The development of an indigenous technological infrastructure has always been considered a public policy goal in its own right. In the early fifties and sixties, technology planners in the developing countries explicitly and deliberately sought to achieve full command of modern, complex technologies (atomic energy, computers, space technology) in the belief that, if a local capacity could be developed and used for dealing with problems involving considerable technical sophistication, the development of local capacity to deal with simpler issues would not present a problem (Bhabha, 1966; Sabato, 1973a). At the same time, countries sought to establish a broad infrastructure for scientific and to a lesser extent technological research, in the belief that technology needed for industrial growth would automatically follow, to be adopted and assimilated by the local industrial sector.

This approach was a natural response to the conditions of the time. Fresh from the experience of World War II, scientists and technologists all over the world thought the complex social problems would yield to the power of laboratory research and development. Besides, political leaders could be convinced to assign high priority to the construction of technological enclaves (atomic energy commissions and the like) even if they were unwilling to devote the necessary attention to their countries' social problems.

In retrospect, it is clear that this approach underestimated the difficulty of applying science and technology to social problems, and it ignored the costs and uncertainties associated with building technological capacity at the enterprise level. Indeed, it even underestimated the difficulty of applying science and technology to the modernization of manufacturing industry—the area which technologists gave their major attention. For the most part, technological infrastructure has in developing countries been isolated from the productive sector—"marginalized," in Herrera's words (Herrera, 1975).

We would suggest that the concepts of technological capacity and technological infrastructure have been confusingly treated in the technology policy literature. This confusion has made it difficult to focus on the real objective—that of developing local capacity to deal with the technological elements of development problems and projects—and to understand and assess the role of the large number of ostensibly non-technological institutions that exercise a critical influence over technological decisions. It has also made it easy to ignore the importance of innovators in the small-scale and the informal sectors of the economy, where much of the GNP and most of the employment in developing countries is located.

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Technological Infrastructure and Technological Capacity

We propose to define technological capacity as the ability to make technological decisions that will influence the allocation of resources and the efficiency of production units. By technological infrastructure we understand the public and private institutions which provide technical services for the selection, adaptation or creation of technologies, for pre-investment and project implementation work, for quality control and trouble-shooting in production processes and for technological management and planning both at the macro and the micro level.

Technology, broadly defined, is the technical means of reaching an objective. Thus, virtually any activity requires technology of some kind—even primitive agriculture with a pointed stick. More formally, it is the organized set of all the empirical and scientific knowledge required for producing and distributing any goods or services (Sabato, 1971b). It includes equipment, installations, and materials (hardware), as well as production, organizational and managerial practices (software).

Technology is commonly said to be "embodied" in hardware, and to be "transferred" through the purchase of equipment, e.g., a turn-key installation of a factory. Strictly speaking, this is installation of hardware, not transfer of technology. Most of the embodied technology remains in the firms that designed, manufactured and installed the equipment, the receiver acquiring only the mastery of the knowledge required to operate them—this only when there is a real transfer of skills and the operation does not remain forever in the hands of expatriates.

Acquisition of production technology begins when local capacity is developed to operate the machinery and to manage and maintain the plant. A further step in technological development is the ability to make minor innovations and improvements, and to design comparable installations. As its level of technological maturity increases, a country reaches international standards of cost and quality and begins to make significant technological improvements through its own research and development and its own intelligence about local and international markets. Even before this has been achieved, it may begin to re-export the technology in the form of products, capital goods, technical services and even turnkey plants.

Technological capacity is needed to identify and define technologically feasible development goals and strategies at the sector and project level; to shop for, select, negotiate for, and acquire technology and insure its adaptation to local conditions and resources; to implement, operate and improve that technology; to solve practical problems as they arise; to evaluate the effect of technology and assess its overall social impact; to generate new technology; to train qualified technologists and insure their productive utilization; to keep up-to-date on global technological developments and on technological elements of problems (such as food and energy) requiring global management; to assess the impact of and opportunities created by real or potential technological innovations; and to advise the government and the public at large on national and international policy issues requiring an understanding of technology.

