a shorter period of time than in the past. In a relatively short period of time, its new products may be produced abroad and perhaps even exported back to the innovating country.

## Role of Multinational Firms

Another relatively new facet of the transfer process is the important role of the multinational firm, which has been responsible in part for the acceleration in the rate of international diffusion of innovations. Multinational firms transfer technology to foreign countries in a variety of ways. In those countries where they have plants, they train people as operatives and managers. Also, they sometimes stimulate suppliers to upgrade their technology. For example, pharmaceutical companies have helped local firms in less developed countries with the fabrication of dosage forms. In addition, multinational firms sometimes set standards for their competitors. For example, American electronics firms seemed to have applied considerable competitive pressure on European firms in the 1960's. Also, they sometimes establish overseas R&D facilities, which aid in the transfer of technology. Beyond this, they often train users and provide service for customers. For example, in the computer area, IBM has transferred a considerable amount of important technology by training potential users, providing software, and servicing computer installations in various countries. Also, whether or not a firm has a plant in a particular country, the availability of its product in that country may be a form of technology transfer.

Many case studies of particular industries attest to the important role played by the multinational firm in the international diffusion of technology. For example, Tilton's study of the diffusion of semiconductors shows that of the major innovations in semiconductors in the

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1960's, American subsidiaries were the first to produce about 1/3 of them in Britain and about 1/5 of them in France. In particular, subsidiaries of American firms were relatively quick to use silicon and planar techniques, and by competing strongly with established European firms, they were able to capture large shares of the market. For example, in 1968, foreign subsidiaries had 44 percent of the market for semiconductors in Britain, 33 percent in France, and 22 percent in Germany.

Many case studies also describe the role played by the multinational firm in the transfer of technology to the less developed countries. For example, Jack Baranson has provided a detailed analysis of the transfer of diesel technology to India. It is important to recognize, however, that these firms face much more difficult problems in transmitting technology to less developed countries than to industrialized countries. Many of the techniques of the multinational firms may not be suited very well to the less developed countries, with their plentiful unskilled labor, few skills, and little capital. Moreover, there is sometimes little incentive for multinational firms to adapt their products, production techniques, and marketing methods to the conditions present in these countries. And unfortunately less developed countries lack the technical capability to effect the necessary adaptations themselves. The technological gap is so wide that multinational firms find it exceedingly difficult to transfer many technologies to less developed countries; and when they manage to do so, its effects often are restricted to narrow segments of the local economy.

#### Effects on Economic Growth

One very important effect of technology transfer is on the rate of economic growth of the country receiving the technology. Although few studies have been made of the effects of foreign technology, economists, after neglecting the study of technological change for a long time, have in recent years shown a considerable interest in examining the relationship between technological change arising from all sources and economic growth. The pioneering studies took place in the mid-1950's, Robert Solow's paper being most influential. Based on data concerning the nonfarm American economy from 1909 to 1949, his findings suggested that for the period as a whole, the average rate of technological change was about 1.5 percent per year. More precisely, the output that could be derived from a fixed amount of inputs increased at about 1.5 percent per year. Based on these findings, he concluded that about 90 percent of the increase in output per capita during this period was attributable to technological change, whereas only a minor proportion of the increase was due to increases in the amount of capital employed per worker.

This conclusion attracted a great deal of attention and resulted in a flurry of subsequent papers, each of which modified Solow's techniques slightly or used a somewhat different data base. Essentially, the conclusions they reached agreed with Solow's. However, after the first wave of papers appeared, economists began to feel somewhat uneasy about the methodology used in these investigations. One weakness in this methodology

lay in the assumption that any growth in measured output that could not be attributed to increases in labor or capital was due to technological change. This obviously was a very crude assumption. For example, the effects of increased education of workers and managers, as well as better health, nutrition, and a host of other factors were included in the measure of the effect of technological change.

In the 1960's, a number of additional studies appeared, including one by Edward Denison. Denison tried to remedy some of the problems of the earlier studies by including variables, like changes in quality of labor input associated with increased schooling, that had formerly been omitted. Because of the inclusion of these variables, his estimate of the effect of technological change on the rate of economic growth was lower than Solow's. But the estimate remained very substantial. In particular, Denison concluded that "advance of knowledge" was responsible for about 40 percent of the increase during 1929-57 of national income per person employed in the United States.

Studies have also been made of the contribution of technological change to economic growth in Europe. For example, Denison and Poullier carried out a detailed investigation of the factors influencing European economic growth rates during 1950-62. Basically, the methodology was similar to that used by Denison in his earlier study of the United States. Looking at Northwest Europe as a whole, they concluded that about 20 percent of the increase in national income per person employed during this period was due to advances in knowledge, and that perhaps an additional 15 percent was due to changes in the lag in the application of knowledge (and a mixture of other such factors). Thus, they estimated that, in all, perhaps 35 percent of the increase during 1950-62 in national income per person employed in Northwest Europe was due to new technology and transfer of technology from abroad.

