TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE 32, 5–18 (1987)

A Framework for Technology Based National Planning

THE TECHNOLOGY ATLAS TEAM

ABSTRACT

Technology, in today's increasingly interdependent society, provides hope, values, and faith for mankind. It brings hope for bridging the gap between the haves and the have-nots; it is responsible for altering economic and social values; and it is the faith upon which the world of tomorrow is being built. Thus, the relationship between technology and the development of our societies is inextricably bound in a complex manner. This paper examines the problems of achieving technology induced socioeconomic progress, as well as the limitations of current national accounting practices. To integrate technological considerations into the national development planning process better technology measurement methodologies must first be designed. Secondly, to make the integration process more organic and effective "make-some and buy-some technologies," based on the concept of an approach to development planning and using three technology domains (importing technology, traditional technology, and exporting technology) is needed.

Introduction

The relationship between technology and the social change process is very intricate and also mutually reinforcing. Advancement of societies—primitive to developing to developed to emerging—made possible by the use of technologies [10] is schematically shown in Figure 1. Historically, human activities have shown a distinctive change from dependence on nature to dependence on technology. In the early days, technology grew leisurely as a response to the gradually changing demand for social advancement. A distinctive feature of this process is the making and using of many kinds of physical tools for the amplification of muscle and brain power. By expanding the individual as well as collective physical and mental strengths, technology has enabled humans to depart from a purely biological evolution to an intellectual phase of evolution. Developing countries may be rich in many ways, but are very poor in technology or technologically less developed. Technology is emerging as the key for socioeconomic development; some even consider it as the panacea. Acknowledging the inevitable risk of losing out, developing countries are emphasizing technology-based development efforts. In other words, technology is now accepted as an important strategic variable for national development planning. However, integration of technological considerations with the development planning process still remains problematic [11]. This paper attempts to identify problems

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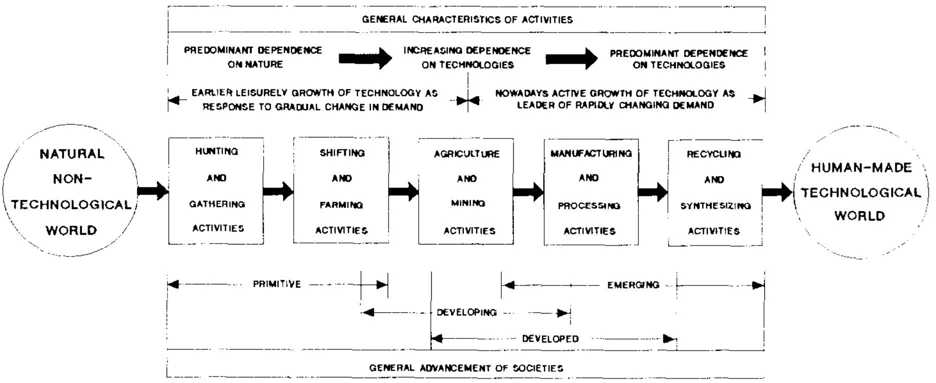

Fig. 1. Relationship between technology and social change.

and issues for achieving technology induced progress and deficiencies in the existing socioeconomic planning process so as to suggest measures and ways for carrying out planning using a technology domain approach.

Technology and Development

Developing countries are technologically less developed [13]. The vicious circle of technology and underdevelopment which has many reinforcing elements are shown in Figure 2. Even though most of the poor countries are, in fact, rich in natural resources and culture, they have three basic problems:

i. They have a relatively large population base, which is increasing rapidly.
ii. Their natural resource base is being depleted due to inefficient use and indiscriminate export.
iii. Their technological base is very small and ineffective.

These countries have to examine how to: i) control the growth of their population base; ii) conserve and optimally use their resource base; and iii) expand their technology base through the application of technology.

