Journal of Philippine Development
Number Twenty-Nine, Vol XVI, No. 2, 1989

CONCEPT PAPER ON SCIENCE AND TECHNOLOGY*

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Introduction

To say that science and technology (S&T) plays a critical role in the development process of a society is almost like citing a cliche. The importance of this field cannot be overemphasized, hence the rationale for this paper. Although the discussion will focus on the relationship of science and technology and economic development, it does not imply that other aspects of society (e. g., cultural and political development) are of less significance. On the contrary, the emphasis on science in the educational system may lead to more rational human relations since a sense of objectivity would generally prevail in society. What may be a more tangible benefit, however, are the effects of science and technology in the economic sense, in the form of greater productivity, higher incomes, and a more comfortable way of life.

The paper is divided into six parts. In the next section, some key terms will be defined in order to set the basic framework of the discussion. The types of technology consistent with the definitions will then be enumerated along two dimensions. These concepts will facilitate a general analysis of the development of S&T found in the third section. The fourth section describes a methodology by which the record of technological development in the Philippines can be traced, while Section 5 discusses the role of government in the development of science and technology in the Philippines. The last section enumerates a list of possible research topics.

Several issues will be given prominence in this paper. These include:

1. A discussion of the nature of the various types of technology and the different ways to develop them.

2. An analysis and description of the present state of science and technology in the Philippines. Included in this item would be a critique of the forces that influenced and shaped the present state of science and technology.

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*This paper was presented during the PIDS-DOST Seminar on Science and Technology Policies held at the NEDA sa Makati Building on 5 May 1989.

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3. Given the present state of science and technology in the Philippines, it is but logical to lay down a set of objectives and goals that identify a preferred state of affairs. Consequently, a set of strategies that lead to the achievement of these goals must be specified. The concept of an appropriate technology is addressed in this area.

These issues are quite broad in their scope and should be made more manageable through individual studies. It must be emphasized that the main purpose of this paper is to simply identify important areas that must be the topics of more detailed research.

The Nature of Science and Technology

Science is a system of activities which seek to describe, understand, and predict natural phenomena in terms of a cumulative body of experimentally verifiable laws, principles, and theories. It is usually classified into the *basic sciences* (biology, chemistry, physics, mathematics, and the earth sciences) and *applied sciences* (agricultural sciences, engineering sciences, and the health sciences). The core activity of science consists of *research and development*. Research aims to acquire new knowledge. Development, on the other hand, involves the transformation of research findings into prototype inventions of new materials, devices, and processes.

Technology is a system of hardware (tools, equipment, machines, materials) and software (processes, techniques, organization, and management) which are used to produce and distribute goods and services. The core activity of technology is *technological innovation* which seeks to transform the prototype inventions of research and development into a commercial product or process. Technological innovation comprises the following chain of activities: pre-investment studies, investment decision, engineering design, tooling and construction of manufacturing facilities, manufacturing start-up, and marketing set-up. A usual indicator of technological development, which is somewhat narrow in scope, is the number of patents.

Technologies can be classified according to the area where they are developed. Posadas enumerates the following basic types:[1]

1. Materials technologies, which deal with the extraction, processing, fabrication, combination, and synthesis of materials;
2. Equipment technologies, which deal with the design and fabrication

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1. Roger Posadas, " Leapfrogging the Scientific and Technology Gap: An Alternative Strategy for Mastering the Future," n.p.

of tools, instruments, devices, and machinery;
3. Energy technologies, which deal with the generation, conversion, and distribution of various forms of energy;
4. Information technologies, which deal with the collection, storage, processing, retrieval, transmission, and utilization of information;
5. Life technologies, which deal with the preservation, repair, maintenance, reproduction, and improvement of living systems; and
6. Management technologies, which deal with the planning, organization, mobilization, coordination, and control of social activities.

In whatever field technology is to be developed, a basic prerequisite to a successful program is the development of scientific and technical minds among the local population. This, of course, depends a great deal on the type of educational system that exists. The priority given to education and skill, or human capital, is part of the shift toward emphasizing *soft* or *disembodied* technology rather than *embodied* technology. The latter has its main proponents in business cycle theorists who contend that forces of production determine the path of economic activity. An extension of the argument is *technological determinism*. Changes in embodied technology are considered to induce changes in social relations. This perspective of technological determinism supports the earlier views of Marx.

