THE INTERNATIONAL TECHNOLOGY TRANSFER PROCESS

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PREFACE

In August 1976, the National Research Council Committee on Technology and International Economic and Trade Issues examined a number of technological issues and their relationship to the potential entrepreneurial vitality of the U.S. economy. The committee concerned itself with:

- Technology and its effect on trade between the United States and other western industrialized members of the Organization for Economic Cooperation and Development (OECD) countries.
- The relationship between technological innovation and U.S. productivity and competitiveness in world trade; the effects of technology and trade upon U.S. levels of employment.
- The effects of technology transfer upon the development of the less-developed countries (LDCs) and the impact of this transfer upon U.S. trade with these nations.
- Trade and technology transfer in relation to national security.

Out of these issues, the committee prepared a report, *Technology, Trade, and the U.S. Economy,** that recommended that further work should be undertaken to provide more detailed examination of government policies and practices that affect technological innovation. This monograph is one of a series on the subject. Other monographs in this series are

- The Impact of Regulation on Industrial Innovation,
- The Impact of Tax and Financial Regulatory Policies on Industrial Innovation, and
- The Impact of Antitrust Policies and Practices on Industrial Innovation.

In the course of setting out the scope of its work, the committee questioned whether or not the U.S. government should (or even could) act to restrict technology transfer abroad? A parallel question is what should be the government's role (if any) in facilitating technology transfer to the less-developed countries? In addition, the committee

* National Research Council, 1978. *Technology, Trade, and the U.S. Economy.* Report of a Workshop held at Woods Hole, Massachusetts, August 22-31, 1976. National Academy of Sciences, Washington, D.C.

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1 INTRODUCTION

International transfers of technology are age-old phenomena. Except for international transfers deemed to affect national security, these transfers have rarely been a matter of major public policy concern in the United States. In recent years, however, vast changes in the structure of the world economy and concerns about international relations have brought the subject of international technology transfers to the forefront of U.S. thinking, mainly within the context of the following three broad public issues:

- Economic competitveness of the U.S. economy;
- National security; and
- Assistance to the developing countries.

These three issues are frequently labelled North-North transfers, East-West transfers, and North-South transfers, respectively.

Briefly, the first issue reflects a belief on the part of a number of people that outflow of technology developed in the U.S. has been a significant factor in the rapid rise and success of our international trade competitors, such as Japan and West Germany. The second issue has to do with a concern that outflow of U.S. technology may contribute to a strengthening of the military capability of the USSR; the Export Control Act of 1949, as well as recent Department of Defense studies and actions, have addressed this issue. The third issue reflects the basic conflict between the U.S. desire to help developing countries through technology transfer and the implications this would have for the U.S. economy and for U.S. labor if this leads to increased competition for U.S.-made products from lower labor cost countries.

International technology transfers are only one aspect of these broad policy issues. Nontechnology factors may also be important in specific situations. For example, the dominant influence in changing the economic competitiveness of certain industries may be currency devaluations or revaluations; or, the dominant force influencing the

Technology is distinguished from science in that science "organizes and explains data and observations by means of theoretical relationships [while] technology translates scientific and empirical relationships into practical use" (Hall, 1970).

Social as well as economic goods and services are included because, assuming that the context for dealing with international technology transfers is the issue of development and that development is broadly defined as improving the quality of life, technology transfers in the social sectors such as education, health, and public administration become highly relevant.

The definition recognizes that spatial gaps, as well as knowledge or other gaps, may exist between the producer and user and that technology includes knowledge, skills, and means for making goods and services available to the users through marketing, distribution, and communications. Therefore, the delivery or distribution of goods and services as well as their production are included. The capacity to develop new technology is considered because technology transfer is a means whereby a receiving or absorbing country expands its capacity to develop new technology. Technology transfers also contribute to the creation of a maintenance capability for existing machinery, equipment, or tools.

A major concern about North-South transfer has been the issue of payments for international technology movements. Payments are most commonly required for the transfer of industrial property rights such as trademarks, service names, and trade names and for licenses under patents. However, technology in this context also includes many types of transfers for which payments are not made by the receiver, but rather take the form of development assistance.

CLASSIFICATION SCHEMES

Some of the more useful classification schemes for technology currently being used are (i) hard and soft, (ii) proprietary and nonproprietary, and (iii) front-end and obsolete. Such classifications represent continuums, with the categories emphasizing the end points of the continuums. Moreover, the technologies are frequently inter-related. For example, hard technology cannot be used without the accompanying soft technology.

Hard technology is characterized as capital goods, blueprints, technical specifications, and such knowledge and assistance necessary

2 INTERNATIONAL TECHNOLOGY TRANSFER PROCESS

Technology is not a self-contained physical object that is stored on a warehouse shelf and shipped as a package from the supplier to the user. Technology is a body of knowledge transferred by a learning process. When the transfer is from one national environment to another, it can be complex, time consuming, and costly. Many transfer modes are available, and many parties may participate in the process.

COMPLEXITY OF THE TRANSFER PROCESS

Few detailed descriptions of the actual transfer process are available. Its complexity has been illustrated in a recent study of manufacturing technology transfers among units of selected multinational enterprises located in different countries (Behrman, 1976). In most manufacturing activities, technology transfers occur in seven distinct phases:

- Planning;
- Product design;
- Facilities design;
- Industrial engineering and training;
- Value engineering for quality control;
- Product development; and
- Technology support to local suppliers.

