IDRC–067e

Science and Technology Policy Implementation in Less-Developed Countries

Methodological guidelines for the STPI project

Office of the Field Coordinator
Lima, August 1975

These guidelines have been drafted by Francisco Sagasti and Alberto Araoz. They draw heavily on previous contributions to the Science and Technology Policy Instruments (STPI) project, on the diverse country team proposals, and on the comments received at the technical meeting held in January 1974 in Lima, where a preliminary draft was submitted, and at the coordinating committee meetings held in April 1974 (Mexico), November 1974 (Cairo), and July 1975 (Seoul).

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Foreword

The Science and Technology Policy Instruments (STPI) Project is one of the most ambitious collaborative research projects yet undertaken on a science and technology policy theme. It is ambitious not only because of the sheer scale of the undertaking — teams from 10 countries in Latin America, the Middle East, southern Europe and Asia have participated — but it is also ambitious in the scope of its objectives. The principal objective of the project is to devise ways and means whereby a country's investments in science and technology can most effectively be related to its industrial development objectives.

A particular feature of the project has been the informal, but extremely effective interaction between the individual teams. While maintaining complete autonomy over their own research program, the teams have sought to focus their efforts on certain themes of common interest. It is the expectation that this will enable a synthesis to be made from the individual country reports, which would be of general interest and value.

The leaders of each of the country teams met to decide on the common themes and asked Francisco Sagasti, who acted as Field Coordinator for the project, and Alberto Araoz, to prepare guidelines for a research methodology which would assist the teams in planning their own detailed research activities on each of the selected themes. It was intended that these guidelines would be the starting point for the development of each team's research. It was recognized from the beginning, however, that as the teams progressed with their research, they would gain insights into the problems which would lead them to develop new approaches more relevant to their own problems. Each team was encouraged to develop its own approach, even though it was realized that this might make international comparisons more difficult. From the beginning of the project it was recognized that the final synthesis was of secondary importance to the principal objective of generating knowledge most appropriate for national policymaking.

The methodological guidelines prepared by Sagasti and Araoz were neither a blueprint for all the research undertaken by the STPI teams, nor just a checklist for the teams to pick and choose the issues to be selected for detailed study. The two authors chose a middle ground and in so doing provided a detailed framework on which the individual teams' efforts could be based.

In fact it is because they were never intended to be used as a detailed blueprint for a specific project that the guidelines are useful for a wider audience than just the teams themselves. As they stand they provide many useful insights which might profitably be studied by researchers interested not only in policy instruments per se but in such topics as the technological behaviour of industrial enterprises, the functioning of research institutes, and many other related topics. It is for this reason that the IDRC is publishing this report.

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Chapter 1
The STPI Project

Introduction

The Science and Technology Policy Instruments (STPI) project is a cooperative research effort undertaken by 10 research teams from Africa, Asia, Latin America, and southern Europe. The general purpose of this project is to gather, analyze, evaluate, and generate information that may help policymakers, planners, and decision-makers in underdeveloped countries to orient science and technology toward the achievement of development objectives.

STPI was formally born as a result of a meeting in Barbados in January 1973, but its gestation took about two years during which its objectives, scope, and manner of organization were clarified. Appendix A of the report refers to the background and characteristics of STPI, and Appendix B lists the various methodological papers and feasibility studies that were carried out before the project began.

Subject matter and specific purpose of the project

The functions and activities that have to do with the production, diffusion, transfer, and utilization of scientific and technological knowledge are rarely an end in themselves. Science and technology are to be regarded as intervening variables[1] that influence socioeconomic development (rate of growth, employment, income distribution, health, welfare, etc.) and other national objectives such as prestige, defence capabilities, and self-reliance.

How science and technology variables act on national objectives is a subject that is abundantly explored in the vast literature about science and technology and their relations to development. However, much less is known about the process of formulating and putting science and technology policies into practice, particularly in less developed countries. Consequently, the specific purpose of the STPI project is to explore how policymaking and policy instruments (independent variables) influence science and technology functions and activities (dependent variables) in the different contexts of underdevelopment.

Structure of the project

National studies will be undertaken by the participating countries according to a common outline. The results will be integrated in several synthesis reports, together with other relevant information. In addition, consultants will undertake a number of special studies including some methodological ones. Other studies will investigate specific issues, such as "technological dependence/self-reliance" and science and technology policy in China and Japan. Furthermore, the field coordinator's office will maintain close contact with research on scientific and technological policies and instruments elsewhere in the world. This information will be fed to the country project teams and into the final synthesis effort.

[1] In this report we use the concept of "variable" as in social science research, making a distinction between "dependent variables," the functions and activities that are influenced, and "independent variables," the sources of such influence.

Objective of the guidelines

The present guidelines are intended to provide the participating country teams with a common set of concepts and research procedures to facilitate cross-fertilization during research work, as well as to ensure that a comparative analysis may be fruitfully carried out during the last phase of STPI.

The basic approach of the STPI project has influenced the preparation of the methodological guidelines in three ways.[2] First, theoretical aspects are stressed less than in an academic exercise because of the action-oriented nature of STPI. Second, the research does not focus on the formation of science and technology policy either at the macro level or at the firm's level. It is concerned with the interaction between macropolicies and microdecisions on technology. Third, the subject matter of the STPI project is approached from a contextual viewpoint because of the existence of different types of underdevelopment. It examines the historical evolution of the relationship between the economic system and the science and technology system, and studies questions of science and technology concurrently with all the relevant aspects of the socioeconomic context.

These considerations are reflected in the nature of the methodological guidelines. Because of the diversity of the teams and of the contexts in which they operate, it is impossible to prepare precise instructions relevant to all the country teams in all their aspects. Consequently, rather than a blueprint, the methodological guidelines offer a direction and an anchor point for translating the teams' research into a common language.

A limitation of the guidelines is that they give a static picture of science and technology policy formulation and implementation: they offer a conceptual framework for interpreting the present situation and do not provide detailed ideas for examining the historical background and the future application of science and technology policy instruments. In this respect the teams will have to study the functioning of policy instruments in the light of a desired societal model that would specify the role that science and technology are to play. Otherwise it would be almost impossible to suggest improvements in the design and operation of policies and policy instruments, for the teams would not know the direction that changes should take. This is a task to be carried out at the national team level and the methodological guidelines have little to say about it.

[2] For a discussion of the basic approach of the STPI project see Appendix A.

Chapter 2

The Research Approach, Concepts, and Categories

The effects of policy and contextual factors on science and technology: an overview

One of the main concerns in the STPI project is to analyze the effects of various influences on functions and activities related to the production, diffusion, transfer, and utilization of scientific and technological knowledge. This may be done: (a) for the whole of the industrial sector (and other areas such as mining, infrastructure services, etc., that may be of particular interest); and (b) for certain branches of industry chosen for special study. The analysis may start from the source of influence, looking at the effects that are produced upon the science and technology functions and activities (the top-down approach) or, from a certain science and technology function or activity, tracing back the sources of influence that produce effects on it (the bottom-up approach). As we shall see, the two approaches are complementary in contributing to an understanding of our subject matter.

The main idea is to explore cause-and-effect relationships in an ordered way, generating partial explanatory hypotheses that, once verified, may provide the basis for better control over science and technology functions and activities so that they make a better contribution to development objectives. Effects may be characterized by modifications in the orientation and magnitude of the dependent variables, or by constraints placed on such modifications. Such cause-and-effect hypotheses will not usually be simple and unidirectional, and many provisos will have to be incorporated in their formulation; moreover, it may not be easy to express them in quantitative terms. A general scheme of the interaction between sources of influence and science and technology functions and activities is presented in Figure 1.

For analytical purposes we have distinguished three groups of "independent variables" or types of influences:

(a) *Explicit science and technology policy and instruments:* Here there exists a definite, identifiable purpose of causing an effect on science and technology functions and activities;

(b) *Implicit science and technology policy and instruments:* Here the purpose is to produce effects on variables that do not belong to the group of science and technology functions and activities but, as a result, unintended effects happen to the latter. Such unintended effects may be termed "side effects" or "implications." A better knowledge of them may enable policymakers to minimize or eliminate their negative influence or to heighten their positive effects, and eventually to transform these implicit policies and their related instruments into purposeful indirect policies and instruments for science and technology;

(c) *Contextual factors:* These are factors that cannot be ascribed to current or recent government policies; they are a consequence of the country's past history, cultural and social features, resources, geography, etc. They are modifiable in the long run, but for the purposes of this

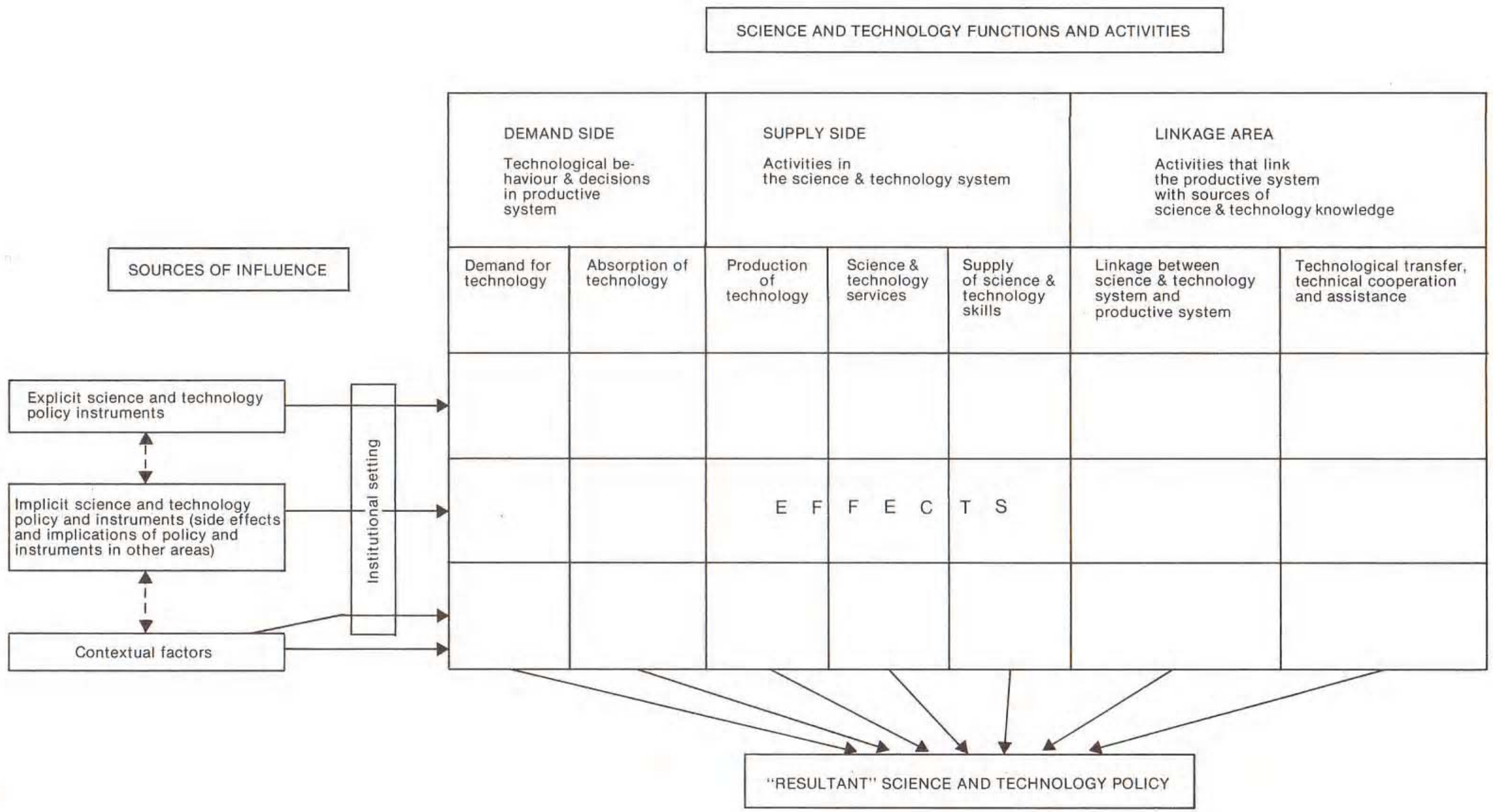


Fig. 1. General scheme of the interaction between sources of influence and science and technology functions and activities.

research they can be considered as fixed. Their effect on science and technology functions and activities is principally to limit the effects of explicit or implicit policies and instruments. They may refer to broad macroeconomic, cultural, or social aspects, as well as to the characteristics of enterprises, research institutes, etc., that are the result of the country's evolution.

Explicit and implicit science and technology policies and instruments may act directly on the dependent variables, but usually they do so through various institutions in charge of wielding them. The institutional setting may modify or distort the "messages" they transmit, thus affecting the magnitude of the resulting effect upon the dependent variable and the effectiveness of the instrument. Contextual factors also clearly influence the institutional setting and the way it works.

The "dependent variables" in the exercise are those functions and activities having to do with the production, diffusion, transfer, and utilization of science and technology. For analytical purposes they have been divided into three groups:

(a) those on the *demand side*, related to the technological behaviour and the technological decisions of productive units;

(b) those on the *supply side*, related to the activities in the science and technology system proper that have as end products new technological knowledge and various scientific and technological services;

(c) those in what may be termed the *linkage area*, linking the productive system with domestic and foreign sources of science and technology knowledge.

Science and technology functions and activities (dependent variables)

The classification of science and technology functions and activities into demand, supply, and linkage groups comes naturally from considering that scientific and technical knowledge is an important input for the production of goods and services and that productive units generate a demand for scientific and technical knowledge that is satisfied from local or foreign sources (demand side); that there is domestic production of scientific and technological knowledge, some of which feeds into productive units (supply side); and that the flow of scientific and technical knowledge between the producers and the users of such knowledge takes place through intermediary structures and institutions (linkage area). Instruments for science and technology policy should act upon the functions and activities of these three areas to achieve stated objectives.

The diagram in Figure 2 may be taken to represent the general situation in a country for all productive units and scientific activities, but a similar sketch may be made for industry and agriculture, or for specific industrial branches. In this case we would be especially interested in science and technology policy problems for the branch in question: the vertex "productive units" would comprise all those in the branch; the vertex "activities of the scientific and technical system" would take into account those directly relevant to the productive units of the branch, and their future development (one may also include in this vertex other scientific activities that support the former ones); the activities in the linkage area would be those that have to do with connecting the productive units of the branch and the activities of the scientific and technical system, as well as sources of foreign technology relevant to it. Some government policies affecting the production, diffusion, transfer, and utilization of knowledge in the branch may be of an industry-wide nature, whereas others may be specific to it.

A key feature of the research approach is the attempt to deal with this complex network of interactions whose elements are policies, science and technology variables, effects on end variables, policy instruments, etc., without introducing excessively simplifying assumptions. The idea is to attempt a systematization of these interactions, maintaining a reasonable degree of complexity that will render useful research results.

