THE SOCIO-ECONOMIC ICEBERG AND
THE DESIGN OF POLICIES FOR SCIENTIFIC
AND TECHNOLOGICAL DEVELOPMENT

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ABSTRACT

In this paper the socio-economic system of a country is viewed as an iceberg with an affluent tip and extreme poverty at the submerged bottom. Making use of this representation the paper describes an approach to science and technology policy-making and planning which is based on the following propositions:

(i) Technological change should be promoted at all levels of the social iceberg, but special attention should be paid to the mobilization of technical resources for the development of the bottom levels.

(ii) To deal fairly and efficiently with all the levels of the social iceberg, efforts should rely on decentralized institutions and make maximum use of non-governmental, grass-root organizations.

(iii) The economic and financial issues related to the production, distribution and use of knowledge at all levels of the iceberg should not be overlooked.
1. **THE SOCIO-ECONOMIC ICEBERG AND THE POLICY-MAKERS**

The socio-economic structure of a country can be modelled after an iceberg. The small part of the iceberg that is above water represents those enterprises having technical structures and financial resources which make them visible to policy-makers. In developing countries the tip of the iceberg is formed of branches of multinational corporations and large local private and public firms. The part which is at the flotation line then represents small firms in the modern sector (many of which have at least one professional or technician among their staff). They are likely to experience the ebb and flow of the economic waves. The bottom submerged part of the iceberg represents the large majority of small farms, enterprises, miners, artisans, and cottage manufacturers and all the people living under subsistence economies. ¹/²

The makers of science and technology policy prefer large, modern enterprises as targets for the work of the technological structures they try to develop, despite the fact that large modern enterprises are those which need less attention from the local technological institutes or research laboratories. Large modern enterprises have their own internal technological capabilities to select the technologies best suited to their economic interests and to the psychological well-being of their owners and managers.²/² They are also able to put into use the technologies they select, using when necessary the most convenient local or foreign consulting and engineering groups to help them in the design and implementation work. Small enterprises would also benefit from building similar internal technological capacity. Their need, however, is seldom supported by fiscal and policy measures. Without tax and credit incentives,
small enterprises do not invest in creating internal capacity nor ask for local technological services. They remain dependent on imported technologies which often do not make the best use of the country's resources and rely on imported technological services which often are overly expensive.

Even in the few instances where local sources of technical support and advice to production have been successfully mobilized in support of the small enterprises, they have not reached the potential and existing entrepreneurs who are at the bottom of the iceberg. The distribution of knowledge has not been based upon needs but upon economic power. Ability to pay for technical services and technologies is a function of current income, accumulated wealth, or both. Those who already possess technical assets are the ones who can increase their skills and talents further.

Those at the bottom of the iceberg rely on the few empirical skills that they have inherited or learned while struggling for their survival. This group has neither economic incentives nor psychological motivations to search for knowledge—not even for free knowledge—that might increase their productivity. They fear the risk associated with any technological change. Failure for them is neither a simple loss of benefits nor a decrease in capital; failure for them can mean starvation.

The science and technology institutions built with the enterprises at the top of the iceberg in mind do not know how to establish contact with those at the bottom in order to assess their requirements for knowledge. The professionals and technicians who work at the technological institutes, research laboratories, scientific councils, technology registers, and technical information services are frequently too far from the people at the bottom, both geographically and psychologically.

A physicist finds it much easier and more rewarding to work at the National Atomic Energy Commission along lines that allow him to exchange ideas with the
most noted nuclear scientists of the day than to spend his time with the peasants in some unknown village trying to develop a solar crop dryer that is simple enough to be built at the nearest metal workshop with a few imported parts.

A chemical engineer is much happier collaborating in the adaptation of a process for a large corporation than trying to launch a cooperative dairy undertaking in some marginal agricultural region.

A business administrator or an economist prefers to be employed by a large enterprise or a government agency rather than organize services that would enable small businessmen to do their work according to sound procurement, stock, and pricing practices.