For these transfers, five general transfer mechanisms are required:

- Documentation, such as manuals and specifications;
- Instruction programs;
- Visits and exchanges of technical personnel;
- Development of specialized equipment; and
- Continuing oral and written communications on whatever problems may arise.

3. *Contracts and Agreements*: Licensing of patents, trademarks, tradenames, and know-how; contracts for management services, equipment maintenance, and service facilities; risk contracts for oil-drilling; etc.

4. *Research and Development*: Location of research and development operations in foreign countries; research subcontracting; joint R&D projects.

5. *Personnel Exchanges*: Development assistance under bilateral and multilateral aid programs; International Executive Corps; employment of nationals by foreign firms; employment of foreign technicians; migration of trained personnel.

6. *Publications*: Professional and scientific literature; patent literature; technical publications, nontechnical how-to-do-it books.

7. *International Visits, Conferences, Exhibitions*: Professional and scientific meetings; academic conferences; technical societies and trade associations; trade shows; private company technical meetings; scientific and technical visits by individuals.

8. *Teaching and Training*: Foreign study in regular undergraduate and graduate university programs; specialized seminars for executives; training programs conducted by the United Nations and other international agencies; internal training programs of business firms; commercial training programs of professional associations and business corporations, such as accounting firms, banks, and research institutes.

9. *Other*: Transfers through international tender invitations; reverse engineering; investment in or acquisition of companies; industrial espionage; government-to-government agreements in such realms as nuclear energy and space research, science and technology, health care, agriculture, education, etc.

As noted earlier, there is some controversy over the cost of North-South technology (developing country) transfers. With the exception of the first three modes -- projects, trade, and contracts -- and of cases such as tuition for foreign study, where part of the cost of instruction is paid by the recipient, virtually all of the other modes do not involve recipient payments. And even in those categories that do, a large amount of soft technology may be transferred without payment.

governments sometimes establish controls over foreign direct investments to improve their balance of payments situation. The effect of such measures on technology flows may be significant. Although some of the transfer modes, such as publications, cannot be easily restrained or regulated, the expediters and controllers can have a major influence on the timing, the kinds of transfers, and the terms negotiated.

International agencies, both public and private, have many programs for expediting international transfers of technology. United Nations agencies, such as the United Nations Industrial Development Organization (UNIDO), the Food and Agricultural Organization (FAO), the World Health Organization (WHO), and the United Nations Conference on Trade and Development (UNCTAD) have extensive programs of publications, training, conferences, and research that expedite the technology transfer process. Most UN agencies also have technical assistance programs to supply foreign experts to member countries. The United Nations is establishing a data bank on the availability and source of specific types of technology. The recent United Nations Conference on Science and Technology in Development also served as an expediter of technology transfers. Private groups, such as the International Planned Parenthood Association and the Society for International Development, have an important technology transfer dimension in their activities. There are numerous other agencies and activities involved in all modes of transfer.

National governments can play a major expediting role in a number of ways. The government of Japan, for instance, supported a massive program for expediting the transfer of technology into Japan after World War II. Scientists, technicians, and business executives were organized into a governmental effort to match Japan's technology needs with available technology through literature searches and worldwide trips and to arrange the necessary licensing agreements. As another example, the U.S. government sponsors international meetings and summer schools through direct support to the organizers or through travel and living support for participants. This form of government transfer expediting is almost unique to the United States.

Development assistance in the form of technical advisers supplied to foreign countries on a binational basis has been extensively supported by national governments. Government support of research in universities where foreign students have participated as postdoctoral fellows is an indirect means of international technology transfer.

views within the United States as to which technologies should be restricted under this program. Of course, attempts to control the transfer of technology may be less than effective because of the number of routes by which technology can flow. A determined and sophisticated would-be receiver can often find a route for obtaining controlled technology. Technology flows via personnel movements are often controlled through immigration laws.

Another large, growing area of control exists in technology importing countries (United Nations Industrial Development Organization, 1977). Many of these countries -- for example, India, Pakistan, Korea, Mexico, and Brazil -- require government approval of technology agreements. The primary concern of such control programs is the terms under which technology is made available. Government interest extends to agreement terms such as payments, avoidance of restrictions as to market areas, the creation of some local R&D supporting activity, and whether the imported technology has a high priority in the national development plan and is appropriate to the conditions of the country. Many governments also control technology transfers through environmental regulations, international trade policies, patent laws, establishment of technical standards, government procurement practices, and "local content" policies.

Because much of the discussion of international technology transfers tends to emphasize the role of the suppliers and the users as the only parties involved, a useful research area would be the identification of the full range of controllers and expediters involved in major transfers and the evaluation of the roles they play in the process.

3 IDENTIFYING AND MEASURING TECHNOLOGY FLOWS

A comprehensive data base that identifies and measures international technology flows would be an invaluable aid for policy making. Ideally, such a system would describe the types, amounts, flow patterns, transfer terms, and transfer modes of technology transfers on a continuing basis.

Unfortunately, such a data base is not currently available, primarily because neither governments nor private parties have given the necessary priority to the measurement issue nor made adequate resources available for the development of an extensive data base. An important aspect of this problem is the absence of knowledge as to which data ought to be collected and entered for the base. In this monograph, the section on Improving the Data Base for Policy Making addresses some of the information gaps.