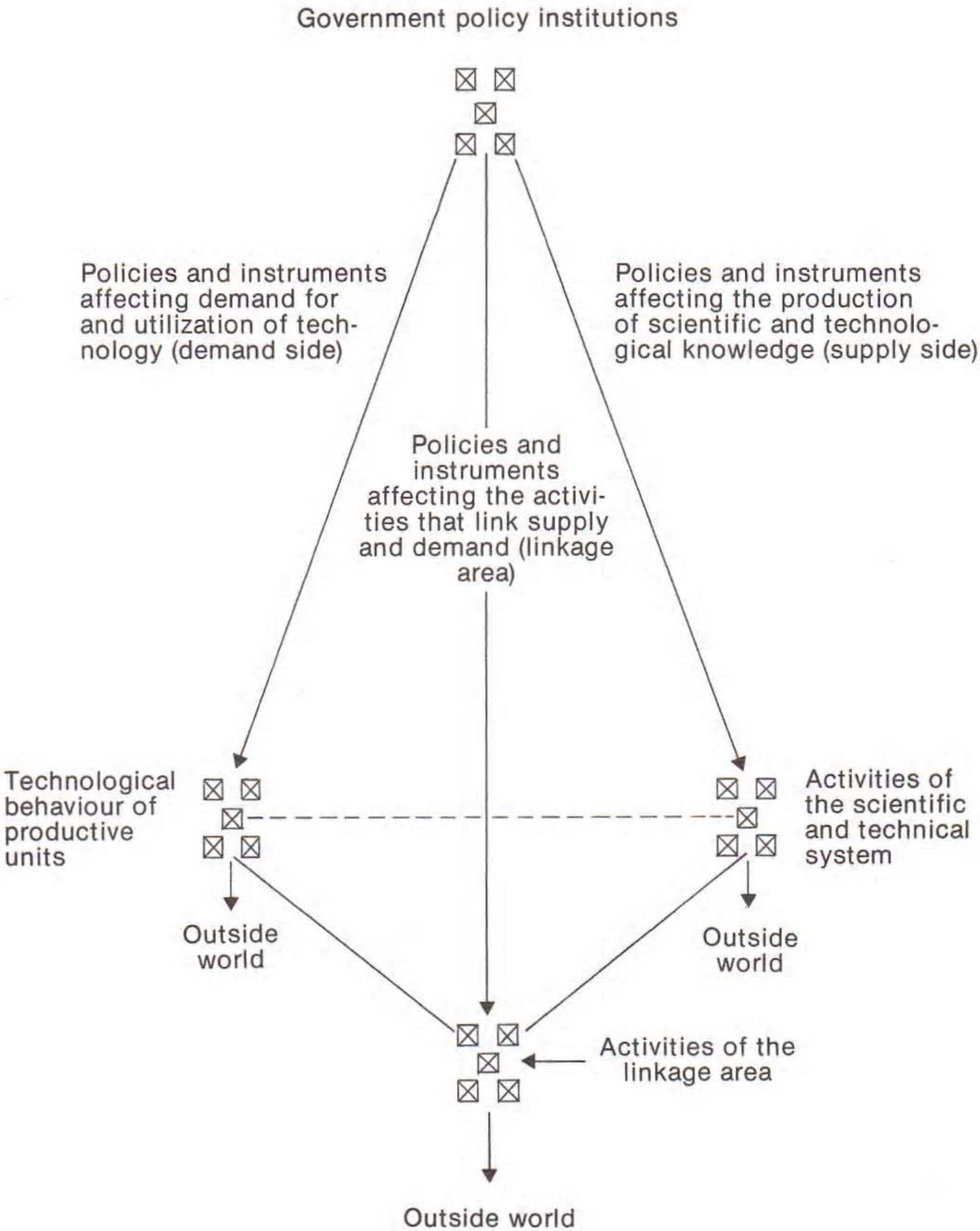


Fig. 2. Science and technology functions and activities (dependent variables).

For the purposes of the research, an attempt should be made to list "dependent variables" in each of the three main areas, in order to study causal chains from policy to effect and put forth partial explanatory hypotheses useful to policymakers. However, to make a list of dependent variables within each of the three groupings is not a simple thing, and any *a priori* attempt at a coherent taxonomy is open to criticism. It is possible that a satisfactory taxonomical classification may be one of the important byproducts of the project, of particular interest for policymaking purposes. At this stage it is possible only to provide some broad suggestions to the national teams, and to look forward to an exchange of ideas and experiences.

Demand side: productive units

Two groupings of major variables can be identified at the productive unit level: the introduction of new knowledge, expressed as the "demand for technology," and the assimilation and improvement of existing technology, which we may call the "absorption of technology."

(a) *Demand for technology* — This refers to knowledge needed for new (for the enterprise) products and processes that may originate from domestic or foreign sources, and that may appear in disembodied form (proprietary and non-proprietary, including knowledge supplied through human resources), or as embodied technology (principally equipment and capital goods). It may be fruitful to break down this heading according to the source of the technology demanded:

   (i) *Demand for domestic technology* — This may come from the firm itself (research and development activities), or from the purchase of research and development activities and their results from outside the firm. Another source is technology that exists elsewhere in the country and is made available through "diffusion," not involving compensation; and

   (ii) *Demand for foreign technology* — This may be proprietary or nonproprietary technology from foreign firms and institutions, technical cooperation and assistance from foreign governments or international agencies, or the stock of freely available knowledge that can be tapped through the literature, personal contacts, and visits or training abroad.

To handle new knowledge and its incorporation into production, the productive unit will have to make a number of technological decisions. Some are clearly concerned with the choice of alternatives regarding the source of new knowledge, the source of equipment, and the use of such inputs. Others have to do with the building up of the firm's capacity (technical and design groups, administrative organization, information) to make such choices, to adapt foreign technology (a very important activity because of the contribution it makes toward the optimal use of foreign technology and of the way it can link foreign technology to domestic scientific and technological activities), and to incorporate effectively new knowledge into production. The attitudes of decision-makers toward technological innovation constitute an important ingredient in the way decisions are made.

(b) *Absorption of technology* — This set of activities is directed toward the assimilation and improvement of technology that the productive unit has already incorporated, and comprises items such as:

   (i) Production research, plant optimization, product development, the search for minor innovations, the adoption of quality control standards, trouble-shooting, and other such technical activities within the firm;

   (ii) Purchase of scientific and technological services directly linked to productive activities that may come from the scientific and technological system or from foreign sources;

(iii) Information about practices in other firms obtained through the diffusion process.

It may be possible to go backwards from these main variables to various types of activities, functions, and decision points related to them, but as mentioned above, at the general level the exercise may not be warranted in the initial stages of the project. However, national teams may find it useful to analyze the structure that is currently being employed by the OECD in research about innovation.[3] (See Table 1.)

Supply side

In this case the outcome is the supply of scientific and technological knowledge relevant to the productive system. We may distinguish three groups of functions and activities behind it:

(a) *The generation of technology* refers to the production or adaptation of scientific and technological knowledge to be incorporated in productive activities. There are a number of parameters and decisions affecting these functions and activities, such as number and characteristics of research centres, quality of the research and staff, orientation of their activities, etc., and it is upon these that a study of the influence of policy instruments should be focused.

(b) *The supply of science and technology services* similarly allows the productive system to use more efficiently the knowledge generated by the science and technology or purchased from foreign sources. These services also refer to the activities that allow the production of knowledge to proceed more efficiently.

(c) *The supply of scientific and technological skills* focuses attention on the set of activities that supply human resources with the skills needed to carry out the whole range of science and technology functions and activities. This requires going beyond the general training given by the traditional educational system. We may mention as examples the activities of graduate schools in science and engineering, various training programs for researchers, and continuing education schemes for engineers. Such activities are of great importance if science and technology are to be promoted effectively and put at the service of national objectives.

A detailed description of parameters and decisions is beyond the scope of the present guidelines. Each project team may attempt to work with an exploratory list that could be shared and discussed with other teams.

Linkage area

The resulting variable, or outcome, is the facilitation and regulation of the transmission of scientific and technological knowledge to productive units. These are the functions and activities that relate the "supply" side to those of the "demand" side, and as such provide the channels through which technical knowledge can flow toward productive activities. On the other hand, they also channel the demands of the productive system to the local or foreign sources of knowledge.

The activities related to such variables are those of extension services, engineering firms, organizations for control of technology imports, and industrial information systems, etc.

Sources of influence (independent variables)

Each of the three types of sources of influence considered in the research will be examined in turn, although more attention is given to explicit policies and their corresponding instruments, since many of the concepts that refer to them will be used throughout the guidelines, particularly in the examination of other sources of influence.

[3] We have refrained from using the category of "innovation" as a dependent variable since we feel that it does not discriminate enough for our purposes; it is too broad and many different interpretations of it have been advanced.

Explicit science and technology policy and its instruments

This category refers to policies and instruments that have a definite and explicit purpose to provoke an effect on science and technology functions and activities. The purpose originates in a *policy* expressed in documents or statements of varying degrees of normative power. A policy may sometimes directly affect the dependent variable it is designed to influence, but more often it needs an *instrument* that acts through an organizational structure and a set of operational mechanisms.

The concept of "policy instruments"

Because the research in STPI focuses on the issues related to the design and operation of policy instruments, it is necessary to define more clearly these concepts.[4]

An explicit science and technology policy is a statement by a high level government official or institution (such as a ministry or the planning secretariat), that deals with an "issue" in science and technology: it expresses a purpose (effects to be produced upon science and technology variables), and may set objectives, define desired outcomes, and establish quantitative goals. Policies also contain criteria for choosing among alternatives with regard to the performance of science and technology functions and activities, providing guidance for decision-making. Although policies refer primarily to orientations set by government officials, they may also be formulated by representatives of the private sector. The issue dealt with may be very specific, referring to some particular purpose or decision to be taken and the criteria associated with it, or it may be of a general nature.

A policy may remain a mere rhetorical statement if no means are provided to implement and realize its potential effect. To do this a number of things may be needed, and we shall incorporate them under the term *policy instrument*. A policy instrument constitutes the set of ways and means used when putting a given policy into practice. It can be considered as the vehicle through which those in charge of formulating and implementing policies actualize their capability to influence decisions taken by others.

A science and technology policy instrument would be one where the ways and means (or actualized capabilities) include as a significant component the manipulation of science and technology variables. Also, a policy instrument attempts to make individuals and institutions take decisions following the rationality dictated by the collective objectives established by those in power. It is the connecting link between the purpose expressed in a policy and the effect that is sought in practice.

A policy instrument is called *direct* when it refers explicitly to science and technology functions and activities and *indirect* when, although referring primarily to policies, functions, or activities other than science and technology, it has an important indirect effect on science and technology functions and activities, through what we have called "side-effects" or "implications."

An "instrument" is a complex entity taken here to comprise one or more of the following items:

(1) *A legal device*[5], which may also be called the "legal instrument." This embodies the policy, or parts of it in the form of a law, decree, or regulation. Formal agreements and contracts may also be considered in this category. The important thing is that a legal device goes one step beyond a "policy" by stipulating obligations, rights, rewards, and penalties connected with its being obeyed.

(2) *An organizational structure*, that is put in charge of implementing the policy. Under the term "organizational structure" we may include:

[4] Although the definition of an instrument is made here in connection with explicit policies, it is equally applicable for implicit policies and "indirect instruments" (see pages 24-27).

[5] We are using the words "legal device" as a translation of the Spanish "dispositivo legal" or "disposición legal," which refers to any legal or formalized agreement that carries prescriptive weight, is imposed by some authority, and is sanctioned in some way by the society within which it is issued.

Table 1
Science and Technology Functions and Activities Used in the OECD Study on Technological Innovation

Overall Aim: To improve the capacity of the firm to innovate

Objectives: to improve	**Subobjective**	**Variables Chosen**	**Measures**
Economic-financial capability	Protection against risk	Technical risk	Risk sharing of development expenses
		Commercial risk	Risk sharing of expenses for export promotion
	Availability of capital	Degree of auto-financing	Fiscal policies
		Availability of risk capital	Creation of specialized establishments
		Access to financial markets	Policies covering market for bond and securities
	Marketing	Public sector markets	Specifications of performance for tenders
		Foreign markets	Services supplying information on foreign markets
		Domestic markets	Services supplying information on domestic markets
Organizational capability	Mobility of personnel	Internal to the firm	Financing of retraining of personnel
		To and from the firm	Redundancy payments associated with modernization of firm
	Flexibility	Structures of production	Special loans for modernization of plant
		Legal structure	Tax incentives for mergers
Scientific-technological capability	Use of existing knowledge	Use of government-owned patents	Exclusive right for a limited period
		Functioning of the market for patents and licenses	Prohibition of restrictive clauses in licensing agreements
		Foreign investment	Preferential tax treatment of imported capital associated with know-how
	Scientific discovery	Appropriation of R&D results	Patent legislation
		Use of external facilities	Tax relief on payments made to cooperative research centres
		Volume of intramural R&D	Financing of certain projects
			Tax exemptions

Economic environment	Favourable market	Ease of entry	Tax incentives for newly created firms
		Degree of competition	Tariff protection of new firms
			Legislation on restrictive agreements
		Minimum size	Exports credit
			Favoured access to government markets
	General economic situation		
	Mobility of employment	Functioning of the labour market	Specialized employment agencies
Institutional-social environment	Consumer protection	Standards	Creation of consumers' associations
		Control of new products	Authorization required before sale to general public
	Environmental conservation	Noise abatement	Regulation of noise level at airports
		Pollution abatement	Regulations concerning detergents
	Protection of employees	Prevention of industrial accidents	Factory safety regulations
Scientific-technological environment	General R&D effort	Government R&D	Financing specific projects
		University R&D	Financing of research
	Innovative climate	Use of R&D results	Creation of specialized agencies
		Individual inventor	Assistance with commercial application
	Growth of industrial research facilities	Access to government-owned facilities	Possibilities of sub-contracting of projects
		Cooperative research centres	Government aid with subscription of firms
	Diffusion of information	Publications	Financing of university
		Access to information services	Establishment of specialized integrated systems

(i) One or more institutions; a policy may be implemented through one or more existing institutions, or a new one may come into being. This may be thought of as the "hardware" aspect of the organizational structure.

(ii) The procedures, methodologies, decision criteria and programs that may span one or more institutions. These are of an administrative and technical nature, and specify the steps that must be carried out in processing or combining pertinent information for the purpose of applying the policy. They may be considered as the "software" aspect of the organizational structure.

Often, science and technology policies are implemented through organizational structures that already exist for other policy areas. For instance, a law allowing the free import of scientific equipment would naturally be implemented through existing import control mechanisms and institutions.

(3) A set of *operational mechanisms*, which are the levers, or actual means, through which the organizational structure finally implements the decisions on a day to day basis, and attempts to obtain the desired effect on the variables the policy has set out to influence.

Throughout the analysis of an instrument it is important to keep in mind the "actors" or key decision-makers who are directly involved in the design and use of a policy instrument. An instrument does not act on its own, and responds to the will of the policymakers and decision-makers using it. We shall come to this later.