A psychologist prefers to counsel rich entrepreneurs or managers and their spouses in the large cities rather than help poor people overcome blocks, prejudices, and centuries-old feelings of frustration that inhibit the increase of their productivity, the enrichment of their daily lives, and the full development of their human potential.

The problem of working with present and potential entrepreneurs at the bottom of the iceberg is highly complex. It is so even in a country such as Denmark, which has an almost totally literate population, a tradition in the organization of agricultural extension work and farm cooperatives that dates from 1800, and an industrial tradition that is proud of having organized a technological institute as early as 1906. In 1978, the Danish Technical Information Center for Industry (DTO) was able to work only above the flotation line of the iceberg, and the lower limit of entrepreneurial size and structure among the clients of the DTO was represented by firms each of which had at least one engineer on its payroll. \(^3\) Efforts were being made by the Danish technological institutes in Copenhagen and Jutland to create organizations and mechanisms
capable of working much below the flotation line of the iceberg in providing technical assistance to enterprises that do not have internal technical structures.

To overcome these weaknesses of previous approaches to the planning of S&T activities, a new approach will be proposed. It will be a systemic approach because it will emphasize the interconnections and relationships among S&T activities at all levels of the socio-economic iceberg. But as much use as possible will be made of the organizations that have emerged from earlier planning efforts.

II. THE PROPOSED MODEL: A SYSTEMIC APPROACH

In the systemic approach (see Figure 1), each field of S&T activity simultaneously rests upon and encompasses the lower ones. Each higher level receives signals and inputs from the lower ones and delivers outputs to them. But the use of knowledge in investment projects, in the operation of the resulting installations and in solving social problems is the primary activity in building the system. Without it the whole structure breaks down, and each level, especially the upper ones, begins working for its own objectives, a cloud floating on its own.

Instead, when all the levels are integrated into a production-based and socially-oriented system, self-reliance is increased. Local and foreign inputs and signals can then be received, processed at the various levels, and transformed into outputs and signals to be delivered either within the system or to foreign systems.

The development of the systemic model will take into account as agents of S&T activities at the various levels:

(i) present and potential small entrepreneurs;

(ii) regional technical-assistance groups and field-based practitioners;
Figure 1: The Systemic Model for S&T Development Planning
(iii) technological institutes;
(iv) national groups that provide project design and implementation services;
(v) institutions for scientific research and training;
(vi) large enterprises;
(vii) financial institutions;
(viii) governments; and
(ix) science councils.

I now consider each of these separately.

A. Present and Potential Small Entrepreneurs

The provision of technical assistance to present and potential small entrepreneurs who are living in villages and poor urban communities should have the highest priority among the S&T activities which aim at increasing the efficiency in the use of knowledge for production and the resolution of social problems.

For an appropriate design of the equipment and organizations required in order to build—or in some cases rebuild—the productive and social infrastructure in villages and poor urban communities it is not enough to assess their technological requirements and their financial and economic possibilities. It is also necessary to assess the system of values and beliefs that establish the frame of reference which orients people’s behavior in their performance of production activities and in the use and consumption of the resulting products and services.

Moreover, the successful implementation of projects at this level of the economy require that villagers and urban poor be able to analyze that frame of reference and make by themselves the necessary adjustments in their system of values and beliefs. Otherwise, their perceptions of the world (weltanschauung) and life styles will not be in accordance with the new technological patterns.
Conflicts that often emerge from this situation may misdirect organizations and delay implementation schedules in projects which in other respects are well designed and engineered.

In successful grass-roots development programs, like the one by the Sarvodaya movement in more than 3,000 villages of Sri Lanka, financial and technical resources are channeled to the villagers only after they have been awakened to an awareness of the causes of their poverty and of the tremendous potential for taking their personal and social development into their own hands and brains.5/

B. Regional Technical-Assistance Groups and Field-Based Practitioners

Regional teams should assess the technical and financial requirements of villages and poor urban communities in the context of their economic, social, cultural and psychological constraints and opportunities. They should train talented young people from the region as field-based general practitioners who can accomplish tasks in promotion, implementation, and trouble-shooting at the grass-roots level. These field-based practitioners would act as village developers and community leaders.