USE AND MISUSE OF INDIRECT INDICATORS

The demand for factual information appears to be growing. In the absence of direct measurements of technology flows, policymakers must make decisions based on questionable indicators collected for other purposes. The principal indirect indicators being used are (i) international payments for royalties and management assistance, (ii) trade in technology intensive goods, (iii) foreign patents registered, and (iv) migration of trained personnel.

Royalty Payments

As a measurement of technology flows, royalty payments data has a number of limitations (U.S. Department of Commerce, 1973, pp. 14-18). The most basic of these are described below:

- Items clearly unrelated to technology transfers, such as film rental receipts, are included in the data on fees and royalties published by directly opposing conclusions as to trends in technology-intensive exports, largely because of these differences in definitions and assumptions (Kelly, 1977).

- Studies that use the trade proxy as a measure of international technology transfers implicitly assume that technology is the principal, if not exclusive, factor in determining the competitive ability of U.S. producers. Such an assumption neglects the crucial role of other factors influencing trade, such as changes in exchange rates or changes in the relative success of different nations in generating new technology.

- The trade proxy does not take into account the interrelationship between trade and direct investment. For example, the decline in U.S. exports of a specific product may reflect the decision of a multinational firm to substitute foreign production for exports by establishing production facilities in a foreign market, rather than the loss of export competitiveness by a U.S. producer.

Foreign Patents

Trends in foreign patents registration have been widely used in the technology field -- more as an indicator of the relative success of foreign countries in generating new technology than as a measure of international technology flows. The share of total patents registered in the United States by foreigners has increased. It is argued, therefore, that the productivity of the United States in technology relative to foreign countries has declined more or less proportionately.

As a measure of the rate of invention, the patent registration data have serious flaws. It fails to differentiate between inventions of different qualitative importance. It includes many patents that will not reach the stage of commercial application. Thus, the decision to incur the expense and effort to register patents in foreign countries is influenced by many factors in addition to the rate of invention. Some of these factors relate to different national policies on registration; others -- probably the most important -- relate to company policies, such as plans to expand operations into a specific foreign country.

The patent registration measure has produced some questionable results as a measure of relative national rates of invention. A recent study has shown that the share of patents filed by foreigners has increased in all of the industrialized countries (National Science Board, and, even where formal training programs are undertaken, present data-gathering programs do not report on such efforts.

Even where a technology transfer event can be identified, it may be extremely difficult to assess the kind, amount, and value of the technology being transferred. Teaching and training of foreigners is an important mode for transferring technology, and it should be feasible to gather data on the number of foreign students who are training in a particular country, their fields of study, and whether the level of study is graduate or under-graduate. Yet, to properly assess the technology transfer that occurs, it would also be necessary to evaluate the quality of the trainee, the quality of the training program, and the opportunity for the trainee to make use of the foreign training in the country of origin. Questions arise -- such as, does a transfer occur if the trainee is unemployed in the home country or if the foreign training is inapplicable to activities in the home country?

Technology transfers through development assistance also present difficult evaluation problems. Only a minority of such missions can be judged as successful technology transfers. In some cases, the foreign expertise made available is not appropriate for the assignment. In others, the failure may result from local environmental constraints or from problems of cross-cultural relations.

The list of difficulties in developing definitive measurements can be extended by assessing the measurement requirements of each of the categories of transfer modes listed above.

4 IMPROVING THE DATA BASE FOR POLICY MAKERS

From a technical point of view, the task of developing a comprehensive data base for international technology transfers involves many difficult conceptual and practical problems. Furthermore, it is not likely that completely satisfactory and definitive measurements can be developed. Nevertheless, a great deal of valuable data and analysis can be made available if there is a willingness to make the necessary investment. A major effort directed specifically toward international technology transfer policy issues could improve dramatically the data base for policy making.

Many technology transfers can be identified, measured, and evaluated. Where quantitative measures are not feasible, expert judgment can be used effectively. A successful example of the use of expert judgment is the study completed by the National Academy of Engineering which addressed technology flows associated with foreign direct investment in the United States and relied upon case histories in specific industries (National Academy of Engineering, 1976).

A general approach for developing a comprehensive data base is to begin with the specific policy issues being discussed, determine what data and analyses are needed to answer the questions being raised, and what criteria are appropriate for resolving the specific policy issue. In some cases, significant amounts of the needed information may be already available; but, in most cases, data and analyses will have to be developed. The kinds of data and analyses needed are illustrated by examining several of the principal policy issues currently receiving major attention.

- *World exports*: changes in shares supplied by

  (i) U.S. production of U.S.-owned firms; and
  (ii) U.S. and foreign production of U.S.-owned firms.

- *World consumption*: changes in shares supplied by the output of U.S. firms and their foreign affiliates.

- *Profitability*: trends in U.S. and foreign firms.

The results of the test of competitiveness will vary, of course, with the market being analyzed and the time period being used for the analysis.

Isolating the Technology Factor

Where U.S. firms have become less competitive internationally, to what extent has this been caused by international technology transfers? In order to answer this question, the role of key nontechnology factors in each of the product areas must also be analyzed. However, where lagging technology has been identified as a major factor in the loss of competitiveness by U.S. firms, the decline in technological advantage may be due to an outstanding innovation by foreign producers through their own R&D rather than international transfers.