The technological capacity of a country is made up of the formal, technical institutions as well as of the technical staff of enterprises, financial institutions and government agencies. The line between productive and technological capacity is sometimes fuzzy, especially when, as in smaller enterprises, productive and technological activities are undertaken by the same small group of people. The engineer of a small or medium-sized business in the modern sector may, for example, test a new prototype at the same time that he supervises the firm's regular production schedule.

Village workshops and cooperatives, individual small farmers and entrepreneurs, also make daily technological decisions. For example, a small farmer in Upper Volta himself invented a system of low earth dikes and culverts to slow the flow of rainwater washing across his flat land and hence to increase percolation and make more water available to his crops. Nor should we forget the volunteer organizations and appropriate technology groups that are springing up throughout the developed as well as the developing countries, and whose efforts are focused on helping the poorest sectors of the economies to develop their technological capacity, consequently improving their living conditions.

The term technological system has frequently been used to describe the technological infrastructure of a country, but its definition and description remain imprecise (Sagasti, 1975). It is hard to know which units each author includes when referring to a technological system. We suggest that the distinction between technological infrastructure and technological capacity has the important advantage that it brings clearly into focus the fact that the major objective of technological policy is to create technological capacity—which is best located in the productive sector—not to create technological infrastructure per se. The primary task in developing such a capacity is to build up the skills to plan for and carry out investment projects, to consider alternative technological approaches, to manage foreign expertise and to train human resources.

Technology: Its Demand and Supply

It is usual and for many purposes useful to distinguish between the demand for technology and its supply (Sagasti, 1978a). From what is said before, the locus of the demand for technology would be the decision maker within an operating entity—a farmer or entrepreneur (large, medium, small or tiny), the managing director of a government-owned plant, or the operating head of a public service such as an irrigation district, a water supply company, or a highway authority.

The technological capacity of such an entity will vary widely—from the three-man shop or small farm whose owner makes all decisions based on his wits and experience, to a medium-sized firm or farm with a full-time production manager who can squeeze out some time for planning and equipment selection, to a ministry, large public or private firm, or multinational corporation with a substantial planning and engineering staff. The willingness of the operating entities to retain technical staff on its payroll or to contract services from units in the technological infrastructure and to use them in the making of technologically based decisions is the first, and in many ways the most important element of the demand for technology.

A decision by an enterprise to undertake a new activity or to improve existing methods may translate directly either into the demand for equipment through dealers and salesmen or purveyors of turnkey plants; or the demand for proprietary technology and know-how through licensing and techn-
Without adequate technical advice for analyzing alternative offers, the decision-making process may be highly inefficient both from a micro and a macro perspective. For this advice the decision-makers may turn to local or foreign sources of technical services (consulting and engineering firms and institutional external to their enterprises) or may rely on their internal technical staff. Particularly difficult investments or planning decisions or particularly thorny problems of product or process design or plant management, may result in the commissioning of discrete projects of research, development, or engineering, either in the entity's own staff, in an external organization, domestic or foreign, or in a combination of both. From this point of view, research and development serves as a backup to such advisory functions as pre-investment, trouble-shooting, and product and process planning and design.

Research laboratories and technological institutes (especially when publicly supported) should serve many purposes in addition to their role of direct support to operational entities. Their job is to scan the horizon for problems or opportunities that others in the country have not recognized, to apply technology to local problems, and to keep abreast of technological progress outside the country and its possible domestic implications.

Linking Local Supply and Demand

For sound and self-reliant economic development, there must be vigorous interplay between the element in the technological infrastructure seeking to "push" technology into the market and the agents whose technological capacity exercises a "pull" on the technological infrastructure and stimulates the creation of new supply. The interplay depends on the broad framework of national economic policy and on the attitudes, policies and practices of financial institutions and socio-economic regulatory bodies which are not usually included in the study of technological capacity and which do not have indigenous technological development as an explicit, let alone a high-priority objective (Sagasti, 1978; Ramakrishnan, 1979).

We would suggest that these institutions should become aware of their critical influence on building local technological infrastructure and on providing opportunities to the local technological capacity for making and implementing technological decisions.