It has been observed that while the prices, in the international market, of the high technology content products have been increasing steadily, the prices of primary goods have been fluctuating widely and in many cases have dropped considerably. Selected examples are presented in Table 1 to indicate the dynamics of value of technology in trade [4]. For example, Indonesia has to exchange more palm oil in order to buy one automobile. International trade statistics indicate that the developing countries [4] mainly export primary goods (agricultural products, and industrial raw materials with low technology content) to the developed countries, while they import mostly manufactured goods (appliances, machinery, etc. with high technology content) from the developed countries. The two trends, first dependence on export of raw materials, and, second, increase in the cost of manufactured goods in relation to raw materials have strengthened the vicious circle given in Figure 2 over the years. If the vicious circle has to be broken it is necessary to understand the problems, constraints and opportunities in achieving technology induced progress.

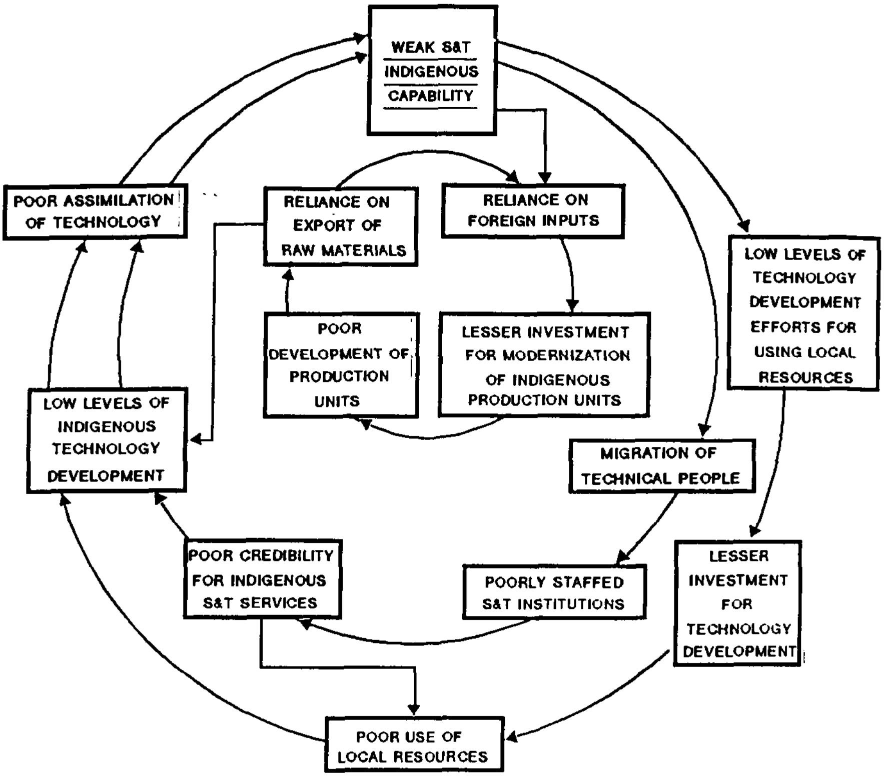

Fig. 2. The vicious circles of lack of technology and underdevelopment.

TABLE 1
Examples of Changing Value of Technology in Trade

Year	Indonesia Tonnes of Palm-Oil Needed to Buy One Car	Pakistan Tonnes of Rice Needed for Buying a Car
1971	5.83	—
1972	8.26	—
1973	6.20	—
1974	3.20	5.51
1975	7.06	4.38
1976	8.40	8.26
1977	8.26	8.24
1978	7.12	6.10
1979	6.40	4.44
1980	7.99	8.72
1981	8.05	8.85
1982	11.98	8.92
1983	15.41	10.47
1984	16.03	—

Problems, Constraints, and Opportunities in Achieving Technology-Induced Progress

In some of the developing countries there is a visible attempt to integrate technological considerations in the development planning process. The APCTT country studies [2] on Technology Policies and Planning (undertaken during 1985–86) indicate the existence of a number of problems and constraints.

