



A Framework for Science and Technology Policy Research*

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No country can remain isolated in today's world which is moving more and more toward a "new internationalism." Globalization of industrial production and concern over environmental degradation have increased interdependence between nations. This globalization has been made possible by unprecedented improvement in transportation and communications technology during the past few decades. Recent advancements in information technology have also helped establish distributed and flexible manufacturing systems, in which economy of scope has replaced economy of scale considerations in production. Even though comfort and convenience are becoming more important considerations for both product and process design, the cumulative effects of an increasingly polluted environment and the degradation or depletion of natural resources caused by industrial activity now seriously threaten the world as a whole.

In recent decades, technology has been the most important source of industrial growth as well as growth in national Gross Domestic Product (GDP). Globalization of industry and trade is the new reality for economic development. The key competitive advantage now dominant in global trade is the ability of a country's production units to apply technology rapidly and to undertake technological innovations successfully. Comparative advantage based on national differences in factor costs is no longer sufficient to maintain economic growth. Competitive advantage based on a nation's technological ability is now more important.

The basic aim of any industrial project is economic growth through higher levels of productivity. Developed countries emphasize innovation and specialization in the process of industrialization for international trade, as the value of a product is determined by the technology that goes into it, not by the raw-materials that constitute it. Industrialized countries expand exports from their more productive industries, shifting less productive activities abroad, and importing goods and services in those industries where the nation is less productive. Developing countries also have to adopt similar policies. The constraints that newly developing nations now face are considerably more difficult than at any time in the past. They are as follows:

- Size and growth rate of population as compared to the geographical dimensions of the country. This constraint can put enormous pressure for rapid (even revolutionary, rather than merely evolutionary) economic growth on a nation;
- Availability of natural resources per capita. As these shrink, there is a tremendous demand for higher and higher productivity, conservation of resources, and development of renewable resources;
- Rising aspirations of both rich and poor for imported fashion brand-names, fueled by the mass media and high-powered advertising, deny governments adequate time to design sensible long-range development plans;
- Adverse balance of payments due to the decrease in export prices of many traditional low-technology commodities and the increase in the prices of high-technology products, almost all of which are imported;
- Environmental degradation due to over-exploitation of natural resources and agricultural land to produce exports in an attempt to offset balance-of-payments problems;
- No alternative but to operate within well-established international systems controlled largely by the industrialized world, which insists on patent rights enforcement and restricts wholesale immigration.

These above constraints suggest that a new approach is essential for development planning which explicitly recognizes the current international situation and the emergence of technology as vital to economic advancement.

THE ROLE OF SCIENCE AND TECHNOLOGY

The role of science and technology (S&T) in production systems is to increase productivity and efficiency in both agriculture and industry, to lower the cost of production and improve the quality of outputs, to reduce losses and increase value added, to introduce new products and processes, to increase flexibility to respond to changing market conditions, and to facilitate the efficient utilization, substitution and consumption of depleting natural resources.

Technology has forced the world economy to undergo profound changes in the past, and shows every indication that it will continue to do so. Thus, building technological ability has become a must for every country's survival and economic advancement. The technological capabilities of a country lie in its production system. Therefore, capability enhancement must be considered in the production context, where natural resources and semifinished goods are transformed into consumer goods and capital goods of market value. Technological skills, information, and management are just as important. However, if one accepts the critical role of technological innovation as the most dominant factor in productivity growth, it is essential to understand technology better. One way to comprehend production technology fully is to separate it into its four components:

- Physical facilities, such as equipment, machines, structures—all tools for enhancing human capabilities (e.g., increasing power of muscle, brain, sight, reach, etc.) and for improving living surroundings (e.g., increasing comfort);
- Human abilities, such as skills, expertise, talent, that help to generate, operate, maintain and improve the facilities used in production;
- Documented facts, such as specifications, designs and manuals, that store systematized knowledge and reduce the learning time and resources wastage for the production of goods;
- Organizational frameworks, such as management techniques, linkages and networks, for effectively coordinating technological components within the market.

All of the above forms of technology, although differing in degree of sophistication, are required simultaneously for any enhanced production activity. This is not yet fully appreciated in the developing countries. To comprehend the scope of developing technological ability, one should keep in mind that technology is a complex combination of continuously improving physical assets, progressively learned skills, routinely acquired knowledge, and evolving management techniques. It is also necessary to understand the strategic importance of technology for sustainable development.