Among the nontechnology factors that may account for a loss in competitiveness of U.S. producers are

- *Governmental Actions:* Devaluations, subsidies, tax inducements, cost-sharing for R&D, environmental controls, tariff and nontariff barriers to markets, foreign investment controls and/or incentives, etc.

- *Labor Costs:* Minimum-wage legislation, legally mandated workers' benefits, wage levels, supply of skilled workers, productivity, etc.

- *Financial Factors:* Availability and cost of capital, debt-equity norms for financial structure, etc.

foreign technology. Thus, prospective control programs should be thoroughly analyzed from a national cost-benefit standpoint before being adopted.

Summary

The illustration of the data and analysis needed for policy decisions on international technology transfers, as related to the competitiveness of the U.S. economy, is not intended to demonstrate that the task is impossible. It is intended to show, however, that the issues are extremely complex, that data collection specifically designed to answer specific questions must be undertaken, and that the indirect measures presently being used are not a sound basis for policy decisions.

ISSUE B: EVALUATING THE EFFECTIVENESS OF VARIOUS TRANSFER MODES

How effective are the various modes for international transfers of technology? Such knowledge would be extremely valuable for the formulation of policies relating to transfers. Some case studies have been made of transfers through direct foreign investment. But the effectiveness of the many other transfer modes has not been analyzed to any great extent.

What is a reasonable criterion of effectiveness? The test might be the extent to which the user or receiver has developed the capability, on a continuing basis, to produce specified goods and services of satisfactory quality at reasonable cost. The standard of reasonable cost will have to vary with such factors as the characteristics of the user, the socioeconomic setting, and the transfer terms.

To evaluate the effectiveness of each of the transfer modes, many variables will need to be considered. Conceptually, the framework for a comprehensive evaluation might be a separate matrix for each type of technology transfer with the transfer modes on one axis and the influencing variables along the other. The applicable transfer modes will vary with types of technology and such factors as national policies. In the case of Japan, for example, technology transfers through direct investment have been restricted by national policy decisions. In all transfers, however, the following variables can influence the effectiveness of the transfer.

developing nations, the socioeconomic environment affecting technology transfers can vary dramatically. One authority illustrates the extreme variations as follows:

> Let's take two extreme examples. One, consider almost any country in Africa -- for example, Nigeria -- and Korea. Korea has a highly literate civil population, a well-developed education system (modified by the Japanese during their domination), highly skilled and well-trained technicians, a single language, ties with both China and Japan, and after the war, a strong connection with the technology of the United States, and finally a spirit of individual entrepreneurship almost unmatched in the developed world. Korea established (with U.S. help) a number of institutions with the ability to adapt the technology and know-how to the needs of Korea and to adjust that technology to their resource endowments. Compare the situation with Nigeria with only the beginnings of literacy and technical infrastructure, with no institutions of significance that have technical capability to adapt, and encumbered by the necessity of importing technology tailored to suit the most advanced countries rather than their own (Hollomon, 1976, p. 5).

Transfer Terms

The transfer terms can influence the effectiveness of the various modes in many ways. A one-payment arrangement provides less incentive to the supplier than a royalty arrangement where the rewards depend on the commercial success of the transfer. The inclusion of arrangements for training local personnel can improve the effectiveness of a transfer. Restrictive conditions in the transfer agreement, such as limiting the market for a licensee and the potential for achieving scale economies, may reduce the effectiveness of transfers.

Expediting Agencies

Expediting agencies can influence the effectiveness of transfers through helping identify sources of technology, providing technical assistance for negotiating transfer terms, offering tax or other incentives, and by

Time Dimension

Time is a key factor in all transfers. The time period required to make the transfers effective will vary considerably with the transfer modes, as well as the duration of the benefits to the suppliers and the users.

An Alternative Approach

The many factors influencing the effectiveness of the various transfer modes make the evaluation process more complex and difficult. Nevertheless, the data base in this area can be greatly enlarged by a series of well-selected historical case studies.

An alternative short-cut to a better understanding of the effectiveness of transfer modes is through the use of expert opinion. With the aid of expert advice, the necessary conditions for making specific types of technology transfers through alternative, feasible modes can be identified. In this way, participants in the transfer process can make an *a priori* evaluation of the potential effectiveness of a proposed transfer and be alerted to conditions that might have to be changed in order to make the transfer effective.

ISSUE C: ANALYZING THE IMPACT OF INTERNATIONAL TECHNOLOGY TRANSFERS

The ultimate or bottom-line public policy issue is the national impact in terms of benefits and costs of international technology transfers. The interests of the individual or institution and those of the nation are not identical. A specific technology transfer may be favorable to the individual or institution but not the nation, or vice versa. From the standpoint of public policy, therefore, the assessment or perception of national costs and benefits is the dominant factor in the formulation of public policies.

Impact analyses generally make use of the conventional techniques for socioeconomic cost-benefit evaluations. The body of knowledge available on cost-benefit techniques is extensive and does not bear description here. However, several special issues related to international technology transfer will be noted.

- Impact studies are only relevant, of course, where technology transfers have been effective. The degree to which transfers are

- Prices and quality of goods and services to consumers;
- Business competitiveness and stimulus to innovation;
- Scientific and technological capability of nation; and
- Taxes and government income.

