A Theoretical Paradigm for Importing Technology

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Abstract

Globalization of business in the recent years has accelerated transfer of technology across national boundaries. Although traditionally popular with less developed countries, technology importation has rapidly gained popularity over domestic development of new methods of production in industrial nations. This trend is partially due to increasing economic and technological interdependence among countries of the world, as well as increasing cost of domestic R&D. Since the appropriateness of the new technology to the recipient environment determines its chances of acceptance, systematic planning for importation becomes a pre-requisite to success. Ironically, there has been little methodical study of the transfer process. This paper presents a conceptual model which identifies five phases in the process of technology importation (see Figure 1). The result is a normative paradigm which provides a planning tool for the importer of technology.

The need for a theoretical paradigm to map various phases of the technology transfer process stems from two main sources: growing popularity of technology transfer and importance of appropriateness of new technology to the recipient environment. These issues are explored in the following sections. Literature on technology transfer commonly reflects two problems: comprehensiveness (mostly partial models) and perspective (mostly exporter's view). The section on methodology of transfer studies elaborates on these problems. What is needed is a comprehensive theoretical construct which reflects user's perspective. This paper presents such a construct.

1. Growing Popularity of Technology Transfer

Decade of 1980's witnessed an augmentation of popularity of new technology importation as a vehicle of economic growth (Garland, 1986, p.88; Mansfield, 1982). Globalization of national economies in the Western world combined with rapid political and social reforms in eastern block countries signals further enhancement of technology transfer in following years. Retrospectively, developing countries generated the primary source of demand for technology importation.[1] To pursue the end of speedy economic development, these nations mainly relied on importing technology from the industrial world (Burch, 1988). The evidence suggests that the rate of technology transfer to these countries has increased. During the 1960-68 period about 27 percent of the technologies transferred by U.S. firms to their subsidiaries in developing countries were less than five years old. This proportion for 1969-78 had increased to 75 percent.

Developed economies, until recent years, depended on internal R & D to generate the new technology required for their economic growth. Due to a number of developments in recent decades, this tendency no longer persists.[2] The U.S. economy has been no exception to this rule. Imported machines accounted for 40 percent of the U.S. machine tool market in 1983, up from only thirteen percent a decade earlier (Garland, 1986, p.2). Increasing demand for compact cars, combined with increasing car imports and the lack of sufficient domestic R & D, attracted the American automobile manufacturers to the profit potential of the imported small-car manufacturing technology (Nag, 1983). An examination of consumer products reveals that many components of American-made products are imported. Remington electric razors include parts from Mexico and the Far East, although the company has emphasized their U.S.-made appeal in their commercials in past.

Acceleration in the rate of technology transfer is prompted by the fact that many major companies have shifted an increasing share of their R&D overseas. In the pharmaceutical industry, for instance, about one-half of the total R&D in Canada and about one-seventh of R&D in the United Kingdom were done by U.S. firms (Mansfield, 1982). The increasing cost of R&D has also contributed to sharing of technology. A fall in rate of innovation in many industries (Grabowski, 1976), a shift away from long-term and risky R&D projects in many profit-seeking companies (Nason, 1978) and a decline in R&D share of GNP (Mansfield, 1982) are some other factors which promote the substitution of transferred technology for domestic development.

A central issue in the transfer of technology is its suitability to the new environment. The following section elaborates on this matter.

2. The Question of Appropriateness

The history of negative consequences of inappropriately imported technology serves as another justification for further study of the technology transfer process. Examples of such negative impacts are more easily traceable in many developing countries, where hastily imported technologies to meet rapid-economic-growth objectives have led to undesirable effects. Fatehi and Derakhshan (1982) used the examples of social problems created by introduction of "Lorena" stoves in Guatemala's Indian villages to emphasize the importance of sociocultural study of the expected effects of technology transfer before a full- scale transfer could begin. They suggested that planning, integrated with an adaptive management style, could help predict and deal with even unusual problems such as the mass hysteria among the female employees of semiconductor factories in Malaysia caused by "spiritual possession" (Fatehi and Derakhshan 1982). In a more recent work the same authors examined the ecological damages caused in some Asian countries due to inappropriate planning (Derakhshan and Fatehi 1999).

To reduce the undesirable consequences; therefore, to enhance its chances of success, transferred technology should be well selected, properly planned, and systematically implemented. "If new economic activities are introduced which depend on special education, special organization, and special discipline, such as are in no way inherent in the recipient society, the activity will not promote healthy development but will be more likely to hinder it (Schumacher, 1973)." The viability of imported technology also requires a continuous adaptation to the concurrent changes in the surrounding environment. In this respect, importation of appropriate technology involves a systematic and dynamic process. It simply is not a random or a one-shot venture.

The emphasis placed on "appropriateness" of technology once again calls for a systematic study of the transfer process. Increasing professional interest in the subject has generated some academic research in various fields. Researching the subject is often a difficult and ponderous task. Difficulties in inquiring into the nature of the transfer process stem from its multidisciplinary nature and the diversity of direction in research. None of the works reviewed by the authors has provided a comprehensive picture of the process of technology imp ortation. Part of the difficulty in constructing such a framework lies in highly abstract nature of the subject (technology), and the other part is due to the normative approach (application orientation). What is needed is a general theoretical framework to guide the decision maker on the transfer of technology. The following section presents a model which provides an integrative picture of the transfer process.