Government policies may use tax credits, subsidies, loans and direct grants for promoting inventions and technological improvements. Other instruments the policy maker may use to link local supply and demand of technology and technological services and to strengthen the elements of the local technological infrastructure are procurement and bidding practices to encourage local suppliers of technology and, and tariff schedules and legislation to regulate foreign investments to increase local value added.

Policy makers should also defend technological institutions concerned with long-term problems from undue political pressures and fluctuations; should ensure that these institutions receive adequate funding, and that the allocation of funds reflects national priorities; and should bring the needs of these institutions and their special perceptions of the needs of the country to the attention of political and entrepreneurial decision makers. These efforts are critical to the long-run technological development of the country and vital to be local officials and administrators with short-term horizons and large sums of money to administer.

The role of financial institutions is particularly important because in most developing countries, capital may exist in the form of savings but only a fraction of this is actually available for industrial investments, the bulk being invested in land or commercial enterprises or channeled abroad. There is no effective capital market for channelling into productive investment a sufficiently large portion of such savings as exist. To overcome these constraints, governments have promoted development banks, investment companies, and risk and venture capital funds for the development and commercialization of innovative technology, and in many instances have attempted to involve commercial banks also.

Insofar as the policy objective is to improve the effectiveness of financial institutions as agents of technological development, it behooves the policy maker to examine among other things the following: (i) the project appraisal criteria used by financial institutions, which influence the extent to which local factor endowments and natural resources will be utilized in projects; (ii) the ways by which financial institutions made available to the enterprises they finance technical and managerial assistance in project identification and formulation, as well as during project implementation and operation; (iii) the availability of domestic and foreign market intelligence and information on technological alternatives to enterprises.

In addition, few enterprises in developing countries combine investment capacity with innovative ability in technology, and the limited initiative on the part of the industrial community to seek out and venture into new areas of activity is handicapped by erratic government policies. The willingness to invest in technological research and development other than routine maintenance and testing is most often conspicuously absent (Mindlin, 1979). The larger enterprises in some of the more advanced developing countries have, instead, paid more attention to diversification and product differentiation. In short, gains from local "learning by doing" — the cornerstone of technological development — are rarely captured by investing enterprises in developing countries because the time required by such a process to yield economic benefits is frequently beyond the planning horizon of the individual firm. In other words, the social rate of discount is lower than the market rate (Cooper, 1976).

Technological Capacity as Part of Overall Development Policy

Just as analysis of technological policies must consider elements apparently far removed from technology, broad analyses of a country's overall development strategy and economic situation should take explicit account of technological issues. Economists have always considered the possibility of policy measures designed to affect capital and labor in order to accommodate their costs to their relative availability. They should also begin to consider technology as a distinct, variable factor of
production which policy makers and project designers can manipulate in order to accommodate, in each particular situation, to the cost and availability of the other production factors and to the existing and desired level of local technological skills and capabilities (Sabato, et al., 1973).

The analysis of a country's overall economic situation has traditionally focused on issues relating to their creditworthiness, e.g., output growth, investment requirements, resource mobilization, balance of payments, pricing, and fiscal and monetary management. The scope of such work is being increasingly broadened to include such topics as rural and urban development, employment, land and income distribution, and population and human resource development.

This shift of focus from short-term analysis of economic and financial policies toward more in-depth exploration of long-term structural problems makes it important to include explicitly the technological dimension, in order to: (i) improve the understanding of how technology can be mobilized in the context of specific development projects and how it can be related to the overall socio-economic development strategy of the country; (ii) bring about a better fit between investment projects and the country's technological needs and resources. Experts in each developing country should have the capacity to carry out such analyses.

Broad economic studies provide essential background on strategic policies and issues that exercise a critical influence on the nature, suitability and impact of technology, and the development of local technological infrastructure and capacity. For instance, a call for a more liberal trade regime and a recommended shift from an import substitution to an export promotion policy implies the need for strengthened local capacity for overseas market intelligence, export standards, quality control and testing, troubleshooting, pre-investment work, product development, engineering, and research and development.