The Asia-Pacific region consists of countries of enormous diversity. Some of the most common problems [12] faced by a majority of the developing countries of the region are:

The first set of problems may be categorized as problems in understanding the unique characteristics and related aspects of technology. For example:

- technology is not just a physical production tool, but really a complex combination of both the tool and the know-how associated with the tool;
- technologies as embodiments of such complex combinations, are marketable and have both economic and political values;
- the world is becoming increasingly interdependent due to technological specialization; and
- technological advancement could be considered as a good measure of national development.

The second set of problems arises due to the existence of a widely varied number of preferences and perceptions, such as:

- the general population's preference for imported technologies rather than locally generated technologies;
- the unrealistic expectation regarding technology transfer as a byproduct of foreign investment;
- the common perception of self-reliance as being equivalent to self-sufficiency in technology for economic growth;
- defining technological appropriateness only with respect to labor intensiveness; and
- following the bandwagon, without selectivity, in building local technological capabilities.

The third set of problems is associated with the organizational infrastructure and prevailing management practices, which include:

- ineffective public sector research and development institutions;
- knowing science (knowledge) being given operational command over doing science (application), the successful use of which reflects a nation's ability to use technology for development;
- missing or weak linkages between users and suppliers of generated and imported technologies;
- the absence of any sort of institutionalized attempt at monitoring, forecasting, and assessment of technology;
- the compartmentalization of technology by institutional design in government organizations (ministry/division/department);

- the ineffective coordination by ex-officio committee members who have other pressing concerns; and
- choices of technology being generally considered only at the lowest level of planning hierarchy.

The fourth set of problems refers to the level of commitment to technological considerations and leadership behavior, such as:

- statements of policy-makers not sufficiently backed by financial, fiscal, and legal support;
- technologists and scientists not being exposed to management and socioeconomic development concepts;
- politicians and planners displaying their own biases or inclinations without a visible compromising approach; and
- attempting unprecedented and revolutionary changes with outdated administrative procedures.

The fifth set of problems may be referred to as the problems of climate represented by the attitudes and preoccupations of the people, such as:

- attention of top leadership being devoted mostly to crisis management, whether warranted or not;
- high-level policy decisions being made in response to immediate political and economic pressures, while questions of long-term sustainability and the implications for the less powerful actors in the development process get overridden;
- scarcity of time, as intellectual priorities are clogged with trivia and ceremonial duties; and
- finding fault with others, and using the excuse of uniqueness to avoid necessary action.

Most of the problems listed above are internal rather than external and can be resolved with strong determination and wholehearted commitment at all levels. However, there are many other problems which are more external than internal. These are listed here as general constraints:

The first set of constraints is basically due to the dependence of many developing countries on external assistance, such as:

- decisions with respect to the selection of development projects being conditioned by the funding source;
- the mode of operation of international institutions inadvertently reinforcing dependence;
- assistance being conditioned by considerations other than the developmental needs of the recipient; and
- nonrelevant research activities being undertaken with easily available seed money from abroad.

The second set of constraints is primarily due to the demonstration effect caused by the communication revolution, resulting in:

- aspirations being raised to frustratingly high levels by ever-increasing coverage in the mass media;
- illusions of achieving in a few decades what the developed countries achieved in centuries; and
- the widespread use of the power of collective indiscipline for nondevelopmental expenditures.

The third set of constraints may be attributed to the situational change faced by the late starters, such as:

- the ratio of naturally available resources to population being worse now for most developing countries;
- a high propensity for suboptimization due to narrow specialization and professional isolation; and
- the adverse skill structure of the labor force due to brain drain and degradation of craftsmanship.

The constraints listed above are not necessarily exhaustive but are the ones commonly experienced, and certainly these are not insurmountable. The negative influence of many of these constraints can be reduced in the long run through visionary zeal and collective sacrifices.

The problems and constraints listed above should not lead one to believe that everything is hopeless in the developing countries. On the contrary, the developing countries also have many late-starter advantages. Listed below are some of these opportunities for exploitation by the developing countries.