The conceptualization of "policy" and "instrument" can be seen in Figure 3; three simpler cases are shown in Figure 4 as follows:

(a) no legal device: the instrument is made up of the coupled organizational structure and operational mechanisms;

(b) no organizational structure specifically involved: the instrument is made up solely of the legal device and its action takes place through existing social and institutional structures. This situation in general will be the case of certain across-the-board or non-discretionary instruments;

(c) no instrument is provided to implement a policy: the effect is obtained solely by means of exhortation and persuasion, acting through cultural and emotive mechanisms. Naturally, a danger exists that the policy will remain a dead letter.

Finally, we may find the case (Figure 5) in which a policy decision is made within an individual institution or organization that does not have a broad policymaking mandate. This is an important case since it exemplifies the situation of policies made in a piecemeal fashion by decisions of state enterprises, individual government agencies, and other organizations without (or in spite of) an overall centrally guided policy.

Other situations may be represented using the concepts we have outlined, such as the two cases in Figure 6. In (a) we find a number of instruments that intend to provoke different effects on account of *one* (complex) policy statement on one or more issues, such as a development plan. We may call this a *policy-oriented cluster of instruments*. In (b) various instruments, which obey several policies, all have effects on *one* variable. We may call this a *function-oriented* cluster of instruments. These two extreme situations are relevant to the research since the first cluster corresponds to the "top-down" approach, while the second cluster corresponds to the "bottom-up" approach to phases 3 and 4.

The description of an instrument

Using the concepts and diagrams put forward above it is possible to describe and analyze a diversity of science and technology policies and instruments. Such description should also pay attention to the policy level at which the instrument originates and the type of science and technology function or activity it attempts to influence. (See Appendix C for three examples.)

We feel that for the purposes of the present guidelines it is not rewarding to prepare an

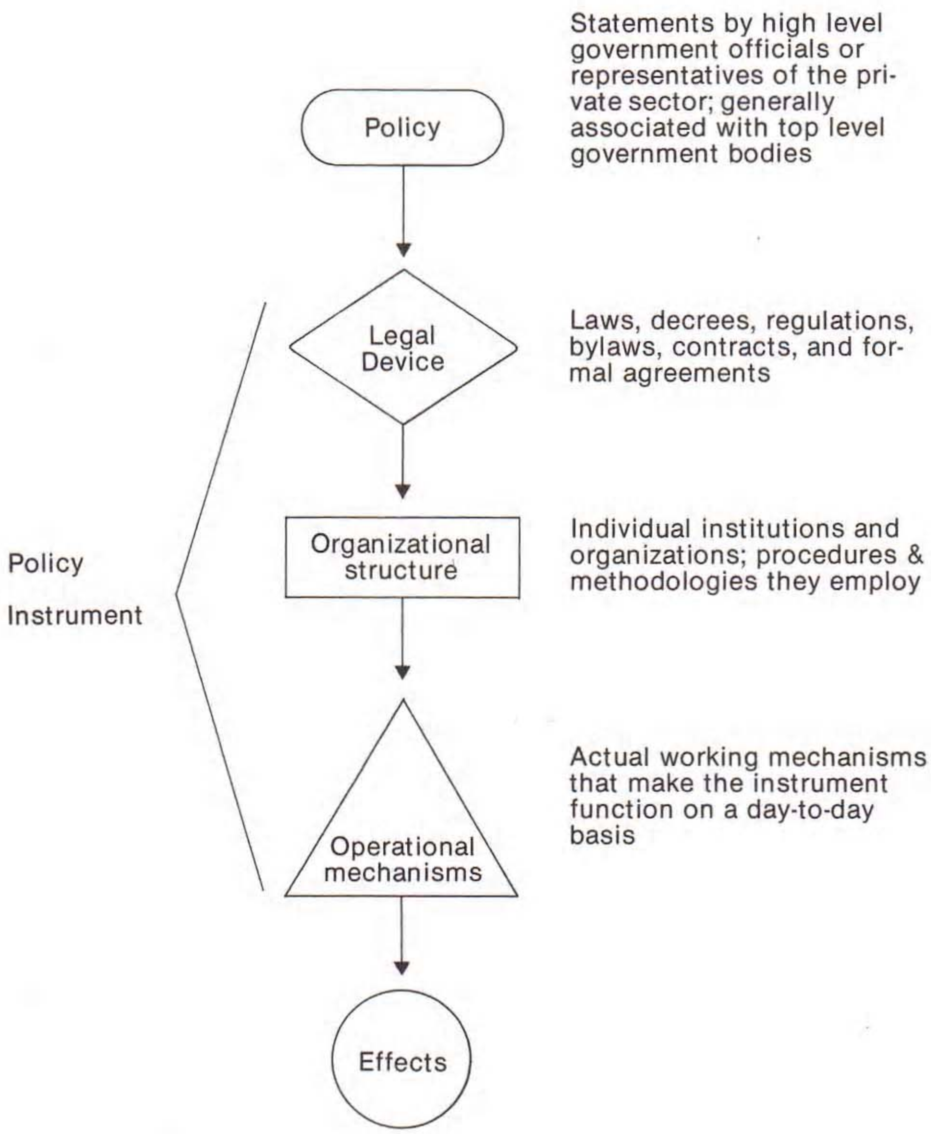


Fig. 3. Structure of a policy instrument.

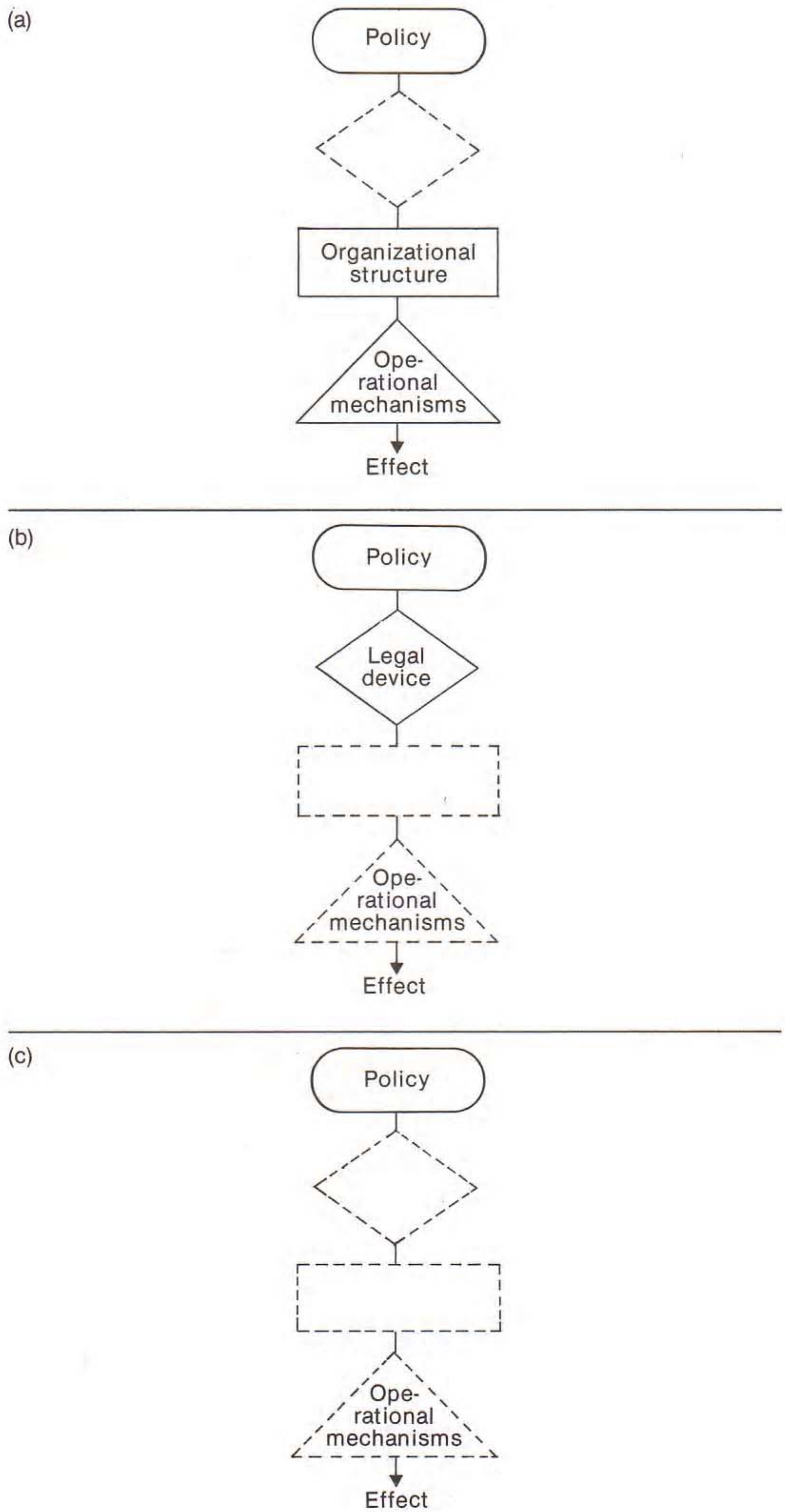


Fig. 4. Three types of policy instruments.

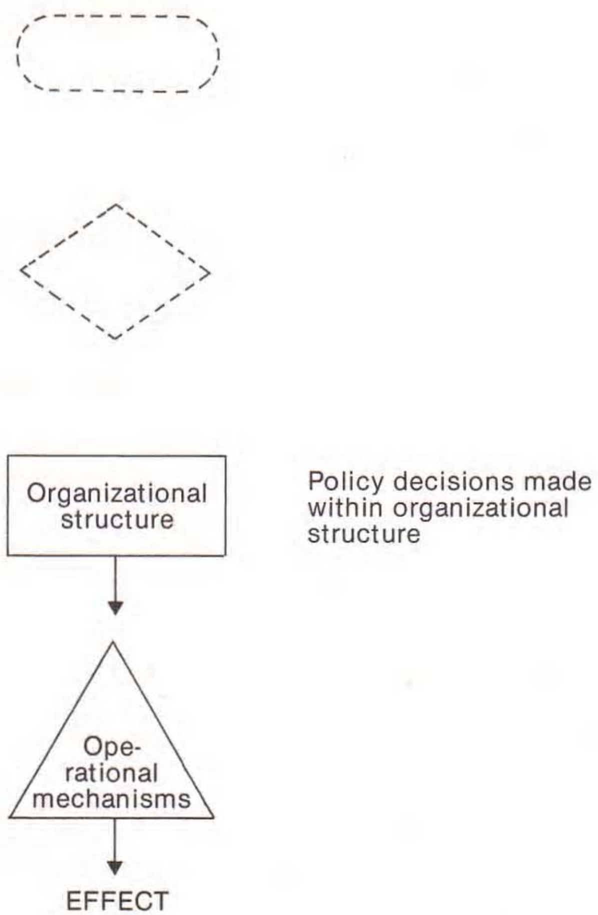


Fig. 5. A policy instrument without centrally guided policy or legal device.

elaborate taxonomy to help in this task, beyond the three categories suggested earlier for examining science and technology functions and activities. Instruments may be classified according to whether the policy/instrument couple affects the demand side, the supply side, or the linkage area. This may be crossed with two categories according to the policy level, i.e., whether the policy originates in a government body that has a broad policy mandate, or in a particular organization at a lower level (that may not even belong to the government, such as a producers' association, a large private enterprise, or a research institute). The distinction between these two levels may be useful when identifying the main policy instruments that act on a branch of industry or on the whole industrial sector. Table 2 shows this two-way classification with some examples.

Other criteria for classifying instruments include whether they have a *discretionary* or *nondiscretionary* character. The former involves a decision by some administrative authority in their application, while in the latter, application follows automatically from a definite rule without the possibility of discrimination. Discretionary instruments require the existence of an administrative capability and allow focusing on individual productive units, research institutes, etc., in the implementation of policies. On the other hand, they give the opportunity for interfer-

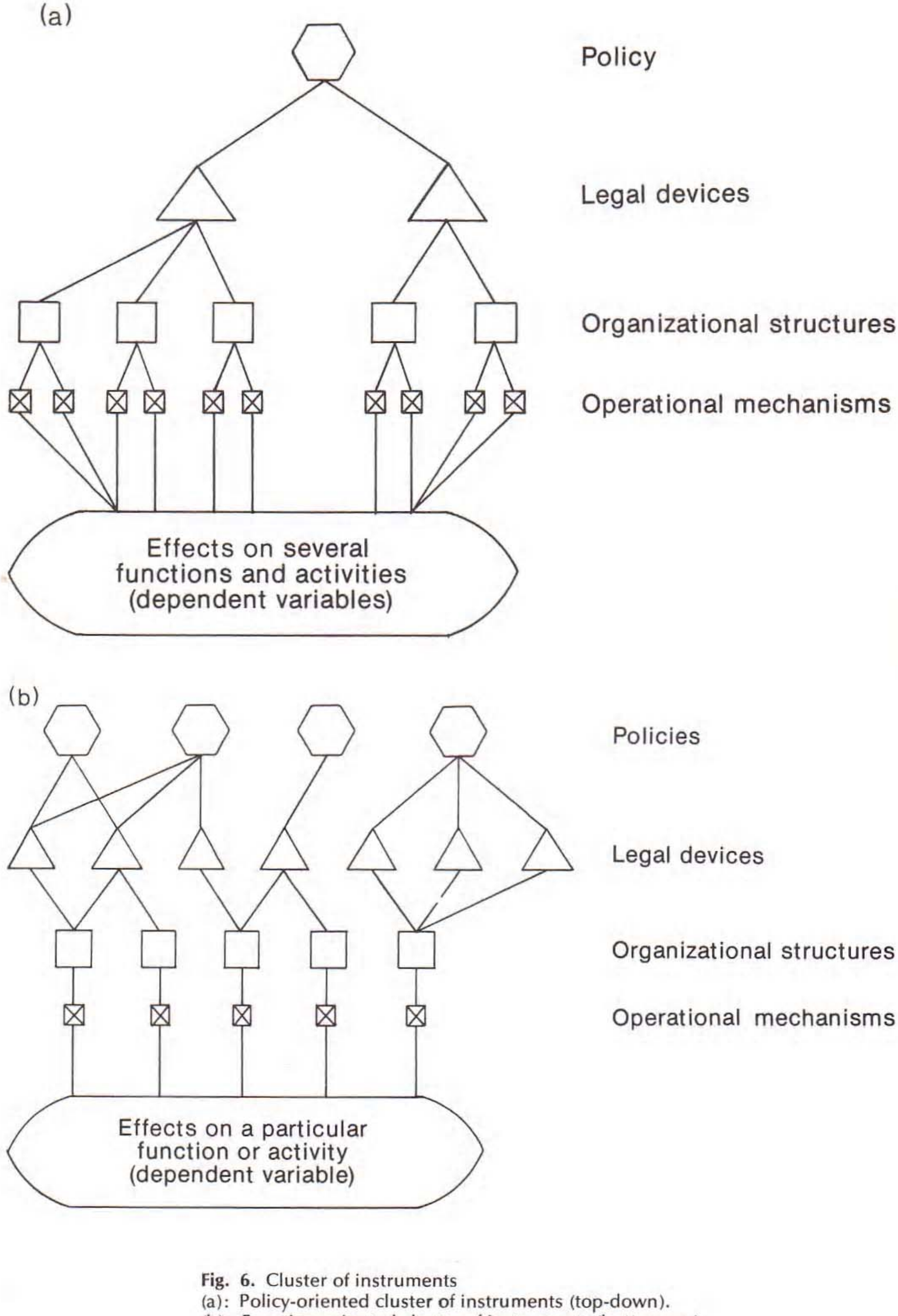


Fig. 6. Cluster of instruments
(a): Policy-oriented cluster of instruments (top-down).
(b): Function-oriented cluster of instruments (bottom-up).