Without such local capacity and in the absence of explicit governmental policies to stimulate its utilization by entrepreneurs, such a shift in strategy could lead to a growing dependence on foreign technological sources. Both public officials and private entrepreneurs tend to favor the importation of the required technological inputs for investment projects in order to save money, reduce risks, avoid responsibility for failure, and shorten lead times and because of the greater political weight attached to short-term development targets compared to the longer-term goal of fostering an indigenous technological capacity.

When developing countries either have no or at best a weak, local technological capacity and do not take measures to counteract this tendency, their growing technological demand is met by foreign sources, a fact that in turn reinforces the weaknesses of the local technological infrastructure. The lack or shortage of domestic skills and capabilities has important implications for a country's foreign exchange position. A number of UNCTAD studies have focused attention on the direct foreign exchange costs of transfer of technology through such channels as feasibility studies, turnkey contracts, licensing agreements, and technical assistance. These costs may be disguised as higher prices for intermediate materials or equipment (UNCTAD, 1976).

At least as important as these direct costs are the indirect costs of having critical investment decisions made by foreign technologists who may not be closely familiar with local suppliers, raw materials, or cultural or ecological conditions, or who may be biased towards unnecessarily sophisticated technology or insufficiently diligent in seeking the lowest price or the best terms for the technology to be utilized.

Another example of an issue which has traditionally not been conceived as an important concern for technology policy, is that of poverty. One of the factors that has contributed to an exacerbation of poverty in many developing countries, is that rapid growth has occurred in a small "modern" sector of the economy using advanced technologies, without much benefit to the traditional areas of economic activity. The number of jobs that can be created in these modern sectors, which primarily involve urban manufacturing, is inadequate to keep pace with the growth in labor force.

A policy aimed at alleviating poverty, through expansion of productive employment opportunities, also demands a strong and efficient indigenous technological capacity at the local level, geared to the requirements of small farms, small-scale rural industries and the urban informal sector, and capable of upgrading the technology already in use in order to increase productivity and improve living conditions. It also signals the need for a reorientation of the activity of the local research laboratories, technological institutes and engineering groups in support of governmental efforts to expand the supply of public services at a cost affordable by the users.

The proper starting point of an analysis of technology policy as part of a broader development policy is the clear definition of the socio-economic objectives established for the latter and consideration of the requirements those objectives will impose on the technological infrastructure and capacity of the country. In agriculture, for instance, such an analysis would consider issues that are not ostensibly "technological" but nevertheless influence technological development, such as rural income distribution and social structure, the availability of credit to farmers of different kinds, organizational systems for procuring inputs and marketing outputs, land tenure arrangements and farm size, and the possibilities of stimulating rural non-farm employment.

In rural water supply programs, for example, most constraints relate to financing, manpower and institutions, low village incomes, undefined or overlapping responsibilities of various state agencies, uneconomic water charges, ineffective means for collecting water charges, lack of public health education and poor and inadequate repair and maintenance procedures. These are all problems which may be overlooked in a typical technological analysis concerned only with problems of hardware or with the building of research laboratories and technological institutes.

This new approach in technology policy analysis would bring out more clearly than in the past that in some cases, the best solution to a development problem may not be the introduction of new technologies per se but rather more participative forms of organization (e.g., farmers' cooperatives for sharing costly agriculture equipment); while other problems, normally looked upon as economic policy problems, could in fact lie in improved technology (for instance, the diffusion of low-cost, on-farm storage facilities for agricultural products to improve farmers' bargaining power in the face of seasonal fluctuations in crop prices).
Conclusions

If local supply is to be integrated with local demand for technology, explicit attention must be paid to the following issues:

(i) the building of technological capacity within public and private enterprises and governmental operating agencies;

(ii) The provision of adequate technical assistance for project design implementation and operation with special attention to small production units which cannot afford to build their own internal capacity;

(iii) the availability of research, development and engineering services to back the technical activities of the productive system at any level of size or sophistication;

(iv) the protection of technological institutions concerned with long-term problems from undue political pressures and fluctuations;

(v) the effect of the policies, practices and capabilities of banks and governmental regulatory bodies on investment priorities, on the pricing of production factors and on the criteria for the use of local technological capacity; and

(iv) the fitness of technological institutions and general technology policies as instruments for the accomplishment of socio-economic development objectives, especially those concerned with poverty.

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