Worldwide industrial activity is damaging the environment and creating a serious threat to the health and survival of humanity. Technology to protect and conserve nature is now urgently needed. With environmental awareness high on the global agenda, emphasis is now rightly on the development of cleaner, more efficient, and resource-saving technology. The emphasis, however, should not be on just protecting the environment, but also on promoting economic development. Technology is generally set in motion by necessity, opportunity or human aspiration. There can be no economic growth without technology, and without economic growth there is inadequate capital to support environmental protection.

Sustainable development has been defined as a process of change in which the exploitation of resources, the direction of investment, the orientation of technological development, and institutional changes are all in harmony. From an environmental point of view this means meeting the needs of the present generation without destroying resources needed by future generations to be economically and technologically self-reliant. Sustainable industrial development ultimately results from production technology becoming internationally competitive and environmentally sound. Sustaining competitiveness depends upon three conditions: factor advantage and the availability of technology; cumulative investment and specialization; and constant improvement and upgrading.

Developing countries have to buy industrial technology (imported through transnational corporations). To be able to pay for it, they have to be able to make and sell other kinds of technology. Selling raw-materials and primary goods is a losing business. Developing countries, therefore, have to adopt a "make-some, buy-

some" strategy. And experience indicates that "make some" has to begin by adapting bought technology.

In recent decades, technological change has gained considerable momentum. Innovations now occur at an ever-accelerating pace and, with industrial research becoming costlier, specialization is a necessity. Technological leapfrogging, however, may be possible, and perhaps essential, for sustainable development by late-starters. Leapfrogging can be achieved only when due attention is given to the problems associated with the development of the four components of technology previously mentioned.

CURRENT PROBLEMS

Poverty in developing countries cannot be eliminated overnight. Also, problems are too many to be addressed concurrently. Instead of preparing an exhaustive list of all problems, this section, therefore, presents only the most common. Understanding current difficulties can help identify major issues and possible action plans for developing technological ability.

Common Problems with Physical Facilities

- Generally old, outdated facilities for production and research activities;
- Equipment and facilities are poorly maintained, and break down very often;
- Machines and facilities are of different standards which cannot be interchanged;
- Lack of spare parts and inadequate repair facilities;
- Locally produced equipment is of poor quality and often very unreliable.

Common Problems Regarding Human Abilities

- Mismatches between the supply and demand of skills required by industry;
- High rates of emigration among technically-skilled individuals;
- Widespread under-performance of skilled personnel due to lack of facilities, or other reasons;
- Education system emphasizing rote knowing rather than innovative doing;
- Training and retraining seldom recognized by management.

Common Problems in Handling Documented Facts:

- Accumulated knowledge rarely documented for later use by others;
- Generally supply-push (not demand-pull) strategy for knowledge accumulation;
- Inadequate sharing of valuable information both within industry and in the developing countries generally;
- Language barrier limits knowledge accumulation and dissemination;
- Very little appreciation of the value and power of information by management.

Common Problems in Management Techniques

- Emphasis on doing things right (efficiency) rather than doing right things (effectiveness);
- Inadequate interest and attention to introducing modern management techniques;
- Failure to adopt and blend imported management techniques with the local situation;
- Paying lip service only to concepts such as networking;
- Failure by management to realize the importance of building technological ability.

Common Problems Impeding Competitiveness

- Weak links between the academia, research institutions and industries;
- Poor work environment and adherence to age-old traditions;
- Inability to deal with long-term considerations in planning decisions;
- Failure to generate team spirit for problem solving and promoting innovations;
- Policy instability causing capital flight and lowering investment.

Negative Aspects for Research and Development

- Compared to developed countries, total R&D effort in most developing countries is insignificant and generally unproductive;
- Due to overprotection, private industries in developing countries feel little necessity for in-house R&D efforts;
- Most public sector R&D organizations have outdated facilities and rigid management styles, inhibiting creativity;
- Public-sector R&D organizations are often engaged in activities that are too diversified and time-consuming;
- Missing links in the development chain and virtual isolation from the market pull are critical bottlenecks for both technology adaptation and generation.

Current Environmental Problems

- Increase in the scale of rural poverty, putting high pressure on the land;
- Inadequate waste disposal infrastructure for the rural poor and in urban slum areas;
- Depletion of natural resources due to inefficient use and over exploitation;
- Significant pollution from agriculture, transport and industry;
- Lack of environmental standards or monitoring and assessment of projects.

IMPORTANT POLICY ISSUES

Since technology is part of the investment cost of production, it is important to understand the rules of the game for technology acquisition through foreign investment.