Examples gathered from fieldwork in different countries show that these regional groups work much better and more cheaply when they come from the grass-roots and are supported by private organizations than when they are bureaucratically organized by a government agency. Outstanding among those examples is again the Sarvodaya Movement in Sri Lanka. In 1979 it included 135 regional technical assistance centers and 15 regional-development educational institutes. Around 5,000 people were working as village developers.

C. Technological Institutes

These include industrial and agricultural research and extension services, and the like. These institutions should work directly with the large and small enterprises of the modern sectors of the economy. Instead, their contribution
to village and community development is better channelled through the field-based practitioners and regional technical-assistance groups.

Many times the amount or type of knowledge that field-based practitioners consider necessary for village or community development cannot be made available by regional technical assistance groups. In such cases, the technological requirements should be conveyed to the technological institutes and their advice communicated to villages and communities by the regional groups in a way that will be easy to understand for the recipients.

The institutes should have the highest degree of autonomy possible and should develop capacity to generate new technologies, adapt existing technologies to local conditions and provide operational support and advice to production units. They should also develop skills in marketing the technologies which they can offer and the technical services which they can provide. Entrepreneurs and managers from the modern sector and leaders of the regional technical groups should participate in the design of the objectives for the institutes and in the control of their accomplishments.

D. National Groups That Provide Project Design and Implementation Services

Consulting and engineering organizations are established with the aim of providing project design and implementation services to enterprises, especially those in the modern sectors of the economy. Regional technical-assistance teams should also turn to them when the tasks of regional planning and the design and implementation of projects at village and community levels exceed the expertise and engineering skills available at the regional and local level.

In providing project design services, these groups should examine each technological alternative to a given investment in the light of its opportunities, constraints and objectives. The technological choice in an investment project is critical to the efficient allocation of a country's resources.
Project-implementation services include detailed engineering of the installations, procurement of the equipment and materials for the production facilities, supervision of the construction and installation of the production units, the training of personnel, and the initiation of operation of the production units. The quality of project-implementation services has a direct bearing on the efficiency of production units.

E. **Institutions for Scientific Research and Training**

A country needs to have at least one small unit in each scientific discipline to teach that subject and to develop an elementary research and scientific information capacity. The main task of these units is to stock and update existing knowledge. As a by-product, they may sometimes make a contribution to the production of new knowledge. Their activities should be supported through the recurrent budget for higher education.

In countries with limited financial and human resources, extraordinary resources may sometimes be allocated to a particular one of these basic research and teaching units. This may occur when its activity will provide inputs to industrial and agricultural research performed by the technological institutes.

On the other hand, countries with abundant resources and a fully-developed S&T infrastructure can invest in scientific research beyond merely updating the pool of knowledge for the education of new generations or feeding new knowledge to technological research for the productive sector. These better-off countries can also grant scientific research devoted primarily to expanding the frontiers of knowledge. In all cases, extraordinary resources for scientific research should be allocated after a careful assessment of the expected social usefulness of the proposed work and an evaluation of the efficiency that the unit may attain in carrying on the work.\(^7\)
Occasionally, a highly gifted scientist comes along in a country with limited resources and an underdeveloped S&T infrastructure. He may want to pursue some field of science that is not directly related to local social objectives or problems. It is simply beyond the scope of this paper to propose a solution for such a situation, except to mention that work by such a gifted scientist does not always require large investments. He may value freedom to think and social esteem more than money. Moreover, he may best consider transferring to a laboratory outside his country where, with more adequate means he may obtain results that can be made universally available through the scientific literature. Such knowledge, unlike technology, is not generally appropriated by individuals or corporations.

F. Large Enterprises

More often than not, large enterprises do not need outside technical assistance for acquiring, adapting, or even creating the knowledge required for designing, implementing, and operating their undertakings. When they do need the help of external institutions, they have the human resources required to establish direct relations with the technological institutes, scientific research laboratories and the groups that provide project design and implementation services.