- Net national benefits need to be measured by taking alternatives into account. The net benefits will be only the incremental gains over what might have happened if the specific transfer had not taken place. Thus, alternative sources, the possibilities of local developments, and the availability of an alternative but less efficient technology must be recognized.

- The costs of technology transfers will include direct expenditures in foreign exchange; higher prices to local consumers if imports are less expensive; the opportunity costs (or shadow prices) of using physical, financial, and human resources that have alternative uses; and the negative impact on goals such as employment. In the case of supplier countries, for example, international technology transfers may substitute for exports and reduce domestic employment, depending on whether a realistic possibility existed for continuing to supply a foreign market through exports.

- Benefits and costs all have a time dimension. In the case of a rapidly changing technology, for example, the benefits of a transfer may have a short duration.

In most situations, precise and qualified cost-benefit evaluations will not be feasible. Developing countries, in particular, may not have the necessary experienced personnel nor the essential data for sophisticated impact studies. Although many of the significant benefits and costs cannot be quantified, the cost-benefit framework for analysis can be an extremely valuable guide for policy formulation. The methodology provides a comprehensive checklist of the factors that should be considered, and in many cases can lead to a well-informed judgment that the net impact is favorable or unfavorable, without providing a precise measure of the impact.

5 CONCLUSIONS

Public policy issues relating to North-North, East-West, and North-South international transfers of technology have been growing in importance. If governments are seriously interested in good policy decisions in these areas, they must become well informed about the nature and complexity of the international technology transfer process. To do this, they need better information and data. Agreement needs to be reached on what is and is not to be included in the label technology. There must be an explicit recognition of the numerous modes by which transfers take place and the many variables that determine the effectiveness of specific technology transfers. And more thoughtful consideration must be given to the appropriateness of the criteria used for decision-making.

Unfortunately, the kinds of data, analytical studies, and criteria needed for making good policy decisions have not yet been adequately developed. In the absence of such a data base, several types of indicators gathered for other decision-making purposes have been wrongly applied to international technology transfers decisions.

The data base for policy making can be dramatically improved if there is a desire to do so and a willingness to make the necessary investment. The approach being suggested is to identify the currently discussed policy issues and to assign priorities. The detailed data needed to answer the questions being raised should be specified. Based on this set of requirements, a determination can be made as to what is available and what essential information is missing and still needs to be developed. The preliminary analysis of the current policy issues undertaken in this paper illustrates that approach.

If the current issues are judged as important as they are alleged to be, a significant investment in improving the data base seems clearly justified. The task is feasible. The alternative is to continue to rely on indirect indicators that do not provide adequate answers to the questions.

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effective will therefore be a variable and will influence the value of the benefits resulting from specific transfers.

- The public benefits and costs will vary for different nations. They will be different for supplying countries and receiving nations. They will differ also among receiving nations, depending upon such variables as the national goals and the socioeconomic infrastructures of the specific nation.
- International technology transfers are usually a nonzero-sum game. In other words, both parties can gain from a transfer, and it is not necessary for the supplying nation to lose if the receiving nation gains.
- Many nations are both suppliers and receivers of international technology transfers. Thus, the benefits and costs of inflows as well as of outflows need to be considered in an overall impact evaluation. This point has been gaining importance for the United States because many foreign nations have become increasingly important sources of new technology in recent decades. Also, many long-established technologies used abroad to conserve energy and materials have become valuable to U.S. producers as a result of recent international trends.
- National benefits will be measured in relation to national goals and assigned values based on the relative priority of these objectives. Some of the principal impacts are likely to be on
    - The growth rate of the national economy;
    - Employment in general and particular skill categories;
    - Foreign exchange savings and earnings;
    - Linkages such as stimulus to related enterprises;

making scarce foreign exchange available to technology transfers. The most comprehensive expediting program by a national government was undertaken by Japan during the 1950s. Japan sent teams of scientists and technicians to four U.S. industries. Commercial attaches in Japanese embassies scanned the economies of foreign countries in search of technological innovations (Tsurumi, 1973, p. 77), and the Japanese government provided tax benefits and subsidies to help industries make the investments necessary to adapt foreign technology (Ozawa, 1975, p. 38).

An example of an expediting program of a supplier nation is the contract between the U.S. Department of State and the Board on Science and Technology for International Development (BOSTID) of the National Research Council's Commission on International Relations. Establishment of scientific and technological institutions in Korea and Brazil, which enlarged the capacity of those countries to receive and adapt technology, was aided in part by this program.

Control Agencies

Control agencies can also play a role in determining the effectiveness of transfer modes. On the host country side, programs regulating the transfer of technology may either enhance or retard it. Enhancement can come from such mandatory provisions in licensing agreements as requiring the training of licensee personnel. Retardation may occur if license agreements are limited to short periods that, in the view of the licensor, may not allow enough time for the receipt of adequate payment for the technology transfer. Another type of host-country policy that sometimes limits the effectiveness of transfer through personnel exchanges is a restriction on the number and kinds of foreign personnel that can be assigned to a foreign subsidiary. Where adopted, the purpose of such a policy has been to enlarge the employment opportunities for nationals.

On the supplier country side, a major example of controls is the U.S. Department of Commerce-Department of Defense control over East-West technology transfers.