3. A Theoretical Construct

Figure 1 presents a framework for systematic importation of technology. Five phases outline the process of technology importation and adaptation. These steps in order of sequence are: need generation, feasibility study, technology selection and planning, implementation, and adaptation.

3.1 Need Generation

Need generation (Figure 2) is a prerequisite phase which creates the demand for new products or services which cannot be sufficiently and/or efficiently provided by existing technology or internal R&D. The desire for autonomy causes many countries to favor internal development over importation (Dahlman, 1981). In many developing economies this residual demand is generated and responded to within the framework of their economic development programs. Within such an environment, it is not unusual to find the role of key government and business figures to be much more important than that of the consumer. The same political and economic mechanism which determines the need for the new technology is often instrumental in establishing a decision agent responsible for organizing a feasibility study, selecting the importing technology and often planning to implement the new technology. The fact that the decision agent should represent and take into account a wide spectrum of interests ranging from political to economic, makes this position very delicate, burdensome, but yet a powerful one. Whether the head of the decision agency would be a politician, a bureaucrat or a businessman is primarily determined by the nature of the ownership of the technology-importing organization, of course.

3.2 Feasibility of Adaptation Study

Feasibility of adaptation study (Figure 3) precedes the decision on what an appropriate imported technology will be. This phase begins by determination of the type of transfer. Hayami and Ruttan (1971) have identified three types, or phases, of transfer. Arranged in the order of depth of transfer, "material transfer" aims at local production, "design transfer" enables local duplication of new technology, and "capacity transfer" involves importation of R&D capacity. Using examples from agriculture technology, transfer of seeds and plants, copying equipment, and movement of scientists represent these three types correspondingly (Pray, 1981). In our example, the choice of the type is based on the agroclimatic similarity of the adopting country with country of origin and also on the sophistication of the research system in the recipient country.

After selecting the type of imported technology, a checklist of major attributes of culturally, technically and politically appropriate technologies is produced to serve as an aid in the forthcoming decision making process. No list of criteria for selection of an appropriate technology could be prepared without sufficient understanding and study of related technical, economic, social and political forces. Examples of commonly used economic criteria are availability of low-cost domestic resources, proper labor intensity, and cost of the project (Pack, 1981). Main political considerations are autonomy and congruency with foreign policy (Nau, 1976). Among social considerations, distribution of income and cultural appropriateness of new technology are important (Ranis, 1981; Evenson, 1981). New technology should also match the present techno-structure of the recipient country, of course.

The pressure exerted from various interest groups complicates the preparation of the list of selection criteria. This pressure is unevenly imposed, depending on the nature of technology and its demand. Traditionally, importing governments have exerted more influence on agricultural technology, while the private sector had had more influence over importation of industrial and consumer-based technology (Heston 1981, p. 8). This has been due to the political sensitivity of many countries to the problem of food production, of course. Influence of the key interest groups also affects the critical contacts with the suppliers of existing technologies and inclusion or exclusion of any supplier among those studied. A developing country that is an economic satellite of France, for instance, will weigh French alternative technologies more than those of other countries.

Specifying the attributes of desired technology helps in identification of a set of candidate technologies which, if technically and financially feasible, and if the time permits, will be tested in small scale under simulated conditions of the importing country at the exporting country. Following on our example in agriculture, many improvements on wheat and rice varieties need to be more narrowly adapted to the specific environment of the recipient country (Evenson, 1981, p.54). International Agricultural Research Centers, The Ford and Rockefeller Foundations, and the United States Agency for International Development sponsor research in this area.

3.3 Selection and Planning

The outcome of phase 2 is summarized in a feasibility of adaptation report which serves as a major input into the selection of the appropriate technology. Based on the findings and recommendations of the feasibility report, a number of alternative technologies are identified which are then compared and ranked on the basis of the criteria chosen earlier (Figure 4). Selection of a "most appropriate" technology is not always a fast or a clear decision. However, a list of predetermined and specific criteria, combined with information on implementation of different alternatives in similar environments, should facilitate the process. In addition to the feasibility report, various international agencies, suppliers of technology, and related journals and publications can provide the necessary information.

Planning for implementation follows the selection of technology and its official approval. The extent and depth of planning is a function of the type of technology specified in the previous phase. The extent of planning required for importation of seeds (material) is different from that required for importation of R&D (capacity). Two major issues involved in this stage are contingency planning and building redundancy to ensure the reliability of plans. The fewer and the more predictable the outcome of events which follow prescribed courses of action, the more attractive contingency plans become. On the contrary, when a particular course of action could lead to many outcomes with little predictability, the contingency planning becomes extremely difficult and costly. Obviously the critical gauge to use for the decision on provisions for redundancy is the cost/benefit analysis based on the probability of the risk of plan failure. Like the space shuttle program, where the cost of project failure is great, an investment project which calls for billions of dollars financial outlay and requires years to complete can afford to go slightly over the budget to build in redundancy. A major economic consideration is to secure the financial commitment and support of the investors.