G. Financial Institutions

The term "financial institutions" refers to commercial banks, development banks, venture capital companies and special institutions for the promotion and support of research, invention and innovation.8/

Development banks and even commercial banks should become involved in the process of selecting the technology for the investments they support. They should also finance the costs of technological activities that are required by
the enterprises in order to increase the efficiency of their production units.

Special institutions should be created to finance the risky investments that are associated with the development of new technologies and the adaptation of existing technologies to local conditions by enterprises at the top of the iceberg or its flotation line. The main instruments for financing the development of inventions through technological research are conditional loans, that is, loans which are totally or partially forgiven in case of failure of the research project.

Venture capital companies are needed to help launch newly developed products or processes onto the market. Equity participation is often the preferred way for financing such new undertakings.

The enterprises at the bottom of the iceberg can neither develop nor adapt technologies by themselves and they certainly cannot afford to pay technological institutes to do this for them. The only practical way to help these units is to provide grants to cover the costs of research work or technical services provided to them by the technological institutes at the request of the regional technical assistance group.

H. Governments

The role of the governments is to strengthen the supply of and to promote the demand for local S&T services. Government is able to increase the demand for local S&T services and products by taking, among others, the following measures:

(i) Granting income-tax rebates on expenditures of enterprises for locally performed scientific and technological research;

(ii) Setting procurement policies of the public sector that would favor efficient local production, especially by small entrepreneurs, and help decentralize the economy. For example, food for public
school nutritional programs could be purchased by each school from small suppliers at the local level instead of being delivered by large enterprises to central warehouses for its distribution to the schools;\(^9\) and

(iii) Setting procurement policies that would favor local consulting and engineering groups when project design and implementation services are required by development projects supported by public enterprises and government agencies.

Government may also strengthen the supply side through measures such as the following:

(i) providing grants for scientific research;

(ii) setting education policies that would make the students aware of their own inner potential for searching out and implementing solutions to local problems at all levels of the economy;

(iii) organizing technological institutes and institutions for the promotion and financing of inventions and innovations;

(iv) creating a legal and political environment that will allow the free exchange of ideas and the exploration of different solutions for social and economic problems; and

(v) providing grants to regional technical-assistance groups to pay for research, engineering and training work aimed to satisfy technological requirements that these groups and practitioners perceive as necessary for the development of a region, a village or an urban community.

I. Science Councils

Science councils should limit themselves to action only at the level of scientific research. They should coordinate research activities to avoid duplication and promote the formation of efficient research groups to work on research along lines of high social value, such as the following:
(i) classification, characterization, use, and industrialization of local species of plants and animals;
(ii) adaptation of foreign varieties of plants and animals and foreign agricultural practices to local conditions;
(iii) adaptation of mining and metallurgical processes to the characteristics of local minerals;
(iv) the scaling down of large-scale production processes to satisfy the demands of small markets at comparable costs; and
(v) solution of local social, cultural, and environmental problems, such as overpopulation, pollution, malnutrition, endemic diseases, violence, and natural disasters.

III. DUALITIES IN THE SYSTEMIC APPROACH

An important premise to bear in mind when applying the systemic approach to the design of S&T policies is that attributes which would normally appear to be opposites and hence contributing to an unproductive duality, are actually complementary and even synergistic, with all the benefits this carries. I now discuss a few of these pairs of attributes.

A. Hardware/Software

The technologies for equipment and installations, what is termed the hardware, should in no case ever be designed apart from its corresponding software—technologies for the organization and management of the productive undertakings and their human environment. New hardware should be introduced at a rate that will allow societies and individuals to adjust to change. One way of promoting this adjustment is by reshaping organizational and legal patterns that too often are practices that have been established thousands of years ago for societies with primitive hardware.
B. Natural Science and Engineering/Social Sciences and the Humanities

Scientific and technological research should be oriented principally toward production problems. But efforts to solve production problems will also bring related social and human problems to the attention of the technological institutes and research laboratories, generating lines of research on education, health, social relations, life styles, art, and so on.