The emerging school of thought on technology has been termed flexible specialization. Much of the attention is on the social relations of production; embodied technology is seen as being largely malleable to alternative sets of social organization.

The Development of Science and Technology

Whether it be embodied or disemboaied, technology still has to be created or acquired. Figure 1 shows a more detailed technology innovation chain starting with basic research and ending with the marketing aspect. The institutions involved in this process are the academe and organizations devoted solely to research, business and industry, the government, and what would be termed foreign sources. Individual inventors also a play a part in the innovation chain, but for the time being, their contribution can be disregarded.

Figure 2 gives a summary version of the innovation chain incorporating the role of the various institutions. It must be emphasized, however, that the diagram is a highly simplified model of the real world. First of all, the process of developing technology does not proceed in a linear fashion. Interactions occur at each interface and even across the various stages. Secondly, the different institutions are involved in all the phases. What is indicated in the diagram is the major player in a particular stage.

Figure 1

THE INNOVATION CHAIN
Research Through Development to Use

Phase Description of Activity

1 Scientific principle, invention or discovery of a new phenomenon
2 Preliminary measurement and analysis
3 Basic research necessary to get an understanding of the phenomenon
4 Contruction of first workable model with application in mind
5 Development of prototype for demonstration
6 Demonstration and evaluation to assess value for production
7 Engineering design of production models
8 Tooling and manufacture
9 Inspection, quality control, and testing
10 Marketing and acceptance by the public buyer

This is the area where close attention by policy management first appears

Improvements and Modifications

Nature of Activity

A Pure research without industrial motive

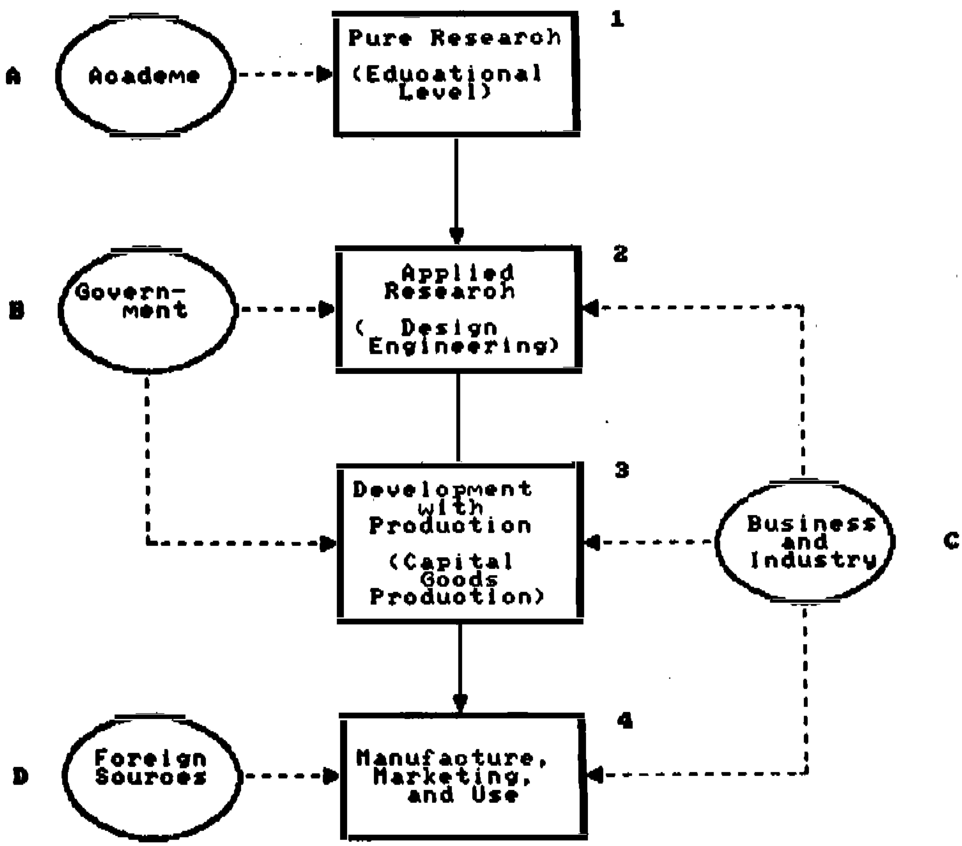
B Applied research where scientific staff trained in A are required