Developing countries do not need to reinvent the wheel. It is possible for them to tap accumulated technologies and knowledge in many ways:

- knowledge can be gained through formal and informal education, training and retraining;
- effective learning is possible from the experiences of both developed and other developing countries;
- many production technologies are available internationally, however mostly through transnational companies;
- information about technologies is available from public and private information centers; and
- expertise is available from local and foreign consultancy service firms.

However, it should be noted that the price of any technology depends on the relative bargaining positions of the seller and buyer.

Developing countries can greatly benefit from the judicious application of some of the emerging technologies because:

- some emerging technologies are multipurpose and pervasive in nature (e.g., microelectronics);
- some emerging technologies are scale neutral for production and use (e.g., biotechnology); and
- some emerging technologies are also situation independent for application (e.g., computer-aided design/manufacturing system).

Developing countries can also take advantage of the inherent characteristics of the technological change process. Since technological change occurs through a series of successive substitution and diffusion process, there are two significant implications:

- eventual catch-up is possible due to the S-shaped growth pattern of any particular technology; and
- leap-frogging is possible sometimes by skipping the intermediate stages of technological change.

Figure 3 gives a schematic representation of stages of changes involved in a typical situation involving technology substitution and diffusion.

Another advantage for late starters is the opportunity for avoiding known pitfalls, through:

- effective learning from the experiences of both developed and other developing countries;
- preventing or minimizing the possible negative impacts of certain available technologies; and
- carefully studying the successes and failures of one's own past experience for determining future activities.

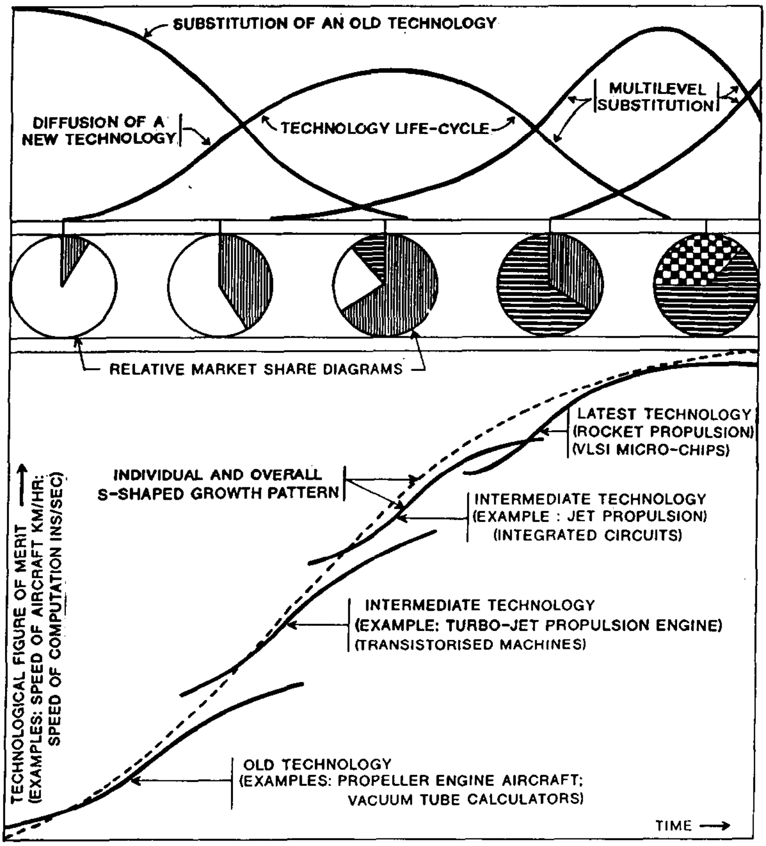

Fig. 3. Sequential S-shaped technological change process.

One of the major reasons for not being able to avail of these opportunities for socioeconomic development has been the inadequacy of mechanisms for integrating technological considerations in the planning process derived from a strong commitment to technology at all levels.