Nature of the Technology

Where the technology is relatively simple, transfers through publications may be effective. Where the technology is complex, some form of personnel exchange and personnel training may be required. In some cases, the transfer may be a discrete event. In other situations, particularly where the technology is dynamic, effective transfers require tying the receiver into a generation process on a continuing basis. For the one-time transfer, the sale of equipment and accompanying consultation may be effective. For a transfer requiring a continuing relationship, a licensing contract, equity participation by the supplier, or direct foreign investment may be the more effective mode. Other characteristics of the technology, such as the need for adaptation and maintenance, will influence the effectiveness of transfers.

Supplier's Characteristics

The supplier's capabilities and motivations are important factors in making the transfers effective. Does the supplier have experience in adapting technology to new conditions? Does the supplier have capable personnel for advising and training foreign personnel? And does the supplier have adequate motivation in terms of goals such as profitability to make a maximum effort?

User's Characteristics

Essentially the same characteristics on the part of the user as the supplier -- namely, capabilities and incentives -- will influence the effectiveness of transfers. In the case of transfers from a multinational company to a foreign affiliate, the similarity of the internal environments and the harmony of interest between the supplier and the user are factors that increase the effectiveness of the direct investment transfer mode.

Socioeconomic Infrastructure of Receiving Nation

An extremely important variable not easily or quickly changed is the socioeconomic infrastructure of the receiving nation. Even among the

- *Externalities:* Availability and cost of materials and components, electric power, and transportation; efficiency of communications systems.
- *Other:* Aggressiveness and goals of firms and their managers.

Through a process of elimination, technology may be identified as playing a dominant role in the declining competitiveness of specific U.S. industries. Then the question will have to be answered as to whether the decline in technological advantage is due to international transfers or to an accelerated technological productivity of non-U.S. firms.

The Control Potential

It is periodically suggested that governments should control technology transfers for economic purposes. To what extent can international technology transfers be controlled by governments? The control potential for different types of technology and for the various modes of transfer can range from substantial control to none at all. Secret and unpatented know-how would, in one sense, be easiest to control; however, the possessor of such know-how is not always the government, and it is not obvious how the government would know there is something to be controlled. At the other extreme, marketing know-how is extremely difficult to control.

Among the many modes of transfer, the most feasible areas for control are projects, trade, and contracts and agreements. By contrast, transfers through personnel exchanges, publications, conferences, teaching and training, and reverse engineering are difficult if not impossible to control through government actions.

As a general rule, controls over international technology transfers will only be effective if alternative sources of the same technology are not available. In nuclear energy, for example, Brazil was able to find suppliers other than U.S. sources after the U.S. denied it this technology. In some cases, control measures will mean only a period of delay for the prospective user rather than a denial of access to the technology.

The feasibility of controls is one issue; the desirability of controls is another issue. Attempts to restrict technology transfers can result in costs as well as benefits. Controls by one country, for instance, may lead to retaliation by other countries and reduce the overall access to

ISSUE A: INTERNATIONAL TECHNOLOGY TRANSFERS AND THE COMPETITIVENESS OF THE U.S. ECONOMY

Identifying the Industries

In which industries, products, or services is technology the dominant competitive factor? Two widely used measures of high technology firms or industries are (i) the number of scientists and engineers engaged in research and development as a percentage of the firm or industry work force and (ii) the firm or industry expenditures on R&D as a percentage of value-added or total sales (U.S. Tariff Commission, April 1972). Usually, an arbitrary cut-off is chosen to separate high- from low-technology industries. In the United States, industries such as airframe, nuclear reactors, pharmaceuticals, electronics, and computers are high-technology industries. Steel, textiles, and some extractive industries are examples of low-technology industries.

In using this R&D definition to identify the relevant industries, several types of adjustments have to be made. Consideration should be given to the fact that some firms will purchase high technology from others instead of investing in their own R&D. Also, some high-technology subsectors of low-technology industries should be included, as well as industries and products where soft technology, such as marketing and management know-how, are important sources of competitive strength and may be an essential element in technology transfer.

Criterion of Competitiveness

What is the test of competitiveness? Several possible measures are available and more than one of the measures may have to be used. Among the possibilities are the following:

- *U.S. market*: changes in shares supplied by
  - (i) domestic production versus imports;
  - (ii) U.S.-owned versus foreign-owned producers located in the United States; and
  - (iii) domestic and foreign production of U.S.-owned versus foreign-owned firms.

1977). Obviously all of the advanced nations have not gained in the rate of inventions relative to each other. In the case of the United States, the large increase in foreign patent filings has been by Canadians.

Migration Statistics

Data on the migration of trained personnel are possible measures of one form of international technology transfer. However, such data cover only one of the many forms of transfers through personnel exchanges. The relationship of migration to technology transfer depends on whether the migrating personnel bring technology with them and on whether they later return and take technology back. Probably because the United States has been historically a major recipient of trained personnel from foreign countries, the migration measure does not receive as much national attention in the United States as it does in a number of developing countries from which the personnel are migrating.

A recent study for the UN Institute for Training and Research (UNITAR) concludes that the so-called "brain drain" from the developing to the developed countries is governed by personal and professional motives as well as economic considerations (Glaser, 1977). The study also concludes that professionals with careers in languages, education, and certain biological sciences are most likely to emigrate and remain abroad. Those most likely to return home and to remain there hold positions in agriculture, business, and philosophy.