Table 2
Classification for Explicit Science and Technology Policy

	SCIENCE AND TECHNOLOGY FUNCTIONS AND ACTIVITIES AFFECTED		
POLICY LEVEL	Demand side: technological behaviour and decisions in productive system	Supply side: activities in the science and technology system	Linkage area: activities that link productive system with sources of science and technology
High (emanating from an institution with a broad policy mandate)	e.g., articles or sections in general laws, industrial promotion laws, development plans	e.g., science policy statements, for instance, on the budget for R&D	e.g., policies and legislation on technology transfer, technical cooperation agreements with other nations
Low (emanating from an individual institution without broad mandate)	e.g., policies and decisions of development banks, state enterprises, and government agencies	e.g., decisions about government R&D contracts and grants	e.g., decision made by agencies in charge of regulating technology transfer and technical cooperation

ence arising in their application (bribes, arbitrariness, etc.). Nondiscretionary instruments affect science and technology functions across the board, without allowing distinctions according to the particular situations of the different entities affected by the policy and the instrument. They require less of an organizational and administrative infrastructure for their application, and reduce the possibility of interference by interested parties.

It is possible to enlarge the set of criteria by which to classify policy instruments, including categories such as "positive" or "negative" instruments, depending on whether they are aimed at stimulating, encouraging, facilitating, and inducing, or whether they impose restrictions, prevent actions being taken, prohibit certain activities, etc. However, the set of categories proposed above should provide a sufficient basis for the work of the country project teams, which could elaborate on them.

The operation of a policy instrument and the role of the "policy-keepers"[6]

The concepts advanced up to now do not take into account the dynamics and changing characteristics of policy instruments and the intervention of those who wield them. In practice a policy instrument does not remain fixed and immutable, but evolves through a series of stages before it is made obsolete and replaced by another policy instrument. In this process of growth, maturation, and decay of policy instruments, the agents in charge of operating them, who may be called the "policy-keepers," play a most important role.

The genesis of a policy instrument spans a period that begins with the formulation of the policy itself. At this stage the policymaker plays the most important role and it is his responsibility to steer the formulation of a policy up to the point where the instruments for its implementation are designed and approved. The life of a policy instrument begins when the legal devices, organizational structures, and operational mechanisms necessary for its functioning are established.

The dynamics of policy implementation will force the introduction of many changes in one or more of the components of the instruments. Modifications of the initial laws and decrees must be enacted, organizations will have to be modified, operational procedures changed, and, in general, the instrument will undergo a process of mutation through subsequent modifications so as to make it more appropriate for the purposes of implementing the policies under consideration. These processes of mutation and change take place through the active intervention of those in charge of operating the instrument: the "policy-keepers." In a sense it can be said that the policy-keeper is a part of the operational mechanism of the instrument, given the fact that he operates within the framework provided by the legal devices and the organizational structures, and that he is in charge of the day-to-day operation of the policy instrument. Nevertheless, this should not obscure the fact that he is also capable of modifying the legal and organizational framework within which he operates.

The policy-keeper thus emerges as the key agent who has the task of keeping the instrument functioning in accordance with the original criteria established in the policy, and to this end he must devise and introduce the modifications that are necessary in its structure. From these remarks it is clear that the scope for action of a policy-keeper will be much greater when we are dealing with discretionary instruments. It is also clear that in many circumstances the distinction between the policymaker and the policy-keeper may be artificial, and that the responsibility of designing and operating the policy instrument can fall on the same person.

In practice, the "policy-keeper" for a particular instrument may comprise more than one individual (for example a committee) and may handle several other policy instruments at the same time. A combination of a

[6] This section is based on a report prepared by Phactuel Rego from the OAS, and presented at the Cairo meeting of the coordinating committee of the STPI project in November 1974. The title of the report is *Agents in the process of scientific and technological development: the policy-keepers.*

few policymakers and policy-keepers may have control over a cluster of policy instruments, carrying out their activities through a network of formal and informal contact and providing support to each other as the need arises. The network of informal contacts of policy-keepers is particularly important, for the actual performance and impact of policy instruments may depend more on these contacts than on the formal procedures established in the legal device, the institutional structures, and the operational mechanisms.

Evaluation of the performance of policy instruments

The assessment of the performance of an instrument of science and technology policy is rather difficult, but an attempt should be made to characterize policy instruments, or clusters of instruments, according to their usefulness in implementing certain policies. This raises several complex questions: Should an instrument be evaluated independently of the policy it is associated with? Is there a group of instruments better suited to a set of policies, purposes, or strategies than others? Is there an absolute measure of the effectiveness of an instrument, or should we attempt to carry out comparative analyses? How should the performance of policy-keepers be evaluated? These issues cannot be resolved *a priori* and each team must examine them in the context of its own situation.

However, there are a few concepts and tentative definitions that may provide some guidance to the national teams. Ultimately, the decision to use one instrument or another in the implementation of science and technology policies should depend on some evaluation of its characteristics along the lines suggested below.

The *scope* and *specificity* of an instrument refer to the range of science and technology functions and activities it affects, or the types of technological decisions it can influence. This attribute of an instrument could also refer to the size and volume of the functions and activities it affects. An instrument would have a wider scope the larger the number of science and technology functions and activities it affects. On the other hand, it would be a very specific instrument if designed to affect one particular science and technology function focusing on some predetermined group of enterprises, agencies, or research institutions.

The *coverage* of an instrument would be defined as the absolute number or the proportion of productive units, government agencies, research organizations, etc., that the instrument is capable of affecting. This concept may be extended to include side effects and implications. The *equity* of an instrument would refer to whether it has the same impact on all units that have similar characteristics. Diverse situations, exceptions, and loopholes may give rise to a situation in which the instrument cannot be applied with fairness in all cases that have similar characteristics.

The *efficiency* of an instrument would be the relation between the effort (administrative, financial, technical) and the effects that result from its use. The effort may include considerations of quantitative character, such as cost involved in its application, or qualitative character, such as expertise needed to operate it.

Other parameters to evaluate the performance of policy instruments may include the *time lags* involved in its application, the *flexibility* with which it can be used (meaning the possibility of applying it or not according to the circumstances), the *amount of information* required for its application (meaning the degree to which it preserves its properties in the light of contextual changes), and other parameters of similar nature.

Of particular importance is the concept of *effectiveness* of an instrument, which refers to the likelihood of obtaining the desired result: that is, implementing the policy, and affecting the behaviour of productive units, units in the science and technology system, and units in the linkage area. However, this may be a rather difficult proposition, because instruments do not function in a simple, linear way, and there exist side effects that complicate the assessment of an instrument's effectiveness. This emphasizes the necessity to take into account the effect of the instrument, not only on the functions and activities it was specifically designed to influence, but also on other variables and on the effectiveness of other instruments as well.

Another problem that arises in the evaluation of the effectiveness of an instrument is that often it is designed to influence more than one science and technology function and may achieve this with varying degrees of success. Therefore, it may be necessary to examine the effectiveness of an instrument as a whole, considering the several science and technology functions it should affect, and even the side effects it has on functions and activities in fields other than science and technology.

Throughout the discussion on performance we have talked of an "instrument" in the singular, but these concepts may also be applied to a "cluster of instruments." Also, it is necessary to take into account explicitly the fact that the performance of an instrument depends on the skills and ability of the policy-keepers in charge of its operation.

Implicit science and technology policy and its instruments

Many policies and decisions aimed at functions and activities other than science and technology may have unintended effects upon the latter. These effects are seldom taken into account in the design of policies and policy instruments, and policymakers have, at best, a dim awareness of them.

It is useful to consider two types of unintended effects, according to whether the effects are potential or actually take place. We may call the first *implications* and the second *side effects*. Implications refer to what may happen to science and technology functions and activities as a result of new policies and decisions in other areas, and the testing of any hypotheses about them would require relying on opinions and other nonfactual evidence. Hence any verification of hypotheses about implications would be weak. Side effects refer to what has actually happened, so that actual behaviour may be studied, giving a strong verification based on factual data. Of course it is not easy to draw a line between the two types of unintended effects, and in some cases the study of side effects may rely on abundant empirical evidence, while in others only bits and pieces may be found. However, the distinction is a useful one for the purposes of the research in STPI.

A wide array of policies may have side effects and implications on science and technology variables. For example, there are:

— high level policies such as articles or sections of general laws (agriculture, land reform, health, mining, etc.), industrial promotion laws, general and sectorial development plans, international agreements (particularly in commercial matters), budgetary decisions at the national level, decisions about wages and social security, etc.

— low level policies and decisions, including the credit system, foreign exchange regulations, characteristics of investment decisions, foreign trade decisions (particularly about import permits and import tariffs), manipulation of operative controls for the regulation of industry, etc.; purchasing decisions by state enterprises, purchasing decisions by large private enterprises (in particular foreign-owned ones), and in general, decisions by government agencies with some autonomy in their behaviour that may strongly affect science and technology functions and activities.

The checklist in Table 3 identifies policies in other areas that may have an important impact on science and technology. Some of the items may also be included in the category of contextual factors.

The study of the effects of implicit policies may follow a pattern similar to that of the explicit science and technology policies and instruments. The sequence: policy – legal device – organizational structure – operational mechanism – can be described in each case. A similar classification employing the six categories of the preceding section may also be used for implicit science and technology policies and side effects.

Table 3
Implicit Science Policy — Policies indirectly affecting scientific and technological activities

(a) **Economic** (primarily directed to the functioning of the economic system)
- — finance (credit, interest rates)
- — fiscal (taxation, exchange rates, exchange control)
- — external trade (tariff and nontariff barriers)
- — internal trade (prices, marketing, government procurement)
- — wages and labour compensation policies
- — foreign investment, compensation, and nationalization
- — economic development policies
- — specific industrial policies
- — specific agricultural policies
- — legal and general instruments
- — policies toward regional development

(b) **Manpower**
- — educational system (literacy, primary, secondary, vocational, etc. education)
- — higher education policies (universities, training institutes, management training, post-doctoral training)
- — fellowship policies
- — industrial training and retraining, technician training
- — policies for the use of foreign manpower
- — policies toward emigration of professionals
- — policies toward repatriation of skilled manpower
- — policies related to mobility of qualified personnel
- — policies for the promotion of human resources
- — salary structure and awards; mobility

(c) **Cultural**
- — mechanisms to modify the general value structures, attitudes, norms, etc., including the position of women
- — policies toward modernization and technological change
- — popularization of science and technology
- — policies toward modifying the structure of status and prestige awarding procedures, mechanisms, etc.

(d) **Physico-ecologic**
- — policies for the exploitation and preservation of natural resources
- — policies toward environmental control, pollution

(e) **Demographic and social**
- — health care
- — mortality rates
- — population control
- — income policies, distribution of income
- — policies toward increasing social mobility

An analysis of the science and technology policies implicit in general laws (on industrialization, mining, foreign investment, etc.) should uncover the main implications or side effects for science and technology functions and activities. The first step would be to identify those policies oriented to areas other than S&T that could have an important impact on them. For this there is a need for a certain understanding of the way the science and technology system functions in the country, through an examination of its place in relation to the economic, social, and educational systems.[7]

Once the set of policies with potential effects on science and technology functions and activities has been identified and ordered according to their likely degree of influence on science and technology, it is possible to proceed with a detailed analysis of each. Although the form and content of laws will vary a great deal from country to country, it is possible to suggest a general outline for extracting the implicit science and technology policies.

The first task would be to focus on the articles and clauses that can affect science and technology functions in enterprises, government agencies, research organizations, universities, etc., describing their possible effect. The second stage would be to put together the implications of different clauses and articles referring to a single issue or science and technology function, assessing their effect by taking them as a whole. These potential effects or implications can then be put together across a single law or several of them, and also across various science and technology functions and activities to identify the overall implicit policy.

When examining the implicit policies contained in general laws, one of three situations may arise regarding the content of the implicit policy uncovered:

(a) The implications of the policy are so obvious and clearly defined that a conclusion may be arrived at as a result of the analysis;

(b) The implications of the policy for science and technology functions and activities are not so clear and obvious, and their definite impact will depend on reactions of the enterprises, government agencies, research institutes, etc. The specific and actual content of implicit policy will have to be determined through empirical analyses, and the most that can be done is to formulate hypotheses on the effect of the law being analyzed;

(c) The law leads to the identification of instances of intervention by government agencies, and the content of implicit policy will depend on the way decisions are made by government officials (the policy-keepers). To uncover the implicit content of science and technology policy, an analysis of such decisions is in order.

Note that we are talking about "implications," although it is clear that if empirical data were available to corroborate the statements spelled out in the implicit policy, we would refer to them as side effects.

A similar procedure could be followed with regard to development plans. In this case it would be possible to make a direct comparison of implicit and explicit policies arising out of a single document. A plan generally contains objectives, policies, and strategies spelled out clearly, such as in the case of general development plans, industrial development plans, manpower plans, etc. The procedure in this case could be as follows:

(a) Summarize the main objectives, policies, and strategy elements of the plan, examining each of them with regard to their impact on science and technology functions and activities;

(b) Deduce what would be required in terms of science and technology functions and activities in order to be able to fulfill the objectives stated, to comply with the policies, or to follow the strategy. This would lead to an identification of the prerequisites, from the point of view of science and technology, that are necessary to carry out the plan. The whole set of prerequisites would constitute the

[7] This would be the result of phase 1 of the research (see chapter 3).

implicit science and technology policy contained in the plan;

c) Summarize the components of the plan referring explicitly to science and technology, putting them in terms of the science and technology functions and activities defined in the research;

d) Compare the implicit and explicit components of science and technology policy in the plan, examining whether they are coherent and whether there is a correspondence between the two.

A plan by definition consists of statements about what is to be done, and therefore, unless we are in a process of comparing past performance with planned objectives, it is only possible to derive implications and not side effects from such an analysis.

If the study of implicit policies were focusing on speeches, white papers, specific legal regulations, or other sources of implicit policies, a different treatment would be required. These two cases may provide an orientation of the research procedures that may be followed.

The uncovering of implicit policies that significantly affect science and technology functions and activities would also lead to identifying the policy instruments associated with them that could be used as indirect instruments to implement science and technology policies.

Contextual factors

These are aspects of the social system that cannot be changed in the short run, as opposed to policies that in principle may be rapidly modified. We suggest, as an operational line of demarcation, that if a certain characteristic may not be changed significantly during a plan period of, say four or five years, it should be considered as a contextual factor.