Transnational corporations (TNCs) invest in foreign countries on the basis of commercial opportunities, such as attractive incentives, including guaranteed profitability, adequate infrastructure for business, protection of proprietary rights, minimal government interference, and government stability. Main attractions include access to natural resources, improved access to national/regional markets, protection of existing and potential markets, cheap and plentiful labor force, and investment incentives offered.

The relationship between foreign investment and technology transfer is complex. It is possible, however, to observe the following flow of technology components under an open market situation:

- Physical facilities for production, other than state-of-the-art, can normally be bought internationally for a price determined by the relative bargaining position of both buyer and seller. A TNC will locate its production unit in a developing country if it is profitable to do so with minimum risk.
- Highly-trained people migrate from poor countries to places offering superior standards of living. Salary, work environment and living conditions are the three most important determinants of labor mobility. Technically-skilled people can be imported, but a country's technical acquisition will, in the long run depend on the learning ability of its people.
- Documented facts are not sold on the open market and such information is a powerful bargaining tool. Valuable raw data generally move from developing to developed countries, while processed and packaged promotional documents normally flow in the other direction.
- Imported management techniques nowadays require very sophisticated computer and communications facilities and bring in alien cultures and values. To be effective, organizational frameworks have to be adapted to local conditions.

It should be clear that, internationally, financial incentives rather than welfare dictate the direction of technology flow. Developing countries, therefore, find TNCs hard to live with, yet impossible to live without. TNCs are the biggest exporters of technology, most of which are matured, material-intensive, energy-intensive, labor-intensive, and sometimes pollution-intensive. Experience has demonstrated that TNCs can establish profitable businesses in developing countries through direct investment, joint ventures, or licensing agreements. Market mechanisms ensure that the beneficiary of technology transaction is the one

who pays. Therefore, it is obvious that one who cannot pay for technology cannot benefit. Under a free and open market situation, technological components naturally move to rich countries, as demand is dependent upon absorptive capacity and purchasing power.

Since technological innovations have become progressively novel, costlier to develop, faster in pace and more pervasive, it is inevitable that the cost of technology imported by developing countries will continue to rise. As balance-of-payments situations become increasingly worse for most developing countries, they will have less money to buy newer (environmentally sound) technology. Hence, the market mechanisms will ensure further deterioration of the plight of the poor countries. For sustainable development, market mechanisms would require that the production systems of the developing countries also become internationally competitive and achieve a balanced trade situation on the basis of technology content of goods traded. In the developing countries, therefore, technological innovations must be made to permeate all production activities—a process that cannot be left to chance and must be guided by governments, although driven by the marketplace.

However, the ability of a country to use a specific technology as its economic growth develops is critical and very dependent on the infrastructure and the degree of industrialization of a country. Fiscal and monetary policies promoting industrialization by reducing cost of production through subsidies, raising product prices through protection, and increasing profit margins through tax holidays seem to have failed in most cases to produce sustainable development. Instead, they have caused distortions, widespread inefficiency and misallocation of resources. Also, poorly managed technology import has led to patterns of development that are not sustainable.

Governments in developing countries need to create an economic and regulatory regime that encourages international technology transactions. A government's real role in national competitive advantage is to create a climate that encourages innovation. Government incentives should help specialization and promotion of clusters of industries that draw on common inputs, skills and infrastructure. It is the responsibility of the government to reduce the crippling mismatches between the supply and demand of human skills, and to provide an up-to-date information infrastructure for technology-based development. This would also require committed, comprehensive and concerted action on the part of the entire nation. Finding the appropriate mix between using market signals and government regulations is critical. Moreover, successful government intervention depends on sound policy research.

MAJOR DIMENSIONS OF S&T POLICY RESEARCH

Considering the present situation, it is possible to enumerate the following key issues of S&T policy research in developing countries:

Vitalizing the S&T Management System

- Affirmation of conviction and strong determination of leadership in using S&T
- Strengthening a central authority for effective management of S&T and R&D
- Establishing an effective S&T management information network

Accelerating Utilization of Available Technology

- Identifying, transferring and adapting pertinent foreign technology
- Strengthening national consultancy and design engineering services
- Enforcing standards, quality control, and certification schemes for production

Strengthening R&D Activities

- Increasing the fund allocation for industrial R&D
- Fostering in-house R&D in private industry
- Establishing direct formal linkages between S&T producers and users

Intensifying Technological Human Resource Development

- Involving private enterprises in skill development and continuous upgrading
- Increasing S&T content of education, placing more emphasis on know-how
- Improving the compensation and reward structure according to quality of education

Fostering Specialization in National Capability Building

- Monitoring world technological trends and market opportunities
- Continuously assessing technological impacts, capabilities and needs
- Selecting areas of specialization by a flexible-learning strategy of make-buy