IDENTIFICATION AND MEASUREMENT PROBLEMS

The task of identifying and measuring international transfers of technology involves many difficult conceptual and practical problems, particularly when addressed using the broad definition of technology proposed in this paper and recognizing the many modes of transfer suggested above. The difficulties of identification are illustrated by the case of reverse engineering. Anyone familiar with developing countries is aware of the extensive practice by capable local artisans of duplicating a machine or a machine part from an imported model. Yet, finding data to measure this type of a technology transfer is difficult. Another example is the case of technology transfers through training programs by foreign firms for local employees. Much of the training is informal the U.S. Department of Commerce. Other questionable items, such as payments for the use of copyrights, are also included.

- Many technology transfers are not reflected in royalty payments. For example, Brazil bars royalty payments by a controlled subsidiary (more than 50 percent ownership) to the parent company on the grounds that profit remittances are payments that should include compensation for technology. Also, in a cross-licensing agreement there may be no royalty payments, even though technology is transferred.

- The distinction between management fees and royalties or licensing fees is uncertain. Some companies receive payments for know-how as management fees, while others may require management fees as a contribution to general overhead expenses of the parent firm.

- The year-to-year changes in total royalties and fees are influenced by the terms of the agreement and by such external factors as economic growth trends in the country of the licensee and commercial success in selling products.

- Royalties measure trade, not technology transfer.

- Royalties from subsidiaries and from nonaffiliated companies need to be differentiated.

Based on these limitations, royalties and fees are questionable indicators of the timing and value of technology transfers.

Export Statistics

The use of export statistics to measure international technology transfers also has serious limitations. The argument has been made that U.S. exports of technology-intensive goods are declining and that the decline demonstrates that the ability of U.S. producers to compete in foreign markets has been eroded by extensive international technology transfers (Boretsky, 1975, pp. 70-82). Some major defects of this indirect measure are as follows:

- Great differences exist among analysts as to the definition of technology-intensive goods. As one result, two different research groups, both in the U.S. Department of Commerce, have reached

Government-to-government agreements provide facilitating mechanisms and financial support for technology transfers in agriculture, health care, national security, and many other fields. National patent laws and international treaties and conventions, such as the Convention of Paris for the protection of industrial property rights, also aid in expediting the transfer.

Many nongovernmental national groups such as scientific and professional associations and private foundations make significant contributions as expediters of international technology transfers. The National Academy of Engineering (NAE) and the National Academy of Sciences (NAS) are examples of professional associations that expedite technology transfers through a variety of programs under contract to the U.S. government. The NAS, for its part, has a long-standing information exchange program for cooperation with foreign scientists. Through this program, foreign countries are helped to plan and implement national science and technology programs. In other instances, the "green revolution" that has dramatically increased grain production in the developing countries has been supported by the Rockefeller and Ford foundations, and universities help expedite technology transfers through training, research, publications, and direct technical assistance.

There are a number of international standards organizations that act as technology transfer controllers as well as expediters. The International Civil Aviation Organization (ICAO), for example, promotes international standards and regulations in civil aviation. The International Telecommunications Union (ITU) has similar responsibilities in radio, telegraph, telephone, and space communications. The objectives of these controllers are primarily safety and uniformity. There are other international activities directed toward national security and political goals. For example, in the area of nuclear nonproliferation, new types of organizational forms are being explored to determine how and in what forms nuclear technology should become available to nations.

The most extensive control activities are probably those of national governments. National control of outbound technology flows is justified in the area of national security. The United States has an export control law that restricts "the export of goods and technology which would make a significant contribution to the military potential of any other nation or nations which would prove detrimental to the national security of the United States" (Frost, 1977, p. 3). As might be expected, there has been and continues to be substantial differences of

Much existing technology is freely available. Whether a user is able to exploit that technology depends on the ability of that user to define his needs and on the availability of qualified personnel who have access to scientific and technical publications and an ability to apply that information to the needs. It also depends on the adequacy of the receiving country's infrastructure for useful absorption, translation, and utilization of the technology.

International tender offers are also used as a means of technology. For example, a Middle Eastern country recently invited tenders for a possible contract to install a national communications system. The potential value of the contract, hundreds of millions of dollars, prompted many multinational companies and consortia to invest millions of dollars in designing systems they hoped would win the contract. In the process of negotiating and awarding the contract, the responsible government officials of the purchasing country received a massive amount of transferred technology. Thus, using the conventional technique of international tenders, it is possible for a major developing country to update its own people on the current state of technology in selected key areas.

A special issue related to technology transfers, especially in foreign direct investment projects, is that of bundled or unbundled technology. In certain cases, the owner of the technology such as unpatented industrial process know-how is unwilling to transfer the know-how without receiving a controlling interest in the foreign affiliate that would use the technology. In other cases, where specific technology is part of the mainstream activity of the enterprise, the enterprise will consider technology transfers as only one element of its total business activity in terms of productivity and profitability and will treat the transfer as an inseparable part of the firm's total package of resources.

EXPEDITERS AND CONTROLLERS OF THE TRANSFER PROCESS

International transfers frequently involve participants other than the suppliers and users of the technology. Many governmental and private groups, some of whom may also be users and suppliers, assume varying expediting and controlling responsibilities. In some cases, the technology flow objective may be secondary to these groups. For example, Transfers made to non-affiliated parties through licensing agreements can also require that the licensor show the licensee how to use the knowledge. In the case of cross-licensing, the principal objective of the parties may be to permit free exchanges of information under an umbrella agreement, rather than just to permit the parties to use existing patents.