The contextual factors that interest us are those that *a priori* appear to have some effects on scientific and technological functions and activities, either directly or indirectly, through their influence on the organizational structure to implement policies. The effects can take the shape of constraints and limitations to what an explicit scientific and technological policy may attempt to do or achieve, or they may imply drawbacks and obstacles to the way the organizational structures function, thus having an influence on the effectiveness of instruments.

Three different types of contextual factors can be identified:

- *Invariant contexual factors* — These refer primarily to the country's physical and geographical characteristics (resource endowment, climate, size, location), which cannot be changed except by cataclysmic events;
- *Superstructural contextual factors* — These refer to the sociocultural structure of the country, and in principle are amenable to change in the long run, but it might be compressed into a shorter period through revolutionary upheaval. Cultural traits, value norms, relations of production, etc., would belong to this category;
- *Contexual factors resulting from long-term cumulative policymaking* — These refer to some of the characteristics of the economic system resulting from policies implemented in a piecemeal fashion over a long span of time. Examples would be the characteristics of the industrial structure arising out of pursuing import substituting policies, and the behaviour and attitudes of entrepreneurs resulting from an artificially easy environment for the pursuit of their activities, and so on.

The concept of contextual factors may be further subdivided according to whether they influence the total economy, or whether they act primarily at the sectorial level.

Many contextual factors carry a negative connotation typical of underdevelopment, and one of the aims of a development process is to change them in the long run. For example, it is possible to point out the lack of pressures to perform science and technology functions and activities in underdeveloped countries arising out of contextual factors that result from the structure of the economy and from cumulative policymaking over several decades.

The lack of demand for science and technology activities is due primarily to the fact that industries in underdeveloped countries developed largely behind protective barriers in markets of limited size. This has resulted inevitably in small-scale plants with varying degrees of cost inefficiencies. Within this development frame, technical adjustments in the product mix or production techniques are of limited advantage. In the absence of competition, there are no commercial incentives to reduce production costs or improve products. Import substitution is often justified as a means of reducing foreign dependence, increasing employment, balancing industry and agriculture, and strengthening the balance of payments. But indiscriminate and excessive import substitution and protectionist policies can result in wasted resources and can have other highly detrimental technological side effects. Technological improvements cannot be expected without a rational industrial policy frame. Among the characteristics that arise out of such policies it is possible to find:

— technological dualism
— excess capacity in many sectors of industrial activity
— deformed price formation mechanisms
— predominance of foreign investment in certain sectors of economic activity
— conservatism and lack of innovation in local entrepreneurial groups
— high unemployment
— large inequalities in income distribution

These characteristics may be significant contextual factors that limit and condition the effect of explicit science and technology policy and instruments. Many more contextual factors of an economic nature may be added to such a list; for instance, size of the national economy, dependence on a few export items, unavailability of a wide range of efficient technological alternatives, chronic inflation, heavy reliance on foreign technology, land tenure patterns, small size of many enterprises, oligopolistic and monopolistic structures, unfavourable salary structures and characteristics of labour legislation, deficient communications and information systems, etc.

Other relevant contextual factors may be briefly mentioned:

- cultural: habits of cultural dependence; ties of scientists to the international network of science; unfavourable value structures, attitudes, norms, etc., such as disdain for manual labour, humanistic and anti-scientific traditions, attitudes toward women's labour; structure of status and prestige, etc.;
- social and demographic: low educational levels, internal and external brain drain, deficiencies in the educational system, poor labour mobility, unavailability of skilled manpower, poor health, overpopulation, heavy rural-urban migration, structural unemployment and underemployment, etc.;
- political and institutional: national development objectives not well defined; lack of awareness of the potential role of science and technology in development; habitual lack of coordination between policies emanating from various first and second level sources; heavy-handed and slow decision-making procedures; excessive red tape; slow and complex control of expenditures; corruption; poor control of the implementation of government policies and decisions; fossilized institutions and mechanisms that subsist long after they stop being useful; inefficiency of public administration, etc.;
- geographical, physical and ecological: lack of certain natural resources; poor transport and communications within and without the country; ecological problems; climatic factors, etc.

It is clear that each country team must identify which contextual factors are of relevance to the formulation and implementation of science and technology policies.

The negative influence of many contextual factors on what an explicit science and technology policy may achieve has induced some authors to believe that proper regulation, control, and utilization of science and technology to further development objectives is not feasible unless vast structural changes are effected in the first place. It is to be hoped that the STPI project will throw light on this issue, and show whether science and technology policy and its instruments have a significant place in changing underdeveloped societies.

Approaches to the research in STPI

There are in principle two approaches to the study of science and technology policy implementation. One would be to start from policies tracing down their effects — the "top-down" approach — and the other to start from the effects tracing back the sources of influence behind it – the "bottom-up" approach. The two approaches are complementary. The first is useful for examining the effects of existing or intended policies (legislation, development plans, and practices of government agencies), and if a screening of key policies (explicit and implicit) is done for a particular branch, or even for the whole industrial sector, a "resultant" policy may be derived. This policy would express the combined effects of the key policies on science and technology variables, acting through the existing institutional setting and within the constraints imposed by the relevant contextual factors.

The second approach seeks to answer more specific questions about the sources of influence acting on a single issue, variable, or problem area, of science and technology functions and activities. For instance, we may be interested in why state enterprises in the metallurgical industries buy their capital equipment predominantly from foreign sources; or why the whole of the modern industrial sector tends to use capital intensive technologies. The bottom-up approach would lead to the identification of significant influences, both external (policies, instruments, and context) and internal (technical capacity, information available, decision patterns, influence of decisions that do not strictly refer to science and technology matters), on the productive unit. This knowledge would help to improve the situation by modifying existing policies, introducing new policies, removing constraints, generating new instruments, and so on. Such an analysis will also give a good idea of the degree of congruence of the various policy instruments and decisions that emanate from different sources – what we have called the function-oriented cluster of instruments – and hence about the resulting effect this cluster has on the variable under study.

We have referred in our examples to the "demand side" of science and technology, i.e., what takes place in productive units, but similar examples may also be given in regard to units in the supply side and the linkage area.

To avoid spreading efforts too thinly, the research teams should focus on a few important policies and their instruments and on a few issues related to science and technology functions and activities. This implies choosing a few branches of industry in each country, but it may be necessary to restrict the domain of inquiry even further.

The sequence of research under either of the two approaches would be: (a) identification of presumed cause-and-effect links; (b) formulation of hypotheses about the effect of policy variables (explicit or implicit) on dependent science and technology variables, as well as hypotheses about the effectiveness of explicit science and technology policy instruments; and (c) verification ("weak" or "strong," as the case may be) of such hypotheses.

In some cases it may be enough to consider the interactions between sources of influence and science and technology variables, without introducing into the analysis the internal characteristics of the decision unit (productive unit, unit in supply of technology, unit in the linkage area) whose "output" is being studied. This is tantamount to considering the unit as a "black box" that receives an input – the policy acting through an instrument within the constraints of the relevant contextual factors – and produces an output, namely changes in the science and technology variable under study (see Figure 7).

This may be a useful simplification when the researcher is interested in the aggregate effect of the policy variable on many decision units taken together, and these units are not too large and have similar characteristics, so that a certain degree of homogeneity may be assumed.

However, when dealing with large units whose particular behaviour is of special interest, or that are in a monopolistic or predominant situation in their branch or sector (such as a large state enterprise in the oil and petrochemical field or an agricultural research institute that handles a large share of research in the agricultural sector) it is necessary also to look into what happens inside the unit. This requires an understanding of the internal characteristics that, together with the external influence of the policy variable(s), may allow for a better explanation of the effect on the science and technology functions and activities under study. Hence the "black box" should be opened as much as necessary for the formulation of better, more powerful hypotheses (see Figure 8).

In the case of a productive unit, the internal characteristics in which we are interested are those aspects of its "hardware" (physical and human resources and their organization) and "software" (procedures, methodologies, decision rules, motivations behind these) that are especially relevant to how the unit makes the set of technological decisions that constitute its technological behaviour. The main advantage of this opening of the black box is that it may give the researchers a better idea about which internal characteristics to modify, through other policies, to permit existing or proposed explicit science and technology policy to obtain the desired effects.

A parallel treatment to what we have suggested in the case of productive units may be applied to units in the supply side and in the linkage area: those large units that

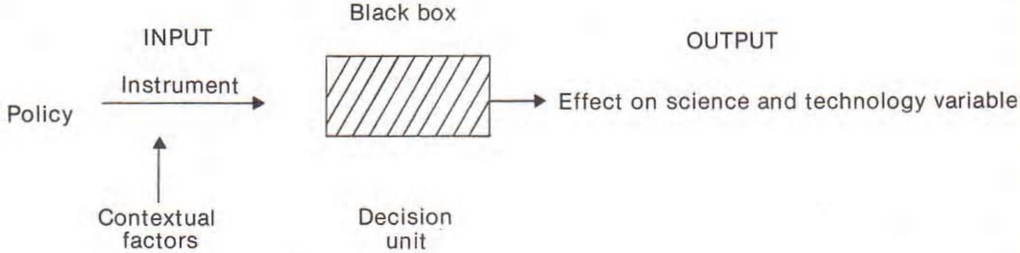


Fig. 7. The technology decision unit as a black box.

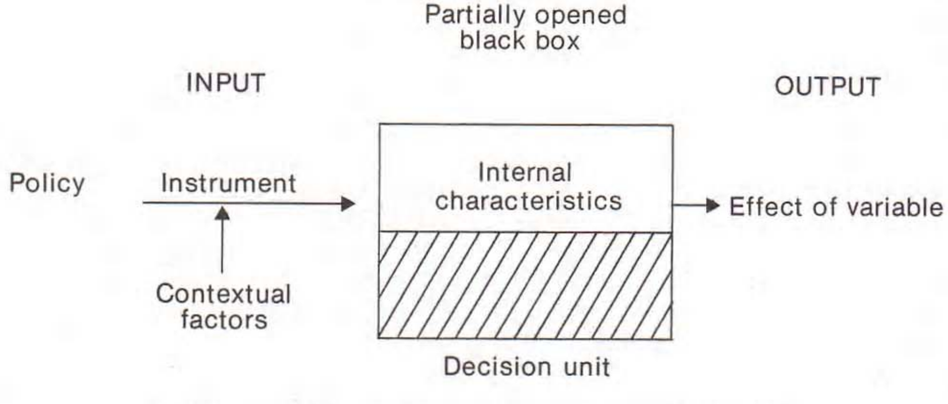


Fig. 8. The technology decision unit as a partially opened black box.

dominate a sector or branch would need an analysis of the internal characteristics that condition their technological behaviour.

Hence, there is a strong case for the study of technological behaviour in the principal types of units of each grouping. Due to the emphasis of STPI on the industrial sector, and in view of conditions in most of the participating countries, it would seem appropriate that such studies should concentrate:

- in the case of the productive sector, on large state enterprises, because of their actual or potential role in some of the principal productive branches;
- in the case of the supply side, on large industrial research institutions;
- in the case of the linkage area, on large engineering consulting and design firms.

These studies of technological behaviour could also be an important input for some of the case studies to be undertaken by the country project teams.

Another important area for research within STPI concerns organizations or institutions that execute many explicit science and technology policies and employ a variety of operational mechanisms. They also behave frequently as policymakers at a lower level. They merit a careful description and analysis as organizational structures. Among them we may mention:

(a) Offices in various ministries in charge of formulating technological policies and controlling their implementation;

(b) Organizations in charge of formulating science policies (in the strict sense) and controlling their implementation, such as science councils, research councils, etc.;

(c) The network of organizations in charge of promoting and executing scientific and technological activities, including university laboratories, research institutes, etc.

Finally, there are certain activities carried out with the participation of many persons and institutions to define policy objectives, policy instruments, and programs of action. Among them there is the preparation of science and technology plans at the national, sectorial, or regional levels. Such activity is worthy of study on account of its actual or potential importance for the subject matter of STPI. This suggests two types of studies: (a) normative studies on the methodology of, and the organization for, scientific and technological planning in less developed countries, and (b) empirical analyses of the science and technology planning process in the countries that participate in STPI.

A summary view of the research in the STPI project

The four preceding sections have presented the framework of concepts and the approach used in the STPI project. Before entering into the organization of the research activities it is convenient to summarize what has been advanced up to now.

At the national or sectorial level the contribution of science and technology to development objectives is conditioned by the behaviour of the agents involved in the performance of science and technology functions and activities, including enterprises, research centres, and government agencies. As usually happens in matters of this complexity, the overall technological behaviour of the country or industry is more than just the sum of its parts. The contribution of science and technology to development is the result of interactions among many types of technological decisions made by different agents at various levels, as well as decisions that do not have the direct purpose of affecting science and technology functions and activities, but that condition them in an indirect way.

The problem of science and technology policy implementation thus consists of designing and operating the policy instruments that would orient the performance of science and technology functions and activities in the direction specified by the objectives of the policy. This is a process that must bridge the gap between policymaking at the government (macro) level and decision-making at the enterprise, research centre, or engineering firm (micro) level. Figure 9 shows some of the agents and elements intervening in the process of designing and operating policy instruments.

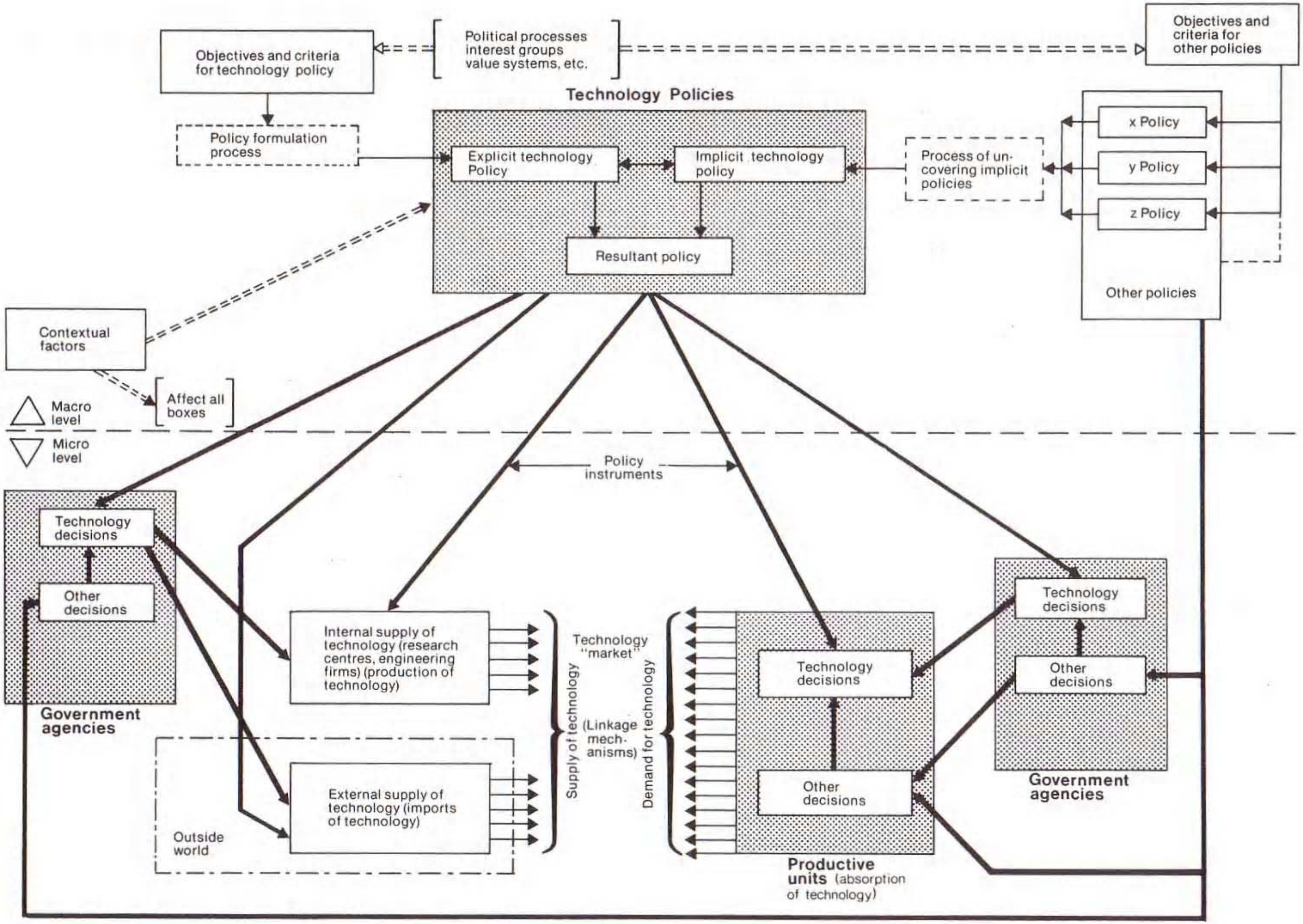


Fig. 9. Issues in technology policy formulation and implementation.