C. Small and Traditional/Large and Modern

The groups at the grass roots level that provide technical assistance to the traditional sector for village and community development should interact with technological institutes, research laboratories and project design and implementation groups that service farms and industries of the modern sector. At all levels technologies, small or large, old or modern, should be considered as potentially useful. The question is not the size or the age of the tools but rather their fitness to the job, the efficiency with which they use the resources, and their contribution to the full development of the human potential. Computers are used by the Sarvodaya Movement to keep control over stock in a cooperative network of several hundred community stores in Sri Lanka. On the other hand, even the most modern pharmaceutical industry may under certain conditions prefer to resort to hand-bottling and labeling instead of investing in costly and sophisticated high-speed automatic equipment.

D. Specialization/Multidisciplinarity

The degree to which the technological institutes must be specialized will depend on the type and size of the market for each of the services required and will vary from one country to another. In very small countries at initial stages of development a single multidisciplinary team of generalists can fulfill the needs of agricultural and industrial research, technical assistance and information services. In other countries the need for specialization may go far
beyond the point at which separate institutes for agriculture and industry are required. It may be necessary to promote technical groups that will serve specific industrial products or agricultural crops. An institute for copper may be needed in Chile or Zambia, for example, or a research group for llamas and alpacas might be useful in Bolivia. Even then, the question can be asked whether those groups should be organized as separate, independent institutes or as autonomous units within larger, multidisciplinary industrial or agricultural technological institutes. Economies of scale would be realized from the sharing of common administrative and ancillary services and synergism would result from cooperation among the different specialities. Even the research on human and social aspects mentioned earlier would benefit from integration within multidisciplinary technological institutes.

The benefits of multidisciplinarity are still greater in the work of the field-based practitioners. Otherwise the picture is the one seen repeatedly in many countries where several different extension workers, each of whom specializes in a given crop, visits the field to teach the villagers appropriate practices and to provide them with seeds, fertilizers, and other inputs. In addition, villagers receive sporadic visits from public-health workers and social workers. None of them can establish deep human relationships with the villagers, for the villagers take them for what they really are—external, occasional, sometimes timely advisers. Full development of the human potential at the bottom of the iceberg would require instead agents of change who were permanently engaged in development of the environment that they share with the villagers.

IV. POLITICAL ASPECTS IN THE DEVELOPMENT OF THE SYSTEMIC APPROACH

Any model for S&T decision-making and planning implies some particular ideology. The basic ideological premises of the proposal set forth in this paper are the following:
(i) A strong commitment to the preferential application of knowledge toward the development of the lowest levels of the economy through participative, self-reliant undertakings. As McNamara, former President of the World Bank, urged in 1972, this commitment is necessary if one really wants "to improve the welfare of the lower 40 percent of (the) populations (of the developing countries) which are living in conditions of the most abject poverty."  

McNamara, R., 1972, p.17

The Bank's new President, speaking on the same subject, stated that "experience demonstrates that development strategies that bypass a large segment of a society's people are not the most effective means to raise a nation's standard of living."  

Clausen, A.W., 1982, p.27

(ii) A willingness to provide adequate local technological support for the preparation, implementation, and operation of development projects at all levels of the economy. The proposed strategy should operate at the two levels described by Mahbub ul-Haq: "On the one hand, a modern sector which grows fast and experiments with all kinds of price incentives and tolerates the prevalence of inequalities for some time. On the other, a large traditional sector where organization and institutional framework overcome the scarcity of capital and development is taken to marginal men through the organization of rural and urban works programs."  

Ul-Haq, M., 1976, p. 42

(iii) Acknowledgement of the fact that the state of the art of technological development allows psychological and socio-cultural needs—participation, autonomy, education, recreation, communication—to be satisfied simultaneously with the basic needs for survival—food, shelter, clothes, and health. Attempts to satisfy the letter without the participation of the beneficiaries often end in the
establishment of repressive controls or in harassment of the feeblest producers by big interests. In either instance, individuals at the lowest levels of the economy see their freedom for emotional, intellectual and physical expressions taken away, their initiative destroyed, and their psychological well-being impaired.