Besides presenting such results for Northwest Europe as a whole, Denison and Poullier also published similar findings for individual countries. It is interesting to look at these results, although their roughness should be noted. They estimate that the advance of knowledge (and other things lumped together with these factors) accounted for the following percentages of growth of national income per person employed during 1950-62: Belgium, 34 percent; Denmark, 20 percent; France, 33 percent; Germany, 31 percent; Netherlands, 34 percent; Norway, 28 percent; United Kingdom, 46 percent; and Italy, 30 percent. Thus, judging from these findings, new technology and technological transfer were very important contributions to economic growth in all of these countries. However, for a variety of reasons, these numbers should not be taken too seriously: they are only crude estimates, as their authors would be the first to admit.

#### Technology Transfer in Less Developed Countries

Technology transfer also plays an important role in the economic growth of the less developed countries. Contrary to some popular opinion, the less developed countries are by no means stagnant economically. For

example, output per capita grew at an average rate of 2.3 percent annually during 1950-67 in 15 major less developed countries. But their growth rate, which fell short of the 4% growth rate of the industrialized countries during the same period, is less than it should be. Clearly, one thing that they badly need is more efficient technology. Unfortunately, however, modern technology often requires considerable capital; and the less developed countries, with their low rates of investment, find it difficult to scrape up the required capital. Also, and this is frequently more important, the less developed countries find it difficult to copy and use modern technology because they lack an educated and skilled labor force, and they often have few good engineers, technicians, and managers.

More fundamentally, it is important to recognize that much of our advanced Western technology is really not very well suited to the circumstances prevailing in the less developed countries. Because the industrialized countries have relatively great amounts of capital and relatively little labor, they tend to develop and adopt technology that substitutes capital for labor, but this technology may not be appropriate for less developed countries where there is little capital and lots of labor. Thus, it is very important that the less developed countries pick and choose among the technologies that are available in the industrialized countries, and that they adapt these technologies to their own conditions. Mindless attempts to ape the technologies used in the industrialized countries can often be expected to result in waste and failure.

In agriculture, important technological advances have taken place in the less developed countries in recent years. In particular, new types of seeds have been developed, which have increased the yields of wheat, rice, and other crops, some of the research having been supported by the Rockefeller and Ford Foundations. The resulting increase in agricultural productivity has been so impressive that many observers refer to it, of course, as a green revolution. There is no question but what production has increased greatly in countries like Mexico, the Philippines, Iran, Ceylon, India, and Pakistan. In almost all of the countries where agriculture has taken major strides forward, foreign technical assistance has made a substantial contribution.

In industry, most of the new technology that is adopted by the less developed countries is taken from the developed countries. There is probably too little attempt being made to devise new technologies more appropriate to conditions in the less developed countries, both because the less developed countries do not have the engineering and scientific resources to attempt such work, and because such attempts have not been very successful in the past. In countries where the private sector finds it unprofitable to carry out research and development, government research institutes sometimes attempt to fill the void, but these institutes frequently devote too much of their limited resources to projects that are not closely related to economic development. In addition, productivity centers have been created in some countries to teach managers and supervisory personnel how to make better use of new technology: such centers have helped to promote the

diffusion of new technology in countries like Mexico and Taiwan.

As noted previously, one of the most important economic impacts of the transfer of technology is on the pattern of world trade. Traditionally, economists have tried to explain the nature of a country's exports and imports on the basis of the theory of comparative advantage, which says that a country will export goods and services that it is relatively efficient in producing and import goods and services that it is relatively inefficient in producing. The important word here is "relative," since it is a country's relative efficiency, not its absolute efficiency, that is important. For example, even if a country were more efficient at producing all goods than its neighbors, it would be likely to export those goods where its relative advantage was greatest and to import those goods where its relative advantage was smallest.

Although the static theory of comparative advantage, together with international differences in natural endowments, can explain many aspects of world trade, it is generally agreed that this explanation leaves much to be desired. In recent years, economists specializing in international trade have devoted more and more attention to the inclusion of technological change in their models. Ray Vernon, Harry Johnson, and many others have done important and interesting work along this line. Their results indicate that American exports tend to be research-intensive goods. For example, there is a high correlation, industry by industry, between the ratio of R&D expenditures to sales and the U.S. share of exports by all OECD countries. Based on these and similar results, there can be no question but that for the United States, at least, export performance is closely related to R&D performance.