Policies for science and technology in the real world are the result of complex interactions between what we have called "explicit" and "implicit" policies, and not a simple translation of science and technology objectives into criteria for government decision-making. If, on the one hand, we have the objectives and criteria that lead to the formulation of explicit technological policies, on the other hand there are many other objectives and criteria for the formulation of other policies (industrial, financial, labour, foreign trade, and so on) that have an important impact on the performance of science and technology activities. It is necessary to uncover the implications of other policies to assess the direction that the real policy resulting from the interaction between implicit and explicit policies will take.

In this process of examining the interaction between implicit and explicit policies, many incoherences are likely to be found, and the "resultant" policy will contain many elements of a contradictory nature whose predominance will be determined by the relative strength of the policy instrument used to implement it. For example, it is generally recognized that fiscal incentives for the performance of research and development in industry are a relatively weak instrument in comparison with credit mechanisms that motivate the entrepreneur to acquire technology abroad. Therefore, it is likely that the component of the resultant policy that promotes the import of technology will prevail over the component that induces the performance of local R&D.

The diagram also points out that the technological decisions made by enterprises determine the technology absorption capacity of the country or industry, as well as the pattern of demand for technology. The decisions made by research centres and engineering firms determine the internal supply of technology, whereas the decisions of foreign consultants, multinational enterprises, licensers, suppliers of equipment, etc. determine the external supply of technology. Among the factors conditioning the decisions made by each of these agents we find the policy instruments employed by the government. The crucial problem in the design and operation of an instrument is that of determining its relative influence on the decisions taken by these actors. Unless this is known with a degree of certainty, it will be virtually impossible to anticipate the actual effect of a particular policy and its corresponding policy instruments.

In the study of science and technology policy implementation it is also necessary to consider the individuals in charge of designing and operating the policy instruments, for these do not come into existence and function independently of the policymakers and the policy-keepers. An assessment of the relative impact of policy instruments must take into account the skill requirements and the characteristics of those in charge of operating them. Finally, the influence of contextual factors must also be taken into account, for policies, policy instruments, and policy-keepers do not exist in a vacuum and are strongly influenced by contextual factors.

The research phases of the STPI project

The concepts advanced earlier in this chapter can be organized in terms of a sequence of research tasks to be performed by each project team. Within the spirit of the present guidelines the phases into which the research tasks have been divided are to be considered as tentative suggestions, and each team can modify them as necessary (altering the sequence, giving more emphasis to one or another aspect, etc.), but within the general structure that will allow the comparison of results.

The project places special emphasis on the study of science and technology policy instruments in certain branches of industry, which are to be determined by each project team. It also contemplates the need to carry out case studies of institutions and instruments of particular interest. To maximize the output of research efforts, it is recommended that, whenever possible, case studies should refer to the chosen sectors.

PHASE 1—Background on the science and technology system and its environment.

The output of this phase will generate the essential background information to orient the work in the later phases and to interpret and assess the results with a view to comparison between countries. It comprises:

(a) a description of the country's socioeconomic system, its evolution in the past, and its trends. Included is a description of the economic and structural aspects of the industrial sectors chosen, with emphasis on technological aspects; and

(b) a description and diagnosis of the country's scientific and technological system and its relations with socioeconomic development objectives, evolution in the past, and trends. Particular emphasis should be put on the part relevant to the sectors chosen.

PHASE 2—Analysis of instruments, identification of effects, and formulation of hypotheses.

This phase will identify the main sources of influence that affect science and technology functions and activities, focusing on the most important for detailed study, and examining the main types of effects they produce on science and technology functions and activities (the dependent variables). There will also be an analysis of the organizational structures that filter, transmit, and mediate the sources of influence over the science and technology functions and activities.

To study the effect of the three types of influences (explicit policies, implicit policies, and contextual factors) the following sequence is suggested:

(a) Identify the main explicit and implicit policies and instruments that may be expected *a priori* to have significant effects on science and technology functions and activities. The same should be done for contextual factors;

(b) Describe each of the items identified;

(c) Formulate hypotheses about their effects. This should be done at two levels: (i) at a general level for the whole industrial sector (and other areas if desired); and (ii) at the level of the industrial branches chosen for special study.

Hypotheses should refer to the nature and characteristics of the effect, and in the case of explicit science and technology policy and its instruments they should also deal with the effectiveness of the instrument;

(d) Collect evidence from various sources, including opinions, that may give support or corroboration for the "general level" hypotheses. This may allow a screening in order to retain those hypotheses that seem more plausible. Hypotheses at the level of the industrial branches are to be tested through empirical studies in phases 3 and 4;

(e) With the results of the preceding point, it is now possible to formulate a "resultant" policy in terms of a set of reasonable hypotheses that expresses the combined action of the different effects on science and technology at the general level. Such a resultant policy may be checked later with the results of phases 3 and 4, as well as with other information that may come up during further research work.

PHASE 3—Testing of hypotheses at the level of productive units.

Within the industrial sectors chosen, and in a selected number of productive units, this phase will:

(a) Verify the hypotheses derived for the industrial branches in phase 2;

(b) Identify and describe the main issues that have to do with the technological behaviour and decisions of productive units. Some of these issues may be of specific interest to the productive unit, others of relevance to the country's development objectives. Trace back the factors that influence such issues, due to the three types of causes mentioned in phase 2;

(c) Derive conclusions regarding the relative effect of the three sources of influence and of alternative policy instruments on the performance of science and technology functions and activities.

It is possible to link some of the case studies considered in the project to the empirical work of phase 3. For example, the study of state enterprises, of financial institutions, and of export promotion mechanisms may be directly linked to the tasks of phase 3.

PHASE 4—Testing of hypotheses at the level of units engaged in the generation of technology and the linkage area.

This phase should consider the main scientific and technical institutions that supply technology and services to the productive units in the industrial sectors chosen, and the main institutions that have to do with the diffusion and transfer of technology from domestic and foreign sources to those productive units. The sequence of research tasks would be to:

a) Verify hypotheses put forth in phase 2 for the industrial branches;

b) Identify and describe the main issues that have to do with the activities of the agents involved in the generation of technology and the linkage area. Some of these issues may be of specific interest to the institution, others of relevance to the country's development objectives. Trace back the factors that influence such issues, due to the three sources of influence mentioned in phase 2;

c) Derive conclusions regarding the relative effect of explicit policies, implicit policies, and contextual factors, as well as of alternative policy instruments on the generation of technology and linkage area. In this case it is also possible to link the case studies of selected institutions, such as research centres, consulting organizations, and science and technology planning agencies, to the main lines of work of phase 4.

PHASE 5—Country reports and comparative analysis.

The results of the work performed in phases 1 through 4 will allow each country to prepare a national synthesis report with emphasis on those aspects that will permit comparison between the various participating countries.

A final report of the project may then be prepared by comparison and integration of the results of country studies, together with the results of studies performed by consultants, and other relevant information. This synthesis should allow policymakers to know about the impact and effect of alternative mechanisms and instruments for implementing scientific and technological policies in a variety of conditions of underdevelopment.

Although the first four phases do not constitute a rigid plan of work, they are organized according to a logical sequence that would facilitate the research tasks of the country teams, and in this sense it is advisable to proceed according to the research plan outlined here. There are circumstances when the tasks could be altered with advantages to the country teams (for example, when there is enough previous material available on phase 1 it might be better to start working on phase 2 or phase 3; or when some material is already on hand it may be convenient to join phases 1 and 2 updating previous results), but in general the research sequence should be maintained.

Chapter 3
Guidelines for Phases 1 and 2

Phase 1

The purpose of research in this phase is twofold. First, it should provide a background for the rest of the study. Second, it should supply elements for work in phase 2 by making a first identification of explicit science and technology policy and its instruments, of policies in other areas that may have unintended effects on science and technology, of organizational structures of particular relevance, and also of the diverse social characteristics that make up the context within which the economic system and the science and technology system work and interact with each other. The first phase should both supply a backdrop to the project and lead naturally into the second phase of the research.

The study is to be concentrated on the country's socioeconomic system, its scientific and technological system, and their interrelations. Other societal systems should be covered not for their own sake, but only insofar as they are relevant to the understanding of the first two systems and their interaction; hence much less detail is expected in their analysis.

A historical perspective should be introduced into the analysis to create a better understanding of how things came to be as they are at present; but emphasis should be put on the analysis of the present situation, and of the trends extending into the future.

Since the main focus of the STPI project is on industry, this sector should be analyzed in further detail. To open the way for phases 2 through 4, a special effort should be made to examine the historical evolution and the present situation of the branches chosen for study and to describe the science and technology activities and institutions of particular relevance to them.

Appendix D provides a list of issues that may be covered. It should not be considered to be an enumeration of steps to be undertaken sequentially, but rather as a broad checklist of topics of apparent relevance to most country studies, and contributing to fruitful comparisons. Country teams could include other items that they feel to be important for completing and rounding off the analysis.

It is hoped that the information needed to prepare phase 1 is already available within each country, and that fresh research of the data-generating type will not be required. This may not be true in the case of the analysis of the present situation of the science and technology system; in such a case the country may need a broad survey, but it should not lead on to a protracted and costly full-blown inventory.

Finally, it should be recognized that any analysis such as that in phase 1 is bound to show different interpretations of historical processes and present situations according to the ideology of the person or group that takes up the task.

Phase 2

Phase 2 is concerned with the identification and description of the three main sources of influence on the performance of science and technology functions and activities: explicit science and technology policies and their instruments, implicit policies that have implications and side effects on science and technology variables, and contextual factors that condition and limit the effects of the first two sources on these variables.

The identification should take into account the spectrum of sources of influence that affect science and technology in the industrial sector, and pinpoint the key sources of influence that may later be studied in more detail, considering particularly the branches selected by the country teams. The study should also attempt to identify the principal policies and their instruments that act upon science and technology. In principle this is not difficult in a less developed country where science and technology policy is not yet too elaborate.

Some countries may wish to carry the research a few steps further, by studying the effects of those key sources of influence on science and technology at the general level of industry. The next sections describe the methodological steps that are recommended for carrying out the exercise. This description may also be valid for that part of research in phases 3 and 4 that deals with top-down studies.

To study the effects of sources of influence on science and technology variables, we refer to the conceptual framework put forward in Chapter 2 of the present guidelines, and in particular to the matrix shown in Figure 1. The purpose of the exercise is to use the top-down approach in the research, from source of influence to variable. This is done by formulating hypotheses about the effects that the sources of influence (independent variables) provoke on the science and technology functions and activities (dependent variables). This requires entering the matrix from the left, identifying and describing the main independent variables that may be expected *a priori* to produce effects (here the results of phase 1 will be useful) and the dependent variables each of the former may affect. Hypotheses may then be formulated about such effects. Obviously, not all the subdivisions of the matrix need have a hypothesis tacked on to it. Such hypotheses may be formulated at two levels:

(a) at a general level, that is, for the whole of industry, and the activities in the science and technology system and the linkage area of direct relevance to industry. However, some of the participating countries may also wish to cover other areas of economic activity, such as agriculture or mining, and other parts, or the totality, of activities in the science and technology system and the linkage area;

(b) at the specific level of each of the industrial sectors chosen for study, and of the activities of the science and technology system and the linkage area of direct relevance to them. Many of the hypotheses in these sets will be particular cases of the hypotheses set in (a) at the general level, but it is hoped that greater precision may be attained in their formulation than in the former case, since they are to be subjected to careful empirical testing in phases 3 and 4.

Hypotheses under (a) may now be subjected to scrutiny, through collection and where the independent variable is an explicit science and technology policy instrument, also to its effectiveness. They should attempt at quantification whenever possible.

Hypotheses under (a) may now be subjected to scrutiny, through collection and appraisal of evidence from various sources, including opinions, that would lead to their corroboration. This screening process would allow retention of hypotheses that seem more plausible.

The results of this screening will produce a body of hypotheses about the effects on science and technology of explicit and implicit science and technology policy and instruments, and of contextual factors. An examination will undoubtedly show many conflicts and contradictions, which are an important outcome of the exercise. Since an idea exists about the direction and intensity of the effects, it is now possible to construct the "resultant" science and technology policy that will combine the effects under each of the main subdivisions of the science and technology functions and activities. This resultant policy may be expressed in the form of a new set of hypotheses, and these in their turn may be summarized into a limited number of statements that may be of great use for policymakers. Such general statements, and the set of hypotheses that make up the resultant policy, may be checked later with the results of phases 3 and 4, as well as with other information that may come up during further research work.

Having described the general outline of research, we shall now examine each step in more detail.

a. *Effects of policy variables and contextual factors on dependent variables*

This task looks deceptively simple in outline. Having identified and described the various sources that *a priori* may have effects on science and technology variables, we must trace such effects and put forth postulates and hypotheses relating to them. For instance, we may take an explicit policy that puts a heavy tax on the import of certain capital goods, with the purpose of developing local production in some high-technology items. We would trace the way this policy is implemented, i.e., describe its instrument (or instrument cluster) according to the outline we have suggested; identify the dependent variables on which it will act (say, the selection of sources of capital equipment for the branches of industry using them), and make hypothetical statements about the direction and intensity of the effect and about the effectiveness of the instrument. Such hypotheses may be made at the level of the whole of industry, and for each of the branches that have been selected for detailed study; in the latter case one would attempt a higher degree of precision.