C Development by engineers with production in mind

D Manufacture, marketing and use

Figure 2

SUMMARY VERSION OF INNOVATION CHAIN



The diagram is useful in enunciating the various methods to develop technology. At one extreme we have the case of autonomous effort in technology generation wherein the accent is on self-reliance. In this case no foreign sources are involved. In actual practice, however, no developing country, even today, is in a position to mount a research and development effort of such scale, quality, and speed as to be able to generate all the technologies it needs. At the opposite of the spectrum we have the case of a *pseudo-transfer* wherein imported technology functions only as an input into production with no repercussions whatsoever on domestic science and technology. In this case, the innovation process is short circuited; in other words, the flow of information or technology runs directly from outside sources to the market. In the short-run, pseudo-transfers are the easiest to work out. They also create the comfortable feeling that one is getting access to the "latest technology." But they ignore the specific conditions of the importing developing country. Furthermore, they perpetuate a situation of complete technological dependence, not to speak of the burden placed on the country's foreign exchange resources for the payments for technology under such forms of transfer.

Since complete reliance on these two polar cases is either undesirable or infeasible, much of the technology should be acquired from outside sources but with accompanying adaptive mechanisms. In other words, renovations on the imported technology or its upgrading should be sourced locally. This is how the innovation chain is transformed into a cycle. The acquired technology is an input into either the first or second stage thus facilitating the integration of the imported technology into the domestic system.

Whatever choice is made, what is crucial is to be aware of these different modes of development, not only at the national planning/policymaking level, but at the sectoral level, at the enterprise level, and at the user level. One should also recognize that there are different types and magnitudes of social costs and benefits, financial costs and benefits, and political costs and benefits. If we were to operationalize this analysis, the central issues of policymaking for designing an integrated strategy for an optimal scheme of technological development would be--

1. What criteria to apply to decide which technology should be imported and which should be generated at home;
2. How to build up the three basic systems of the innovation chain, i.e., educational, research and engineering, and design engineering and capital goods production, and how to interconnect them in ways that technologies chosen to be generated at home are, in fact,so generated in defined time frames, and with high probabilities of success; and

3. In cases where it is decided to import the technology, how to integrate that imported technology into the domestic science and technology system so that the indigenous technological capacity is strengthened, subsequent import of similar technology is obviated, and the locally generated equivalents, if not superiors, are generated and utilized.

To elaborate, we will focus on the topic of technology transfer. The question as to what type of technology is to be transferred must be resolved. Enos cites the distinction made by Ranis between "core" technologies (chemical, electrical, electronic, or mechanical) and "peripheral" technologies (materials handling, storing, packaging, etc.).[2] This distinction is a variant of the debate between embodied and disembodied technology. If only peripheral technology is transferred, then what will probably result is a turnkey plant with only a superficial involvement of disembodied technology (i.e. actual learning) without the necessary backward and forward linkages that are crucial to economic development.

The type of technology transferred is not independent of the vehicle used in the transfer. Most transfers of technology are carried out through commercial arrangements between domestic firms and transnational corporations (TNCs) or other foreign firms. The vehicle is the chief device through which owners of technology extract the rent that is derived from possession; it is also an extension of their own organization, a bearer of their mode of operation, and a re-maker of their reputation. Such vehicles of transfer or arrangements may take the following forms:

1. Marketing agreements for the domestic sale of foreign machineries, equipment, and parts;
2. Licensing agreements for the domestic manufacture of foreign-brand consumer products;
3. Direct investment of a TNC in the domestic market through the establishment of a local subsidiary;
4. Joint venture agreements between a local and foreign firm;
5. Service contracts or management contracts involving a foreign firm's sale of technical services to a local firm; and
6. Purchase of complete industrial facilities from TNCs on a turnkey basis.

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2. A more complete review of the issues involved in technology transfer is given by J.L. Enos in "The Transfer of Technology: A Survey."

Other factors that influence the choice of vehicle of transfer include the policy stance of the host country, the maturity of the product or process to be transferred, and the level of technical competence of the host country. For example, if the government is bent on integrating foreign technology with the domestic system, it would encourage the use of licensing agreements and joint ventures and would frown upon direct investments.