Technology and the National Planning Process

The existing macroeconomic planning process [9] consists of the following steps:

- formulation of a macroeconomic policy;
- translation of policies into growth rates of various sectors;
- allocation of resources for various sectors based on the planned growth rates;
- project formulation and appraisal.

The planning procedures aims to achieve the socioeconomic goals through investment analysis and an optimal allocation of resources. Development planning limited only to project level or resource allocation makes it difficult to coordinate planning at the different levels [5]. When this happens, technology, which is the transformer of the resources, is considered only indirectly. Most often, technology is treated as given and does not appear as a planning variable [1]. Very rarely has the change in technology, involving change in technical knowledge manifested in new forms of physical capital and organization of the production process, been considered explicitly in planning. The planners in the developing countries thus tend to assume that technology remains constant or changes in not such a significant manner so as to create an independent impact on total production [1]. This problem has been further aggravated by certain deficiencies in the national accounting system.

Deficiencies of the National Accounting System

Absence of reliable and precise data, inconsistencies in their collection and compilation and incompatibility of the compiled data from different sources within a country itself, etc., have been identified as some of the major problems of the existing accounting systems [7, 9]. In the field of national accounts a wide variety of information is collected and presented for use in economic planning such as commodity input–output tables, intersectoral accounts, income distribution measures, socioeconomic indicators, etc. Despite the overwhelming attention paid to growth, the deficiencies of GNP per capita as an indicator of economic development has become apparent [7]. However, the basic inputs for all economic transformations, namely, natural resources and human resources, do not appear explicitly anywhere. Natural resources have not entered the agenda of analysis in development economics and national planning so far [3]. Even sophisticated government decision-makers often set the notional prices of resources *in situ* as zero, i.e., they treat them as free goods and undervalue them. Furthermore, another deficiency in the national accounting system is that in calculating the net national product of any economy one deducts depreciation of physical capital from the figure for GNP, but not the depreciation of the national resources consumed, (i.e., reduction in the index of their stock). Since natural resources are also capital assets, perhaps the prime type of capital assets, a consistent set of national accounts ought to display their changes [3]. In other words, the present planning methods and national accounts do not explicitly depict the nature and role of technological transformations of resources in development. Thus, other perspectives which will help to obtain a more realistic picture of transformation of resources rather than a pure flow of monetary resources are required. Such a basis may provide better insights into the transformation processes. Thus, there seems to be a strong need to have measures of technology in terms of the transformation processes for development apart from the existing or conventional national accounts.

Need for Better Measures of Technology for Development

Since the existing national accounts do not depict the nature of transformation of natural resources into goods and services for the utilization of the produced goods, developing countries need to have better measures of technologies in terms of their own scientific and technological activities both in relation to their own societal needs and in comparisons with world standards. Thus, there is a need to apply existing science and technology indicators and also to develop new measures so that current limitations in the measurement of socioeconomic changes can be overcome by changing over to a more appropriate basis for measurement.

Technology measures can play an important role even from the point of descriptive purposes. Well-defined technology measures can help in comparisons among countries from various angles. If such comparisons are carried out, attention can be drawn to critical issues for public attention and for the consideration of national planners. Technology measures, if suitably devised, can also be used for analytical purposes which will help in the understanding of the economic consequences that result from carefully planned technology development activities. Thus, technology indicators can be an important aid to a better understanding of causal structures relating science and technology to the development system of a country.

Science and technology measurement activities are currently [6, 8, 11] carried out at four levels as indicated below:

Level 1. Firm/department level analysis;
Level 2. Inter-firm/inter-department comparisons;
Level 3. Industry level/national analysis;
Level 4. Regional/international comparisons;

A summary is given in Table 2.

While various classifications of existing science and technology measures, often called Science and Technology Indicators (STI), are available, the most popular grouping divides STI into:

1. input indicators;
2. output indicators.

Input indicators attempt to evaluate the resources which are required as inputs for the pursuit of S&T activities. Examples include funds, personnel, and institutions. More detailed examples of input indicators at various stages of the S&T system are shown in Table 3.