#### Technology Transfer and the United States

Technological innovation, whether it raises exports or displaces imports, can undoubtedly strengthen the competitive position of the innovating country. But the advantage arising from any single innovation is likely to be transitory, since the technology is bound to spread, sooner or later, and basic cost and demand considerations will dictate where the good will be produced and where it will be used. Thus, it is the rate at which innovations occur, one often replacing or obsolescing another, that determines a country's trade advantage from technological change. Moreover, besides the rate at which innovations occur, another factor that determines a country's trade advantage from technological change is the rate at which the new technology is transferred abroad. Obviously, unless the country where the innovation takes place enjoys a fundamental cost advantage in the production of the new product, its trade position will be improved only if there is a lag between its production of the product and the time when the product is produced in lower cost locations. Thus, technology transfer plays a crucial role.

This effect of technology transfer has received considerable attention, in Congress and elsewhere. In recent years, much concern has been expressed in the United States concerning the transfer of technology. During the past ten years or so, many observers feel

that our technological lead over Western Europe and Japan has shrunk considerably. Unfortunately, we really have little hard evidence as to the extent to which the so-called technology gap has narrowed in various fields, but fragmentary data seem to indicate some reduction of the gap in particular areas. For example, according to studies I am currently doing for the National Science Foundation, about one-third of the important process innovations in the chemical industry in the 1960's came from abroad, whereas less than one-tenth came from abroad in the 1950's. To some extent, such a reduction in the technology gap was to be expected as the war-torn economies of Europe and Asia got back on their feet. But in addition, there are other factors, including the considerable increase in recent years in the amount spent by Germany, Japan, and other countries on research and development.

Many observers attribute the deterioration of the U.S. balance of trade to the narrowing of our technological lead. They point out that domestic producers seem to be having a harder time maintaining the technological edge over foreign producers that enables us to sell effectively abroad and to hold our own against foreign competition. To some extent, this certainly is true, but we lack data indicating the extent to which a narrowing of our technological lead is responsible for the deterioration of our balance of trade. Obviously, lots of other factors were also at work. For example, during the late 1960's and early 1970's, our price level increased substantially. Also, there was the Common Market which eliminated tariffs among members but retained them on American goods. In addition, there were other factors, including the prevailing set of exchange rates, which over-valued the dollar.

Some groups, feeling that the narrowing of our technological lead is due in considerable part to the technological activities of multinational firms, argue that the activities of such firms should be subject to various new kinds of regulation. They point out that multinational firms have been an important factor in transmitting American technology to our foreign competition, thus narrowing our technological lead. Among the most vocal critics of the multinational corporation are the American labor unions. For example, representatives of the AFL-CIO have testified that, "While we share the concern of those who talk about the decline of America's trade balance . . . , we are equally concerned about the export of technology itself"<sup>1</sup>. Needless to say, the unions are concerned about the effect of the export of technology on jobs. In their view, the multinational firm is a runaway corporation, which takes jobs away from the American economy.

More specifically, the AFL-CIO has said that, "U.S. government policy has encouraged the export of technology in recent years . . . . This policy should be reversed by giving the President clear authority to regulate, supervise, and curb licensing and patent agreements on the basis of Congressionally determined standards. These would include the kind of investment, the product involved, the country of investment, the linkage to trade flows from such transfers and the effect on U.S. employment and the economy"<sup>2</sup>. As you no doubt know, legislation has been introduced in Con-

gress by Senator Hartke and Congressman Burke to give the President power to regulate the outflow of technology.

In general, economists are not inclined to favor interference with the international diffusion of technology. Some economists, notably Richard Cooper, of Yale, have suggested that, if international monetary arrangements cannot be worked out to permit American firms to compete fairly in world markets, "it may be necessary to restrict the activities of American firms abroad, that is, to exploit what remaining immobility of technical knowledge there is"<sup>3</sup>. But he hastens to add that this "is distinctly a second-best solution"<sup>4</sup>. This seems to me to be the case, both because it would be difficult to accomplish and because it would invite retaliation. After all, technology flows in both directions across the Atlantic — as evidenced, for example, by the fact that about one-third of the significant new chemical processes in the 1960's came from abroad, and that over 30 percent of the significant new pharmaceuticals marketed here since 1950 came from abroad.

In conclusion, it is important to recognize that economists are only beginning to study technology transfer in a serious way and that far more research is needed. We know far too little about the nature of the transfer process, the determinants of its costs, and the relative efficiency of various kinds of transfer techniques. We also know far too little about the effect of technology transfer on trade patterns and economic growth. However, I do think that economists are far more aware of the importance of technology transfer than they were 10 or 20 years ago, and that the chances are good that we'll know a lot more about these matters in another 5 or 10 years.

#### References

<sup>1</sup>See the testimony by A. Biemiller before the Subcommittee of Science, Research and Development of the House of Representatives, July 28, 1971.

<sup>2</sup>Ibid.

<sup>3</sup>R. Cooper, "Technology and U.S. Trade: A Historical Review," p. 16.

<sup>4</sup>Ibid.