Following the arguments outlined above, criteria must be set first in order to determine whether foreign technology should be acquired on a turnkey basis or assimilated into the domestic science and technology system. Then based on this first decision, a subsequent choice has to be made as to the mode of transfer, a selection which should also be consistent with the pre-set guidelines. A myopic policy that puts too much weight on the employment generation effects of new technology and neglects the longer term consideration of self-reliance would have a bias toward pseudo-transfers and direct investment. [3] It is important to determine these criteria so as to lead to the development of a science and technology base supportive of the national interest. If a free market solution does not conform to these criteria, then the government should play a more active role in the innovation chain. This assures maximum benefits derived from the imported technology. Government can do this by setting up or supporting various institutions that are involved in the development process. The role of government will be further discussed in another section of this publication.

That the criteria for evaluating technology conform to the national interest is quite a sweeping statement. Essentially these guidelines will be translated into cost-benefit analyses. One important point though is that the criteria should be on an *industry-specific basis.* Another facet that could readily be incorporated is the degree to which the technology will strengthen the backward and forward linkages in the economy; in this regard, a longer-term strategy should be delineated. These should be considered when defining the appropriate criteria.

Approaches in Analyzing S&T in the Philippines

This section will outline some of the topics that must be explored when studying the development of science and technology in the Philippines.

The first item would be a presentation of the record of technological development in the Philippines (see for example Lamberte). [4] The approach

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3. We adopt a pragmatic concept of self-reliance. The latter does not mean autarky or isolationism but rather "the assertion of our right to formulate our policies, programmes or institutional mechanisms." (Ashok Parthasarathi quoting Indira Gandhi, p.141.)

4. Mario B. Lamberte, "Science and Technology and Economic Development," *PIDS Working Paper Series No. 88-28* (Makati: Philippine Institute for Development Studies, 1988).

to be adopted here is to compare the performance of the Philippines with that of other countries using some rough indicators such as the ratio of research and development expenditure to GNP, capital output ratios, total factor productivity, and the number of scientists and engineers relative to the total population. Another useful undertaking would be to measure the impact of science and technology on economic growth.

In order to better appreciate the current state of science and technology in the Philippines, a critical analysis of the history of the development of this field must be presented. It is hypothesized that in a significant number of cases the choice of technology could be modelled within the framework of a principal-agent problem. A major output of this section would be the reasons for the failure of the development of science and technology, in general, and of appropriate technology, in particular. Examples of reasons cited in the past studies include:

1. Too much emphasis on innovative capability (the first phase of the innovation chain);
2. Lack of technological capability to search for or to use the most appropriate technology because of insufficient competition. This can arise from an overly protective trade regime or from excessive regulation of domestic competition; and
3. Very little linkage between research and development centers and the productive sector.

Given the present situation and the attendant problems of science and technology in the Philippines, the next step should be to make policy recommendations which would help improve the current situation. It is here that the role of the government will be made more specific. Prior to the development of any program in science and technology, however, the criteria for choosing the appropriate type of technology must be formulated. This should help define the desired state of science and technology.

The Role of Government

In a 1987 unpublished World Bank report,three areas were identified where government policy could play a role in technological development. These are :

1. Giving explicit attention to technology in the industrial development strategy,
2. Providing an adequate technological infrastructure, and

3. Promoting particular technological activities. [5]

Judging from the most recent Medium-Term Development Plan, it would seem that policymakers have a clear understanding of the importance of science and technology. The specific objectives of the science and technology sector are the following:

1. To generate and upgrade technologies appropriate to the needs of the production and social services sectors;
2. To utilize indigenous and imported technologies to help increase the growth and productivity of the production and social services sectors;
3. To improve the selection, assimilation, adaptation, and diffusion of appropriate imported technologies;
4. To develop and upgrade the national scientific and technological manpower, financial, informational, and institutional capabilities; and
5. To develop the national infrastructure for advanced science and technology and ensure the country's economic viability and technological competitiveness in the 21st century.