Even in this apparently simple example many problems may soon be observed, because a complex chain of effects is set in motion when the instrument acts. One way of looking at it is to say that on raising the value of certain inputs, management decisions in the productive units will be affected so that there will be a shift (how big? how quick?) from foreign imports to domestic production. This will, in time, have several repercussions:

- In the short run, the rise in price may cause the firm to lean toward less capital-intensity of their investments. Or the firm may look forward to a raise in the prices of its products, on account of both higher price and less efficiency of national equipment. Such types of behaviour have an impact upon end variables of economic development (employment and rate of inflation in this case).
- Suppose that local manufacturing is not well developed as yet for this particular type of equipment. The firm cannot any longer just order from a catalogue from an overseas supplier whose costs and quality are familiar and trusted. One may hypothesize that the firm's technical staff will have to assume the responsibilities of setting up technical specifications for would-be local suppliers of equipment; moreover, it will have to locate such suppliers, help them with their technical production problems, follow up their work, and control the quality of deliveries. This would be a likely effect *if* certain other conditions exist, such as a forward looking management, a minimum technical capacity to start from, a firm that is not small, etc. If such favourable conditions (that belong to the firm itself) do not exist, the replacement of foreign by national equipment may mean a penalty for the firm in terms of cost and quality, unless action is taken by an outside institution (a research and industrial promotion agency, for example).
- There are evident repercussions of the firms' behaviour upon the local producers of equipment, which would have a higher demand for their products. This in turn may push the latter to make technological improvements, particularly if help is provided by the client firms and/or by other institutions.
- Local producers may make a demand to the scientific and technical system for knowledge to help them meet the users' technical requirements; or they may look for foreign technologies through licensing.
- The existence of a tariff barrier may make

it profitable for foreign capital to install a local subsidiary for the local manufacture of the equipment. The implications of this course of action should in turn be considered.

Hence, the full effects of this policy are not easy to trace. There will be a first-order effect, or direct impact, upon one easily identified function or activity, as well as high-order effects within and without the firm that take place over time. When studying a recent measure many of these effects may have not yet had time to manifest themselves and we would then more properly speak about "implications." But even in the case of long-standing measures, it is not simple to trace through the network of effects.

The analyst, having made an effort at identifying the network of effects, may then summarize his belief of what happens (or may happen) in the form of a hypothetical statement, which in our example may be thus: "This policy is intended to provoke local manufacture of equipment X. We hypothesize the following effects: state firms will on the whole continue to import the equipment since state decision-makers tend to totally protect their investments[8]; private firms of local and foreign capital will tend to buy locally but only in a few cases will they act upon the suppliers to make them produce better equipment; suppliers cannot expect help from the science and technology system since there is little capacity related to the manufacture of this type of equipment[9]; suppliers will tend to buy licences abroad; one or two foreign manufacturers may set up shop in the country, and through new investment, purchase a local firm or a joint venture with it; the final effects upon macro-economic and social variables will be higher foreign exchange outlays and loss of control in a part of the industry. As to the effectiveness of the instrument, it may be said that it has attained its purpose of bringing about local manufacturing at not too much direct cost (in handling the instrument) but that if all the effects are considered, it is not clear whether the measure by itself has been a good one." Once he has verified this proposition the analyst might recommend something like: "Measures of this sort should in the future be adopted only after a careful study of their implications, and concurrent measures should also be taken to assure its best social impact, such as a scheme to help technically and financially equipment manufacturers with their technological improvement, and a stiff control of investment decisions by state enterprises that will make them purchase the local product." The analyst now is really speaking about a "function-oriented" cluster of instruments to act upon the science and technology variable.

To spell out such a hypothesis the analyst must have a good knowledge of how the economic system in the country actually works, of how firms are bound to react (which depends on numerous factors and variables specific to the firm), of how the science and technology system and the linkage area function, and of what constraints are imposed by the context. The research undertaken under phase 1 will therefore be of great relevance to national teams when working in this part of phase 2.

Some types of hypothetical statements, obtained through deduction, may be accepted as they stand without the need for empirical testing. These we may call "conclusions." Other types, which stem from deductive and inductive reasoning, are in need of verification and may be considered as "hypotheses."

However, the testing of the latter type of statements may have varying degrees of conclusiveness. At one extreme we have what we may call "hypotheses about implications," which refer to policies that have not yet been in operation, or have been operating only for a short period; here there are no actual effects to be looked at, and it is only possible to corroborate the hypotheses by asking persons and institutions that may be affected by them how they will react. This corroboration based on opinions and anticipated reactions we may term "weak." At the other extreme we may have "hypotheses about actual effects"

[8] Note that the constraint put by a contextual factor is clearly identified.

[9] Note that the constraint put by a contextual factor is clearly identified.

that may be verified by analyzing actual behaviour, leading to a "strong" corroboration. Intermediate situations may give rise to weaker or stronger corroboration. Of course, it may be impossible to verify certain hypotheses about actual effects if there is no access to data about actual behaviour; here perhaps some weak corroboration may be looked for through opinions or the examination of secondary sources.

We have referred up to now to explicit policies and their instruments, but the implications and side effects of implicit policies may be treated in a similar manner and give rise to conclusions and hypotheses of a similar nature.

In the case of contextual factors, we may also put forth hypotheses about the constraints and limitations they place on the effects of policy variables, either directly or through their influence on institutional structures. However, it seems unlikely that any strong corroboration may take place by analyzing actual influences, since by definition a contextual factor cannot be changed in the short or medium run. Contextual influences "are there," so to say; they do not suffer rapid changes that would easily uncover their effects. Two ways of "weak" corroboration seem open. The first one is taking a historical perspective, looking many years back to see how slow changes in a certain contextual factor had influenced the effects on certain science and technology variables. The problem is that most of the countries in STPI have a very short history in science and technology, and perhaps the time span will not be enough to adequately reveal the effects of slow changes in contextual factors on this history. The second way is to rely on opinions about possible reactions to hypothetical questions like: "would university scientists be more interested in working in national problems if they were to take their advanced degrees at home and not abroad?" Such questions, not easy to phrase, would naturally follow from the hypotheses that have been formulated.

However, one of the advantages of a comparative project like STPI is that we may put forth hypotheses to be cross-tested among countries, since differences in contextual factors will be found between the participating countries. Hence, from the various outcomes of the national reports to be obtained after phase 4, a number of central questions about the influence of contextual factors on science and technology may be tested in phase 5. Hopefully, the corroboration will be "strong" for some of those questions.

We have already stated that, for each source of influence, conclusions and hypotheses should be formulated about their effects upon science and technology variables under the three headings of demand side, supply side, and linkage area. Such hypotheses will only rarely be simple and unidirectional, or easily amenable to quantification; they will tend to be complex statements of cause and effect. We are not interested in having an exhaustive set of hypotheses that cover all causes and all effects, nor is it possible to think of such a comprehensive set. The aim should be to cover the principal sources of influence, and for each, the principal effects or implications.

(b) *Corroboration of general level hypotheses*

At this stage we should have a description of how the main explicit policies, implicit policies, and contextual factors act on science and technology variables, together with a set of hypotheses at general and specific levels, about direction and intensity of the effects, and about the effectiveness of instruments in the case of explicit policies.

The general hypotheses should now be subjected to corroboration, as far as this is possible with the help of existing data, opinions, and other elements. We suggest that this be done at this stage for two reasons: one is the intrinsic value of finding out how valid the hypotheses are, and the second because the exercise will allow a much better planning of activities in phases 3 and 4, particularly regarding the preparation of checklists, questionnaires, and other methodological instruments. It may also be said that this general type of corroboration will allow more careful reformulation of the specific hypotheses to be tested at the micro level.

The research team, on preparing the analysis of effects and formulating hypotheses, will already have amassed a body of evidence. But it is now a question of casting the net wider, of collecting published information and approaching people and institutions with questions framed as precisely as possible. Though we can hardly suggest a set procedure for this stage, we may refer to a promising technique: to set up panels of knowledgeable persons to whom these questions are put, so that they may be able to give their opinion about the validity of most of the hypotheses. This panel would also be important in bringing to the attention of the team various types of recent information that may be of help. Discussions among panel members would also be of interest to the research teams.

Once this is done, the team may screen the hypotheses and retain those that seem more plausible leaving the corroboration of more precise and detailed hypotheses for phases 3 and 4.

(c) *Resultant science and technology policy*

The results of the previous steps will have produced a body of hypotheses, to which high plausibility may be attached, about the effects on science and technology of explicit and implicit science and technology policy and instruments, and of contextual factors.

An examination will undoubtedly show various conflicts and contradictions that are an important outcome of the exercise. Since an idea exists about the magnitude of the effects, it is now possible to construct what may be termed a "resultant" science and technology policy that will compound the effects of all the sources of influence.

To give an example, we reproduce in Table 4 some statements about the impact of the economic system and government economic policies on the science and technology system in Latin America.[10] Most of the characteristics shown in this table would seem to have a negative impact on the development of domestic technological capabilities. The resultant policy might be expressed as follows:

> Domestic scientific and technical capabilities do not need to be developed beyond a certain minimum. The greater part of technological knowledge to be employed in productive activities should be imported, especially from the countries where technology is most advanced, even if this implies higher cost. Therefore, only the strictly necessary science and technology activities to support such productive activities, particularly those of a routine nature that do not imply research, will be undertaken domestically.
>
> The larger enterprises, particularly those associated with foreign firms, are the only ones that should use science and technology inputs intensively. All other enterprises would be better off using traditional production methods, even if they are obsolete, and should not try to introduce science and technology research.
>
> Enterprises should be protected from foreign competition and guarantees should be given them so that they will yield benefits. It is irrelevant whether or not they employ technologies that are adequate to local conditions; what matters is to stimulate entrepreneurial activity.
>
> The production of goods and services should be oriented toward the satisfaction of the demand from the higher income brackets, to which the production of the most dynamic industrial branches with high scientific content is directed.
>
> Capital intensive production techniques should be preferred over labour intensive techniques. Incentives must be given to entrepreneurs for strong investment in machinery and equipment, even though they should not be fully utilized. Machinery and equipment should be imported whenever possible and therefore there is no need to promote the development of labour intensive techniques adapted to local conditions through science and technology research.

Perhaps no government official would accept that this represents the policy of his government. And he may point to certain

[10] Extracted from F. Sagasti and M. Guerrero, *El Desarrollo Científico y Tecnológico de América Latina*, BID/INTAL, Buenos Aires, 1974.

Table 4

Some Characteristics of the Economic System and of Government Economic Policies in Latin America and Their Impact on the Scientific and Technological System

Characteristics of the economic system and of government economic policies	Implicit impact of the scientific and technological system
Characteristics of the economic system	
Technological dualism (a few advanced firms coexisting with a large number of backward ones)	Only a small number of firms are capable of absorbing modern technology and hence potential users of the knowledge generated by scientific and technological activities. These are generally connected with foreign corporations.
Underutilization of existing capacity	No need for doing production research to increase level of output, production can be easily expanded.
Deformed price formation mechanisms (protectionism, oligopolies, myopic price controls)	Entrepreneurs have no real incentives to reduce costs and operate more efficiently, hence there is little demand for scientific and technological activities.
Predominance of foreign investment (particularly in key dynamic sectors)	Need for scientific and technological activities, particularly research and development, are satisfied from abroad. Only routine activities are performed locally.
Gross inequalities in the distribution of income	Industrial activities are oriented toward producing goods for a small segment of the population with high income. Technologies are geared to producing a large variety of goods for this population segment and imported for this purpose.
Conservatism of local entrepreneurs	Distrust for local scientific and technological capabilities, preference for well known and proved technologies (generally foreign). Risk capital for new and advanced technologies are not available.
High rates of inflation	Long-term capital-intensive investments are preferred particularly when funds are borrowed from state sources.
Lack of viable technological alternatives	Unsuitable technologies developed elsewhere are imported and used in a different context.
Characteristics of government economic policies	
Credit policies biased toward capital equipment, particularly when foreign aid and credit are involved	Capital-intensive technologies are preferred over capital-saving or labour-using technologies.
Fiscal incentives geared toward promoting additional capital investments (tax credits, tax exemptions, etc.)	Investment in equipment becomes more attractive than investment in working capital to enlarge the labour force.
Social policies that make labour expensive (social security, unemployment funds, medical benefits, etc.)	Demand for capital equipment, machinery, and even intermediate products is oriented outward, particularly toward developed countries.
Overvaluation of exchange rates (making imports cheaper)	Importing foreign machinery and equipment becomes attractive.
Tariff barriers and protectionist measures are taken as part of an import substitution industrialization strategy	Indiscriminate protection makes inefficiency profitable and reduces effective demand for scientific and technological activities.

policies that would seem to correct the situation. In Peru, for instance, the Development Plan 1971–75 has a chapter on technology policy with various statements that would attempt to redress the situation. In this specific case the explicit policy of the Peruvian government shows contradictions with the implicit technology policy derived from its economic structure and from the characteristics of some government policies (for instance, explicit policy desires to develop labour-intensive technologies but there are implicit obstacles to this possibility). The exercise of contrasting explicit and implicit policies cannot be resolved exactly, nor is it possible to reach deterministic conclusions. The implications of many implicit policies are derived through deductive reasoning and are not easy to verify empirically. In a similar way, it is difficult to know what the real effect would be of explicit policies that sometimes are not implemented properly, or just remain on paper.

On account of these difficulties it is proposed that the resultant policy should be expressed in the form of a new set of hypotheses that themselves may be subjected to corroboration — as far as this is possible — through the same procedure of panel discussion as we have referred to above. From such an examination it may now be possible to summarize the resultant policy into a limited number of statements that may prove of great utility to policymakers.

Such a summarized resultant policy, which has been obtained through work at a general level, may be checked later with the results of phases 3 and 4, as well as with other information that may come out during further research work.

Chapter 4

Guidelines for Phases 3 and 4

The industrial "branch" as a unit of analysis for research and policy

The first two phases of the research in STPI deal with the scientific and technological system, the economic system, and their interactions at the national level. Phases 3 and 4 examine the behaviour of a few industrial branches to assess the effectiveness of policies and policy instruments in achieving technological objectives. They involve a process of narrowing the scope of research efforts to obtain specific results that later could be generalized within the framework of the work carried out in phases 1 and 2. Also, by coming down to the level of specific industrial branches and their constituent units, it will allow gathering empirical data to corroborate or reject the hypotheses put forward at earlier stages. All of this would allow a comparison of results among the different teams participating in the STPI network.

Three groups of science and technology functions and activities were distinguished in Chapter 2: (a) those in the demand side (demand and absorption of technology) normally arising out of the behaviour and technological decisions of productive units in the branch; (b) those in the supply side (generation of technology, provision of science and technology services and skills), normally carried out by research institutes and educational institutions; and (c) those in the linkage area (relating the science and technology system to the productive system, regulation of technology transfer) usually carried out by a variety of institutions such as engineering firms, government agencies, etc.

The approach in the STPI project involves a general study of these influences in an industrial branch, as well as a detailed study of certain important units in the demand side (e.g. state enterprises), the supply side (e.g. technological institutes), and the linkage area (e.g. engineering firms). These are the "case studies."