Output indicators attempt to measure the results of S&T activities. Some examples of S&T output indicators are publications, patents, and innovations. More detailed examples of output indicators are shown in Table 3.

Application of existing STIs, like other social and economic indicators, always require careful interpretation. They should not be used mechanically and their application

TABLE 2
Levels of Science and Technology Measurement Activities

Level	Scope and Purpose	Users
Level 1: firm/department level analysis	Collection and publication of a variety of partial indicators for purposes of internal monitoring, budgeting, and planning	Firm level managers Academic researchers Specialists in industry and national planning agencies
Level 2: interfirm/interdepartment comparisons	Interfirm comparisons supplemented by information collected specifically for each study Can point to important conclusions for national policy making	Academic researchers Specialists in industry and national planning agencies Business associations Sectoral level policy makers National level policy makers
Level 3: industry level/national analysis	Industry level/national statistical surveys carried out by government/private agenices Requires use of standardized definitions and concepts Can point to important conclusions for national policy making	Academic researchers Specialists in industry and national planning agencies Business associations National level policy makers
Level 4: regional/international comparisons	Carried out by regional/international agency Requires harmonization of various national definitions and procedures Useful only if activities are innovative and catalytic which leads to dissemination of "best" practice" across national frontiers	National governments International agencies

requires an awareness and understanding of the complexities affecting both the measurements themselves and the social system which gives rise to these measurements.

Past experience has indicated that in general, more than one STI should be used to analyze a problem. For instance, while U.K. and U.S.A. show strong performance with respect to bibliometric measures, their patenting performance is inferior to that of Switzerland and Japan. Thus, while the examination of only bibliometric measures or patents may be misleading, their joint examination show that while U.K. and U.S.A. have greater capabilities in basic research, Japan and Switzerland have better innovative capabilities.

Currently available science and technology measures have been developed over a period of time by the industrialized nations in relation to their development and use of science and technology. The pattern of economic development and usage of science and technology in the developing countries has been substantially different. Thus, it is imperative that technology measurement efforts in the developing countries recognize this fundamental difference and develop measures which can evaluate important technological activities previously not considered to be relevant by the early developers.

TABLE 3
Review of Existing Science and Technology Indicators

Stage	Input Indicators	Output Indicators
Basic research	Stock of S&T personal by • category • field of specialization • type of employer • sectors of performance • primary work activity • qualifications	Bibliometric measures
Applied research	R&D expenditure by • type of expenditure • sector of performance • source of funds • type of R&D activity • type of employer • field of specialization • major socioeconomic aims Auxiliary personnel associated with S&T	Bibliometric measures Patent measures Object specific measures of technology
Development		Bibliometric measures Patent measures Object specific measures of technology
Production	Stock of S&T personnel by • category • field of specialization • type of employers • sectors of performance • primary work activity • qualification R&D expenditure by • type of expenditure • sector of performance • source of funds • type of R&D activity • type of employer • field of specialization • major socio-economic aims	Object specific measures Diffusion measures Technology transfer payments
National level	Tertiary level education • student enrolments and graduations by field of study • teachers by field of study • funding by field of study Primary and secondary level education • student enrolments and graduation by field of study • teachers by field of study • funding by field of study Publication and S&T subject distribution of academic books Adult literacy rate	Technological balance of payments Trade in high-technology products

Some of the aspects which are not examined by current technology measurement activities are as follows:

- evaluation of the level and quality of scientific and technical information;
- evaluation of national capabilities with respect to management of R&D;
- evaluation of national capabilities with respect to commercialization of research results;
- evaluation of national capabilities with respect to reverse engineering, adaptation and improvement of imported technologies;
- evaluation of national capabilities with respect to engineering services and quality assurance;
- evaluation of technology gaps and levels of specific sectors/fields;
- evaluation of the technology level of national production systems;
- evaluation of the degree of availability and quality of natural resources;
- evaluation of the national technology climate.