Providing Essential Support for Technological Innovation

- Providing technological consultancy service to small- and medium-sized enterprises
- Providing venture capital for starting new technology-based firms
- Enabling participation in international seminars and trade fairs

S&T Culture and Future Orientation

- Popularizing S&T through the mass media
- Instituting an award system to encourage creativity and innovation

QUESTIONS THAT NEED TO BE ANSWERED

For each of the major areas of S&T policy research a large number of key questions can be identified. This section provides a list of questions which need to be answered through S&T policy studies. This is not an exhaustive list. Nor are the questions placed in order of priority. Only the most important questions are raised here.

Vitalizing the S&T Management System

- How to ensure sustained political commitment which would allow S&T to play a leading role in promoting socioeconomic development?
- How to secure a disproportionately high level of resources allocation for S&T development which can no longer be neglected?
- What should be the proper role of government intervention with respect to type (fiscal, financial, legal), time period and target (producer, user) of S&T?
- How to strengthen the effectiveness of linkages between the supply and the demand sides of S&T for development?
- What kind of organizational infrastructure would be the most suitable to manage the S&T-led economic development strategies?
- What lessons can be learned from the experiences of newly industrialized countries and other developing countries?
- How can the government, as the primary engine of economic growth, hasten technological ability?

Accelerating Utilization of Available Technology

- How to provide an effective service in identification, transfer and adaptation of foreign technology for local small and medium enterprises?
- How to improve local management capability to apply technology rapidly and to undertake technological innovation continuously?
- How to encourage R&D investment for adaptation of imported technology?
- How to promote the use of the patent information system for the benefit of local industries?
- How to consolidate governmental procurement policies and procedures to encourage local adaptation

of imported technology?

Strengthening R&D Activities

- How to ensure effectiveness of R&D activities by the public sector organizations?
- How to strengthen support services for commercialization of R&D results?
- How to foster industrial technology development by private sector enterprises?
- How to select, evaluate and prioritize national R&D projects for funding and joint operation?
- How to strengthen the national capability for design engineering, industrial consultancy, standardization, quality control and certification scheme?

Intensifying Technological Human Resource Development

- How to secure and nurture a cadre of creative scientists and high-caliber technologists needed by industries to be internationally competitive?
- How to keep S&T manpower up-to-date, functional and flexible in an age when knowledge is doubling every five years?
- How to encourage creativity and self-reliance at all levels of education and promote training and retraining as a life-long process?
- How to emphasize know-how (application) as well as know-why (theory) in education and training at all levels?
- How to reduce the crippling mismatches between the supply and demand of human skills?
- How to determine skill requirements for the future and evaluate the characteristics of the current skill structure?

Fostering Specialization in National Capability Building

- How to monitor and continuously assess the impact of world technological trends and evaluate international market trends?
- What ways and means could be introduced to encourage the formation of new technology-based firms in the country?
- How to implement the strategy of make-some, buy-some technology for sustainable and internationally competitive industrialization?
- How to identify areas of specialization and determine priorities for research programs and manpower development in new and emerging technology?
- How to assess technological ability and determine the technological needs of local industries?
- How to create and sustain a competitive technological edge in selected industries?
- How to achieve technological leapfrogging in selected areas to take advantage of the unique characteristics of the technological change process?

Providing Essential Support for Technological Innovation

- How to strengthen international linkages (personal and organizational) for intelligence gathering with respect to S&T?
- How to make local industry realize that not to invest in factor creation is a fatal error in international competition?
- How to establish special mechanisms contributing to the synergistic partnership of business and government?
- What needs to be done to maintain the natural resource base of the country and ensure environmental protection for future generations?

S&T Culture and Future Orientation

- How to ensure that the decision-making process will not shy-away from the long-term considerations essential to building technological capability?

- How to instill in the minds of the people that quality is more important than quantity?
- What should be done to deal with intellectual property rights and the brain-drain?
- How to use the electronic mass media (television) to promote an innovative culture and increase awareness about the role of S&T?
- How to achieve a genuine shared vision for technology-led development?

The above listed questions may serve as a guide to formulate specific research projects.

CONCLUSION

The main purpose of this paper is to present a rational basis and a general framework for S&T policy research in developing countries. Using this framework, first, it is necessary to review past and present activities of institutions engaged in policy research, and then, one can identify further research needs by comparing the activities completed so far with the relevant research questions (some of which are listed in the previous section). Finally, S&T policy research topics have to be selected on the basis of resources available and priorities assigned.

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