Political support for the program is equally important, especially if there are substantial government investments in the project. Planners should also assess the social reaction toward the new technology and devise a program to attract the support of the importing society. This is particularly a major consideration if the public visibility of the new technology is substantial.

3.4 Implementation

Implementation, (Figure 5) involves the actual transfer of technology into the importing country. The choice of the mechanism for transfer, e.g., turnkey operation, is determined by the chosen alternative.[3] Another related decision is the form of facility set up. Facility set up could take two forms: miniaturization and full-scale set up. Miniaturization involves a small-scale implementation of technology to reduce the cost of possible failure. The technology will grow to its potential if the environmental acceptance reinforces it. Success or failure of the miniaturization will ultimately determine the feasibility of full-scale implementation. While the full scale implementation would be the normal consequence of a successful experience, a failure of miniaturization could lead to either: 1) selection of a new technology if there is enough support for continued search, or 2) abandoning of the idea if support of the program is lacking.

Starting small is not always feasible or even possible. Despite the high cost of set up, which increases the expected value of the risk of failure, often a full-scale set up is the only alternative available due to technical economic or marketing considerations. Technically speaking, not all set ups could be miniaturized. Economies of scale sometimes provide cost saving opportunities that make miniaturization unattractive. And finally, if the marketing potentials are substantial, the full-scale set up permits management a production level that utilizes full potentials of the market before other competitors arrive. Examples of industries which are particularly prone to full- scale implementation are steel, aluminum and automobile (Baranson, 1978, pp. 41-69).

After completion of facility set up, the actual production and marketing of the output begins. In many instances these activities begin before facilities are fully completed. This is usually due to the pressing demand for the output of the new facility. At this stage, the actual testing of the production, marketing, and management systems begin. The initial environmental reactions to the imported technology are measured. The information concerning the degree of acceptability and support from the economic, social, and political sub-environments are received.
This information is gathered and analyzed in respective sub-environments within the organization and the initial adaptive reactions are triggered. Reconfirmation of supportive responses clears the path for full-scale implementation if a limited scale implementation was initially chosen.

3.5 Viability Cycle

Last phase of the importation process involves as action-reaction (stimulus-response) loop which stays operative as long as the technology remains viable in the surrounding environment (Figure 6). The initial acceptance of the new technology depends on the severity of the problem it addresses as well as the degree of its appropriateness to the surrounding environment. The green revolution, for example, received high priority because of the food crises of mid-1960's caused by droughts plus, in the case of Pakistan, the cut-off of American food aid at the time of Indian-Pakistani war (Pray, 1981, p. 72). This technology was rapidly accepted by farmers in areas of the world where agro-climatic and economic conditions were favorable (Pray, 1981, p.68). Environmental consequences of the new technology determine its viability in long run. Increased income, better income distribution and increased capacity of domestic R&D were some positive consequences of the green revolution in Asia, which in turn led to internalization of the program in importing countries (Pray, 1981, pp.74-80).

4. Conclusion

No discussion on importing technology is complete without a reference to its alternative, internal development. Dahlman and Westphal (1981) provide a theoretical construct for internal development of new technology, which they refer to as "techno-logical mastery." Similar to the model presented in this work, their process of project execution outlines various steps. In order of sequence, these steps are: Pre-investment feasibility studies, detailed studies following establishment of viability, basic engineering, detailed engineering, procurement, training, construction and assembly, and trouble shooting. Nine steps outlined provide a guiding frame of reference for planners. Given the internalizing tendency of adapted technology, Dahlman and Westphal's model provides more insight into the adaptation process. Therefore, their work are complementary to the framework presented here.

The described model used a systems methodology to outline the phases of the technology importation process and provided a list of the activities contained in each phase. In practice, however, the agent interested in importing a new technology rarely maps a formal plan which includes all the steps in presented model. In essence, this model portrayed a prescriptive framework which, if followed, could reduce the risk of failure associated with arbitrary technology importation. However, the gain from risk reduction comes only at the expense of lost time. It is ultimately up to the technology-importing agent to evaluate the cost efficiency of each phase, and determine whether that phase should be undertaken or forgone.

The normative model presented here serves as a beginning step. Two descriptive studies could naturally follow. A tempting hypothesis concerns investigating the significance of listed phases and activities for the success of actual transfers. Another interesting hypothesis to test is the frequency of the actual use of each phase.

Footnotes

[1]. Most literature on technology transfer in this period reflect this emphasis. For examples see: Frame (1983); Emmanuel (1982); Sahal (1982); Nau (1976); Baranson (1980).

[2]. Growing concem over economic and technological interdependencies among developed nations, including U.S. started to be expressed as early as 1970s. For examples of related discussions see Sternheimer (1981); Nau (1976) and Frame (1983).

[3]. For a comprehensive discussion on various transfer mechanisms at this phase see Frame (1983), pp. 71-83.

* For figures contact the corresponding author.

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