It is thus imperative that the aspects outlined above be dealt with adequately by the developing countries, to ensure the effectiveness of the technology-based development planning approaches currently being considered by them.

Technology-Based Development Planning

The role of government in technology planning is a major one while it may be a minor one in the developed countries where the private sector is well established and appreciates the role of technology in economic growth. Observed trends of deliberate specialization throughout the world are expected to increase technological interdependence among all countries. Natural resources and human resources being so widely distributed, attempting self-sufficiency with respect to all technologies may indeed be uneconomical. Therefore, the "make-some-and-buy-some-technology" is perhaps the most pragmatic strategy for sustainable and self-reliant national development. In the present day developing countries, which could not afford to wait for a gradual technological change in response to the needs of their almost economically stagnant societies, technology is expected to cause rapid socioeconomic development. It is also essential that specific considerations be given to the "make-some-and-buy-some-technology" strategy which gives a country an opportunity to take advantage of its late-starter status, the advantage of selecting an appropriate area of specialization, and the potential to exploit the advantages of technology exchange in the international market place.

Development Planning Using the Technology Domain Approach

It is desirable that an integrated approach to development planning, which aims at harnessing the full potential of technology for development, be considered by classifying national development projects into three "technology domains" [11]:

i. projects belonging to the "importing technology domain";
ii. projects belonging to the "traditional technology domain";
iii. projects belonging to the "exporting technology domain."

The importing technology domain represents areas for which a country has chosen to depend on imported technologies. Usually these are areas which involve:

- technologies requiring long periods and large amounts of funds to be developed locally;
- technologies which are not currently available in the country but which can have significant impact on quality improvement and cost reduction;
- technologies protected by industrial proprietary rights;
- technologies embodied in capital goods which cannot be produced locally;
- technologies which can have a beneficial impact on other technologies being developed for exports.

The traditional technology domain represents areas for which a country has chosen to improve endogenous technologies such as:

- technologies with traditional heritage;
- technologies which attempt to promote harmony in human surroundings;
- technologies which are directed to rural people, etc.; these projects are based on endogenous technologies which could be modernized by introducing advanced knowledge and techniques, either locally developed or imported, to gradually improve the life of a country's rural population.

The exporting technology domain represents areas for which a country has chosen to develop state-of-the-art technologies for local consumption and export because:

- the country has relative advantage in terms of necessary resources;
- the country has a geographic or locational advantage, etc.; these projects are expected to provide a source of foreign revenue for making technology imports possible in the long run; the production and export of some high-potential technologies (either hardware, software, or both) represent new and nontraditional activities for a developing country.

Very often a country may have developed a certain amount of expertise in a technology for certain specific applications but not for others. For example, if a country has developed crop husbandry capabilities in the area of tea cultivation but not in horticulture, then it may be necessary to get this latter expertise from another country while exporting available capabilities in this area to some other country. For certain technologies all three technology domains may be relevant. In certain areas such as remote sensing, genetic engineering, and the like, due to lack of local human resources the country may need to rely on foreign technology in the short and medium term. However, the ultimate objective should be to master these imported technologies and the table shows that provision has to be made for setting target dates for acquiring certain levels of capabilities or producing desired impacts in all three domains.

Concluding Remarks

Technology has emerged as a crucial strategic variable for rapid socioeconomic development in an increasingly competitive international environment. Therefore, even in the developing countries there is an attempt to integrate technological considerations in the development planning process. However, the internal problems, external constraints, and opportunities make this exercise a complex and challenging task.

These aspects have been examined in this paper and attention has been drawn to the fact that current national planning processes, national accounting procedures, and technology measurement approaches have many inherent deficiencies which need to be rectified if technological considerations are to be effectively integrated into the development planning process. One possible method to harness the full potential of technology for development—the "technology domain approach"—has also been proposed. It is envisaged that this approach will enable a holistic view to be taken in a technology-oriented planning exercise.

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