The interaction of this ideology with the prevailing political patterns will finally establish the extent to which the proposed model can be made a reality in each particular country. As Denis Goulet has written "Technology policy embraces a vast network of domains relating to a nation's scientific and technical pool, material and financial infrastructure, overall incentive system, attitude toward outside agents, degree of control over the direction and speed of planned social change, level of integration into global or regional economies, and relative priorities attaching to technological modernity itself." [Goulet, D., 1977, p. 145]

Taking this complexity and the political constraints into account, the designers of a national policy for S&T will need to choose from among the instruments and organizations that seem generally feasible, those that can be used under particular national conditions. Among other things the designers should:

(i) Analyze whether the existing economic policies will promote and support the building of the technological capacity needed to accomplish development objectives and guide technological change in the expected direction, at the necessary speed. The analysis should establish which policies have to be modified and propose the creation of new ones when necessary; and
(ii) Define the type, size, and scope of the scientific and technological organizations that would be required for support of the various social and economic activities.

A systemic approach for the design of a national policy for S&T can be seen as encompassing three processes:

(i) A process of finding out who is dependent on whom for the supply of knowledge and resources for adapting, creating, and using knowledge. By the same process it should also be possible to discover on what kind of knowledge the system depends;

(ii) A process of incorporating all participants in a system with their relevant motives, perceptions, and skills and of integrating the unique outputs of each level of activity into a synergistic whole; and

(iii) A process of co-learning and of using jointly both knowledge rising from the bottom and knowledge purposely sent down from the top of the socio-economic iceberg.
NOTES

1/ In the more developed Latin American countries, fewer than 1,000 enterprises are found at the top of the iceberg, and millions are found at the bottom.

2/ The word "technology," as it is used in this paper, refers to the organized set of scientific and empirical knowledge required to design, implement and operate a productive or a social system undertaking. Technology is put into use through technical services like engineering, quality control, trouble shooting, marketing, programming and budgeting, accounting and management.

3/ From a total universe of around 90,000 industrial firms only 3,000 were among the clients of the DTO.

4/ Data and comments on Danish technical tradition and the work of the DTO have been obtained from its Director, Mr. Kjeld Klintoe. Information on the efforts of the technological institutes has been provided by Mr. Jorgen Hammervig from the institute based in Copenhagen. In accordance with the Danish tradition of establishing close linkages between science and production, it is also worth quoting Mr. H. C. Orsted, the Danish scientist who discovered the electromagnetic effect. In 1824 he wrote, "The results arrived at by scientists must be made available to the layman in a popular form and in a language understandable to ordinary people. The manual worker, artisan and farmer must be educated to look at nature with understanding." Orsted had only contempt for those who "from made-up words build a castle of soap bubbles which looks very grand." He dedicated a paper in which he gave brief instructions as to how to boil saltpetre to "My dear fellow countrymen of the honourable farming class." The quotations have been taken from a special issue of The Danish Journal published in 1977 to commemorate the 200th anniversary of Orsted's birth.


6/ See more on project design in [Kamenetzky, M., 1982]; and on the role of consulting engineering design organizations in [Kamenetzky, M., 1979]

7/ See more on the allocation of resources for research work in [Araoz and Kamenetzky, 1975]

8/ See a description of some examples of institutions for the promotion of research, invention and innovation in [Rao, K.N. and Weiss, Ch., 1982]

9/ Example taken from an unpublished study of government procurement practices by Alberto Araoz.

10/ In describing the three processes I have made free use of the pattern for design of organizations proposed in [Smith, W.E., Lethem, F.J., and Thoolen, B.A., 1980]
BIBLIOGRAPHY


Clausen, A.W., 1982, Address to the Board of Governors in Toronto (Canada), World Bank, Washington, D.C.


Kamenetzky, M., 1979, Preinvestment Work and Engineering as Links between Supply and Demand of Knowledge in Integration of Science and Technology with Development, Thomas, D.B. and Wionczek, M.S., ed., Pergamon Press, USA.


McNamara, R., 1972, Address to the United Nations Conference on Trade and Development in Santiago (Chile), World Bank, Washington, D.C.

Rao, K.N. and Weiss, Ch., 1982, Government Promotion of Industrial Innovation, World Bank, Science and Technology Unit, Washington, D.C.