The detailed recommendations of the World Bank clearly focus on enhancing of the innovation chain. In developing technological infrastructure, the World Bank recommends that the government: 1) strengthen technological information systems, 2) promote closer and better links between publicly funded research institutes and the production sector, 3) further develop product standards and testing services should then be diffused throughout the country, and 4) strengthen the Philippine patent office. Another closely related proposal is the development of science parks that would stimulate basic research. [5]

On the promotion of technology activities, the World Bank contends that: 1) greater spending by firms on industrial technological activities must be stimulated by government incentives, 2) a greater emphasis must be placed on the dissemination of existing technologies, 3) the development of engineering consulting firms should be promoted, and 4) an area where the government can play a potentially important role in the monitoring of technological trends and identifying major areas of thrust for local technological effort is through a publicly funded research or technological institute. The strengthening of the ASEAN cooperation in science and technology is another worthwhile endeavor . [6]

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5. Tomas Kalin, " Science Parks in Developing Countries," n.p.

6. Chee Peng Lim, "Science, Technology and Development: ASEAN Regional Cooperation," n.p.

These recommendations call for a direct role of the the government in fostering the growth and development of science and technology. Based on the neoclassical paradigm, the appropriate strategy for government in promoting industrialization would usually be to provide incentives such as a uniform and temporary subsidy to value added, or a modest degree of effective protection. Some neoclassicals would also advise the public provision of social overheads too large or expensive to be undertaken privately, and most would advocate policies to support human capital formation. Such programs would have to be granted equally, in overall effective terms, across industries, and without administrative discretion.

We choose to take one step further and advocate for direct intervention by the government in the industrialization process of the country in the spirit of Pack and Westphal.[7] Pack and Westphal argue for selective intervention (i.e., implementing policies with a strong industry bias) with the objective of achieving dynamic efficiency in the preferred sectors. Dynamic efficiency means attaining international competitiveness within an explicitly specified, medium-run time horizon. International competitiveness should be understood in terms of ability to compete - without selective interventions - in the domestic market as well as in the international market; it should not be understood simply in terms of export performance.[8]

At the heart of an industrialization process is technological change. The reason for government intervention is that, unlike the neoclassical assumption, technology is not freely available and cannot be costlessly assimilated. Because of the inherent non-tradability of technology, investments to acquire and integrate them can generate externalities which are not considered by private agents in their investment plans. These consist of pecuniary and non-pecuniary externalities. The former include a local firm's possession of some real advantage vis-a-vis imports, part of which accrues to its buyers via a lower price or a set of product characteristics more suited to local conditions. Non-pecuniary externalities are typically intra-industry externalities wherein one agent's investments to obtain information leads to a significant reduction in transaction costs for access by other nearby agents to the same and closely related information.

This discussion points to the relevance of a sound science and technology program as the backbone of an industrialization strategy. Again, we emphasize the need to proceed at an industry-specific basis. Part of this industrialization package is a set of consistent macroeconomic policies. For

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7. Howard Pack and Larry E. Westphal,"Industrial Strategy and Technological Change: Theory Versus Reality," n.p.

8. See p. 103 of Pack and Westphal.

example, an overvalued currency, interest rate ceilings, and subsidized credit combine to encourage capital intensive investments which may not be compatible with the resource endowments of the country.

Possible Research Topics

The following suggested research topics are drawn from the previous sections:

1. The economics of technology choice (both a review of literature and a theoretical framework).
2. An analysis of the technological development in the Philippines focusing on the three production sectors: agriculture, industry, and services. This topic should touch on the following:
   a. The impact of technology on economic growth and development;
   b. The types of technology transferred along the different dimensions defined above (embodied or disembodied, and autonomous, adaptive transfer, or pseudo-transfer);
   c. In the case of technology transfer, the choice of vehicle of transfer and the reason for such choice;
   d. The shortcomings in the development of technology and the possible reasons for these; and
   e. A description and analysis of a preferred state for the science and technology sector and a definition of the selection criteria consistent with this goal.
3. The role of the private sector in the development of science and technology in the Philippines.
4. The role of government in the development of science and technology in the Philippines. This topic should be expounded with a full-scale industrialization strategy in mind. It should touch on the [direct] role of the government within the framework of the innovation chain and its influence via macroeconomic policies. The manual prepared by Forsyth [9] would be a useful guide in this case.
5. Other more focused topics like the impact of biotechnology on developing countries, and an assessment of some proposals to alleviate the present state of science and technology (e.g., technological leapfrogging as suggested by Posadas).

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9. David J.C. Forsyth, *Appropriate National Technology Policies: A Manual for their Assessment*, n.p.

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