The transfer process often involves participants other than suppliers and users of technology. In the case of international transfers, national governments frequently play an important role as expediters or controllers of the flows and terms of the transfers.

The amount of time required, the expense incurred, and the effectiveness of technology transfers will vary with such factors as (i) the nature of the technology being transferred, (ii) the characteristics, capabilities, and objectives of the parties involved, (iii) the absorptive capability of a country, and (iv) the specific economic and social sectors within the country. A transfer of electronic technology from a U.S. firm to a Japanese company could occur rapidly, inexpensively, and effectively, while a similar transfer to a developing country with a limited supply of trained and experienced personnel might not. Likewise, the potential for technology transfers through published professional and technical literature will depend upon whether the receiving country has a well-developed scientific and technological community and whether the receiving country has or is able to develop an infrastructure in order to keep the technology from becoming obsolete.

MODES OF TECHNOLOGY TRANSFER

The numerous modes of international technology transfers can be grouped into the following nine broad categories:

1. *Projects*: Establishment of a business operation controlled and owned by a foreign parent company (i.e., foreign direct investment); turnkey projects in which all the necessary elements for an operating plant are provided by a foreign firm for a fee and without a continuing financial stake in the operation; other construction projects; coproduction, such as the British-French Concorde aircraft development and manufacture; other joint ventures.

2. *Trade in Goods and Services*: Sale of equipment, tools, end-products materials, and consulting services.

for the efficient utilization of the hardware to produce materials, components, and end products, while soft technology refers to management, marketing, financial organization, and administration techniques. Proprietary technology is owned or controlled by particular individuals or institutions. It may be held as a trade secret or it may be published as a patent. Nonproprietary technology includes knowledge contained in technical literature, hardware, and services that can be imitated or reproduced by observation and through reverse engineering without infringing on the proprietary rights. The classifications front-end and obsolete relate to the newness of technology and its competitive advantage. Front-end technology is the latest available, while old technology, in some cases, is obsolescent.

development aspirations of specific developing nations may be international trade policies, such as securing greater access to markets in developed countries. Nevertheless, an understanding of international technology transfer is important, and policymakers in government, industry, foundations, and academia have become increasingly concerned with the subject.

Unfortunately, policy formulation as related to technology transfers is handicapped by several realities. There is no common agreement as to what is being discussed under the label of international technology transfers. As might be expected, parties participating in policy debates may each be using a different definition without being aware that the others have an altogether different concept in mind. Another shortcoming is a frequent lack of understanding as to the nature and complexity of the international technology transfer process and the variety of transfer modes. It is not surprising, therefore, that little data and analysis specifically related to the three policy issues are available.

This paper has been prepared as an aid to the policy- and decision-makers in the United States and in foreign countries who are concerned with international technology transfers. Its primary objective is to provide a more uniform understanding of the nature of the international technology transfer process and to stimulate the development of an adequate conceptual and factual data base on technology transfer.

A first step toward this objective is to develop a definition of technology appropriate to the broad types of policy issues being considered. Next, the paper examines the international transfer process, the modes of transfer, and the parties involved in the transfer. Finally, the paper develops an awareness of the problems involved in identifying and measuring technology flows, in analyzing the effectiveness of various transfer modes, and in evaluating the effects of transfers on the parties involved and their objectives.

DEFINITION OF TECHNOLOGY

For purposes of this paper, technology is defined as

> a perishable resource comprising knowledge, skills, and the means for using and controlling factors of production for the purpose of producing, delivering to users, and maintaining goods and services for which there is an economic and/or social demand.

considered a corollary question -- namely, "Does the United States possess some unique technologies that would be in the best national interest not to transfer to other nations or even to attempt to transfer?"

Questions like these often arise during West-East, East-West, or North-South dialogues about the transfer of technology. One of the major stumbling blocks in such discussions is common agreement on what the term "transfer of technology" means. To someone from industry it means one thing, to an academic it may mean something else, while to a government policymaker it may convey an entirely different meaning. Yet, certain fundamental concepts must be agreed upon by the participants in a discussion of the subject if they are to understand each other.

Thus, the Committee on Technology and International Economic and Trade Issues commissioned a paper that would briefly outline the myriad ways in which technology is transferred. The paper would indicate, among other matters, the principal agents involved in the transfer process. Accordingly, Stefan H. Robock of Columbia University was commissioned to write the paper in cooperation with the committee.

A word is in order about the methodology for preparing this paper. The committee conducted a workshop in order to (i) involve additional experts in the field, (ii) obtain the views of representatives of various government agencies, and (iii) provide a forum for the committee members, academic and private industry experts, government specialists, and the author. The workshop was held February 3 and 4, 1978, in New York City. To give some structure to the workshop, Professor Robock provided an outline of the major aspects of many facets of the transfer process. Following this, the participants were given an opportunity to provide individual statements and evaluations on the subject. This monograph is the product of the workshop, but does not constitute a workshop proceedings. Successive drafts prepared by Professor Robock were circulated to the committee for review. He met later with the committee to discuss any criticisms and comments by the members. Therefore, the monograph expresses not only the author's views, but also generally reflects the views of the committee.

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