A difficulty arises from the fact that science and technology functions and activities taking place within a branch usually cannot be ascribed exclusively to institutions belonging only to the supply, demand, or linkage areas. We must keep in mind that often a single unit or institution performs more than one type of science and technology function and activity at the same time, and that the guidelines offer only a conceptual distinction that would allow the national teams to tackle their research efforts in phases 3 and 4. A few examples of overlapping functions may be in order:

(a) Productive units may have research and development groups. It is open to question whether these groups are put together with identifiable units in the "supply side", such as research centres and technological institutions. Enterprise research groups may display different patterns of behaviour since they must obey the enterprise rationale. Moreover, they also perform functions that could be grouped under the heading of "technology absorption".

(b) Units engaged mainly in "supply" activities such as research institutes, may carry out linkage activities that cannot be assigned exclusively to a particular individual or group of persons, but are disseminated among research groups and individual researchers. Unless the institution is totally isolated from the users of the research, one is likely to find linkage activities performed by members of the institution.

(c) Units in the "linkage area" may prove difficult to identify and separate from organizations providing technical services to industry. A partial list of such units would include information and documentation centres, productivity centres, promotion and extension groups within research units, engineering firms, extension institutions, organizations for the regulation and control of foreign technology imports, and institutions involved with foreign technical assistance.

A further point to be considered in the conduct of the research in phases 3 and 4, is that the technological behaviour of the industrial branch is more than the sum of the individual behaviour of its constituent units. To understand the technological behaviour of the branch, it will be necessary to consider also entities other than those directly involved in scientific and technological activities. This arises out of the need to include contextual factors and implicit policies in the research, and from the realization that an industrial branch may be the appropriate level of aggregation for the design of science and technology policies. However, it becomes necessary to define the concept of "branch" in a special way more in accordance with the purposes of research in STPI. Furthermore, the concept of an "elementary unit of analysis for science and technology policy" emerges as an important concern. This refers to the smallest collection of productive, research, and service units for which it makes sure to define science and technology policies, and it may or may not coincide with the "branch."

One of the main difficulties in using the term industrial "branch" arises out of its ambiguity, and the same happens to the term "sector". Both have several uses and misuses. In economic statistics, "sector" would encompass all productive units engaged in agriculture, mining, manufacturing, and so on. The "branch" is a subdivision of the sector, and specifies in more detail the type of productive activities of the unit. The UN International Standard Industrial Classification (ISIC) provides a skeleton for this type of taxonomic scheme. Manufacturing industry is divided into more than 20 headings, each of which is further subdivided. Most countries have adopted this system for economic statistics with some adaptations to suit their own specific needs. Thus, as a starting point it may be suggested that a "branch" is the collection of productive units that undertake an activity listed in the ISIC (or the corresponding national classification) at two, three, or more digits according to the specificity desired.

However, ISIC and its derivations have been devised for the purpose of gathering economic statistics. In practice, productive units may group themselves differently, disregarding the type of "final product" classification system on which the ISIC and its derivations are based. For example, when productive activities are integrated vertically it may be more relevant to take an industrial "branch"as the collection of closely interconnected productive activities that follow the successive transformation of the raw materials that may intervene, and this spans two or more ISIC headings. Such may be the case of the "iron and steel" branch. In other cases it may be more relevant to consider the branch as a collection of enterprises manufacturing a certain product and its close substitutes. It may also be necessary to use entirely different classificatory schemes that are more relevant for technology policy purposes (e.g. taking into account producers' associations, export-oriented industries, productive units with the same technological characteristics, etc.).

The first issue in the conceptualization of a "branch" refers to the definition of criteria to determine whether a particular unit (productive or otherwise) is to be included or not. The ISIC system uses the "final product" criterion: an enterprise or productive unit is included in the branch if it manufactures the product to which the code refers. Other alternative criteria may be:

(a) The **vertical integration** criterion. In this case, the branch would be defined as the collection of productive units manufacturing a stream of products that feed into subsequent production stages until a range of final products of predetermined characteristics is obtained. The case of the steel industry was mentioned before, and it may include the production of iron-ore pellets, coke, the generation of the energy required, and all the intermediate processes such as blast furnace, rolling mills, special alloys plants, etc. The final product in this case may be iron rods, bars, sheets, planks, etc. A similar criterion could be used to define the "petrochemical branch" in which a range of final products may be specified and all the feeding industries that have backward linkages could be included (intermediate petrochemicals, basic petrochemicals) up to oil refining itself. The point to be stressed here is that the criterion of vertical integration may lead, in a certain country, given its characteristics, to a more meaningful definition of the "branch" for technology policy purposes.

(b) The **common modular technology** criterion. In this case the "branch" could be defined as the set of productive units that share the same type of "modular" technology, that is, they have the same basic production process, even if they may be involved in the manufacture of very different products. For example, the manufacture of alcoholic beverages, yeast, certain chemical products and pharmaceuticals, and even the concentration of copper ores via hydrometallurgy with bacterial leaching, share the basic production process of fermentation and the growth of bacterial cultures. In this case it may be relevant to treat all of these different processes as a "branch" for the purpose of training manpower and human resources. A more familiar example would include basic foundry techniques common to a variety of metal, mechanical and electrical industries. In this case it may be more useful to design technological policies for the foundry "branch" of industry.

(c) The **administrative jurisdiction** criterion. In this case, the "branch" could be defined in terms of the structure of the government machinery, with the idea in mind of facilitating the formulation and implementation of science and technology policies. In some countries, the structure of ministries, state enterprises, and government agencies has little to do with any of the classification schemes mentioned earlier, although this structure may be better suited for the formulation and implementation of technology policies. For example, a ministry of mines may have jurisdiction, not only over extractive activities, but also over the primary and secondary transformation of minerals and over the supply of equipment for mining and refining operations. In this case, the ISIC, vertical integration, and modular technology criteria would give way to the criterion of administrative jurisdiction for the purposes of technology policy formulation and implementation.

These are not the only criteria for defining a branch. We could also include criteria such as the "common technological strategy," grouping those productive units in which the same type of technology policy should be followed (reliance on foreign technology, performance of R&D activities, etc.); the "property ownership" criterion, which would divide productive units according to whether they are foreign, private, or state owned; and others that may be devised to suit the conditions prevailing in a particular country (sources of finance, labour characteristics, degree of automation, and so on). Also, the branch can be defined in finer detail through application of more than one criterion at a time. This would lead to the formulation and implementation of highly specific policies for scientific and technological development.

The point should be made that each country team may need a definition of the concept of "branch" suitable for the purposes of research and policy, and that this specification is a prerequisite for carrying out the tasks involved in phases 3 and 4 of the STPI project.

Up to now the industrial "branch" has been treated as the collection of productive units, grouped in accordance to some common characteristic using the criteria mentioned above. The demarcation of a branch would thus be obtained from the application of one or more criteria to the selection of productive units to be included in the analysis. However, from the point of view of designing and implementing science and technology policy, the definition of a "branch" in terms of productive units alone would be insufficient. We have already stressed the need for incorporating supply and linkage units in our analysis, and there is also a strong case for including service units such as finance organizations, specialized government agencies, marketing and distribution firms, and associations of professionals and of producers. All of these entities interact significantly with the productive units included in the branch. In effect, this implies going beyond what is conveyed by the term "branch," replacing it by a wider concept of "basic unit for science and technology policies."[11]

Therefore, an industrial "branch" would be defined as the collection of productive, supply, linkage, and service units that interact closely among themselves and form a coherent whole from the point of view of formulating and implementing science and technology policies. The productive units to be included are determined in accordance with criteria such as the products manufactured, the degree of vertical integration, commonalities with respect to the modular technology they use, etc. The supply, linkage, and service units to be included are determined in accordance with the interactions they have with the productive units thus chosen. Government agencies (their divisions or departments) that perform policy functions are also included among the service units.

Interactions take place not only among productive and supply, linkage, or service units, but also among the productive units themselves. These interactions may be a source of interdependencies, such as in the cases of backward or foreward linkages, associations of producers, and enterprises using the same raw materials. They may also be the source of tensions arising out of competition at the final product level, or at the level of factors of production. There would also be many interactions among linkage and supply units, among service and supply units, etc. The point to be made is that the degree of interconnections among all types of units is what makes the "branch" a system and the appropriate unit of analysis for technology policy.

In practice a "branch" may be more or less well defined or complete, depending on whether all the units deemed relevant for its functioning are present and on whether all the necessary interactions are established (although it may be the case that some undesirable units or interactions should be removed). This would lead to an assessment of the completeness of the "branch" and to the identification of some missing units or missing interactions.

For example, the process of examining the completeness of a "branch" may lead to the realization that linkage units are missing, or that an existing financial institution should establish linkages with some productive units, or that an association of producers linked to an educational organization may be the best way of assuring that technology policies will be implemented.

The degree of completeness of the "branch" can only be established through an iterative process that requires both an initial conceptualization of the "branch", its function, purpose, and the elements it should have, and the gathering of empirical information. Gradually, the image of what a "branch" should comprise will emerge from this iterative process, thus allowing — at the end of phases 3 and 4 — the identification of measures for the creation or elimination of units and interactions.

An example may illustrate the process of identifying the "branch" as a unit of analysis. Initially we may take the branch as the whole of capital goods producing entities and the service, supply, and linkage units connected with them (using roughly the ISIC criterion). However, the diversity of productive units contained in this category may make the research difficult and also may not make sense from the point of view of formulating and implementing policies. Therefore, we may try to see whether parts of this system may constitute "branches" on their own right, such as machine tools. Looking at the array of productive units included in this new

[11] Rather than inventing a new word for this concept, we shall continue using "branch" in quotation marks. In the remainder of the Methodological Guidelines this expanded meaning of "branch" will be employed.

"branch" we may appreciate that they indeed constitute a system, and that their degree of homogeneity may allow the formulation and implementation of meaningful policies. If we wish to pursue the disaggregation process in further detail, we may distinguish "subbranches" such as chipping machine tools and metal forming machine tools, or divide productive units into large and small. However, upon further analysis, we may conclude that neither of these "subbranches" present systemic characteristics on their own, because no significant supply, linkage, or service units may be associated directly with either of them. Therefore, we go back to the machine tools "branch"as the basic unit of analysis for technology policy purposes, and for the research in phases 3 and 4.

The identification of a "branch" may proceed on the basis of existing information to be gathered by the teams from various sources (ministries, international organizations, industrial associations, previous research material) on the basis of consultation with experts, either directly or through a panel organized for the effect, or through preliminary surveys with productive, supply, linkage, and service units that are identified *a priori* by the research team.

As an *aide-memoire*, the following list may help in the identification of units to be included in a "branch." It should be interpreted and modified in light of the circumstances prevailing in each country.

(i) *Productive units* — Includes enterprises engaged in the production of goods and services. These could be classified according to size (value of production, value added, employees), ownership (state, foreign, private, cooperative, joint venture), market share, structure of imports and exports, capacity utilization, average productivity, type of technology used, and other similar parameters.

(ii) *Units engaged in the supply of technology* — These include research centres, technological institutes, research departments of universities, specialized research groups (private or publicly owned), individual inventors, service laboratories, and related organizations.

(iii) *Units in the linkage area* — Includes consulting firms, engineering design firms, specialized construction companies with large service departments, documentation centres, libraries, technical information and extension units, trade companies representing suppliers of equipment and know-how, agencies that regulate technology imports, technical assistance units, centres that offer "refresher" courses for high-level professionals, etc.

(iv) *Service units* — These can be subdivided into several categories:

- marketing, such as trading companies, distribution firms, wholesalers and retailers, and specialized trade fairs;
- finance, such as government departments that finance project studies, development banks (general and specialized), commercial banks, special funds established by the state, financing corporations, grant programs of private and government organizations, international organizations and funds, private investors, etc.;
- policymaking, such as government departments in ministries, independent government agencies, special committees and councils, large state enterprises (particularly their boards of directors), pressure groups (academic, professional, industrial, foreign, private, etc.), and so on;
- education and training, such as universities, technical centres, extension centres and agencies, workers' training centres, fellowship programs (local and abroad), special programs for training the staff of enterprises abroad (particularly by the supplier of foreign technology) etc.;
- other significant service units such as producers' associations, trade unions, professional bodies, etc.

It is also important to characterize the interactions between the "branch" and its environment, describing its size and place within the industrial sector and the economy (markets, imports, exports, suppliers, price and quality of goods produced, consumer groups it serves, etc.); its importance for development, as reflected in the priority the government attaches to it; the most important government policies that affect it; the degree of protectionism it is given, and so on. From the technological point of view, the transactions between the branch and its environment would include the technical constraints introduced by the structure of demand for the goods produced (such as the case of the automobile industry where the technology used is constrained both by the type of vehicle to manufacture and by the sources of technology), the services received from science and technology institutions that cannot be ascribed directly to the branch, and what comes from abroad in the form of technology transfer.

The systemic nature of the "branch," as we have defined it, implies that the technological behaviour of the "branch" is more than just the aggregation of the individual behaviour of its productive units. This is because of the introduction of supply, linkage, and service units, as well as the existence of interactions among all of these.

The parameters that would characterize the technological behaviour of the "branch" include the overall rate of technical change as shown by the evolution of productivity; the technological level of the branch in comparison with world standards (identification of technological gaps); the sources of local and foreign technology and their relative weight (for example ratios of R&D expenditures to payments for foreign technology); the degree of self-reliance for the introduction of improvements and refinements in the technology; the rate of increase of organized technical capabilities within the branch (the structure of technical skills embodied in human resources may be used as an index); the characteristics of the branch with regard to capital/labour and capital/output ratios and their evolution; the structure of sources of raw materials and intermediate products; the structure of research and development expenditures by productive and other types of units in the branch; the types of modular and peripheral technologies used in the "branch" and their dynamisms (expressed as the rate of obsolescence of products and processes), and other parameters of a similar nature.

Through an analysis of these parameters it will be possible to begin an examination of the relative effects of different policy instruments for the attainment of technology policies. These effects would be reflected in the change of some of the parameters that characterize the technological behaviour of the "branch." In a similar way it may be possible to examine the influences of contextual factors and the changes in behaviour that their modification induce. Finally, these parameters may also reflect the relative impact that changes in the internal structure of the "branch" (through the creation, suppression, or modification of units and relations) could have on the attainment of policy objectives.

From the above remarks, it can be deduced that the "branch" becomes a category of analysis mediating between the categories of industrial sector, national economy, and scientific and technological system, on the one hand, and the categories of productive unit, research centre, and linkage institutions on the other. The technological policy for the "branch" could then be differentiated from the policies aimed at productive, supply, and linkage units. The latter would be contained in the former as partial elements, and the former would contain an array of partial policies oriented to the different service units that also compose the "branch."

There would also be policies aimed at regulating the interaction among different industrial "branches" and at interpreting, at the "branch" level, the policies and regulations for the industrial sector, the economic system, or the scientific and technological system as a whole. The interpretation, translation, and implementation of these overall policies then becomes a key aspect to study when considering the "branch" as a unit of analysis in its own right. This is shown in Figure 10.

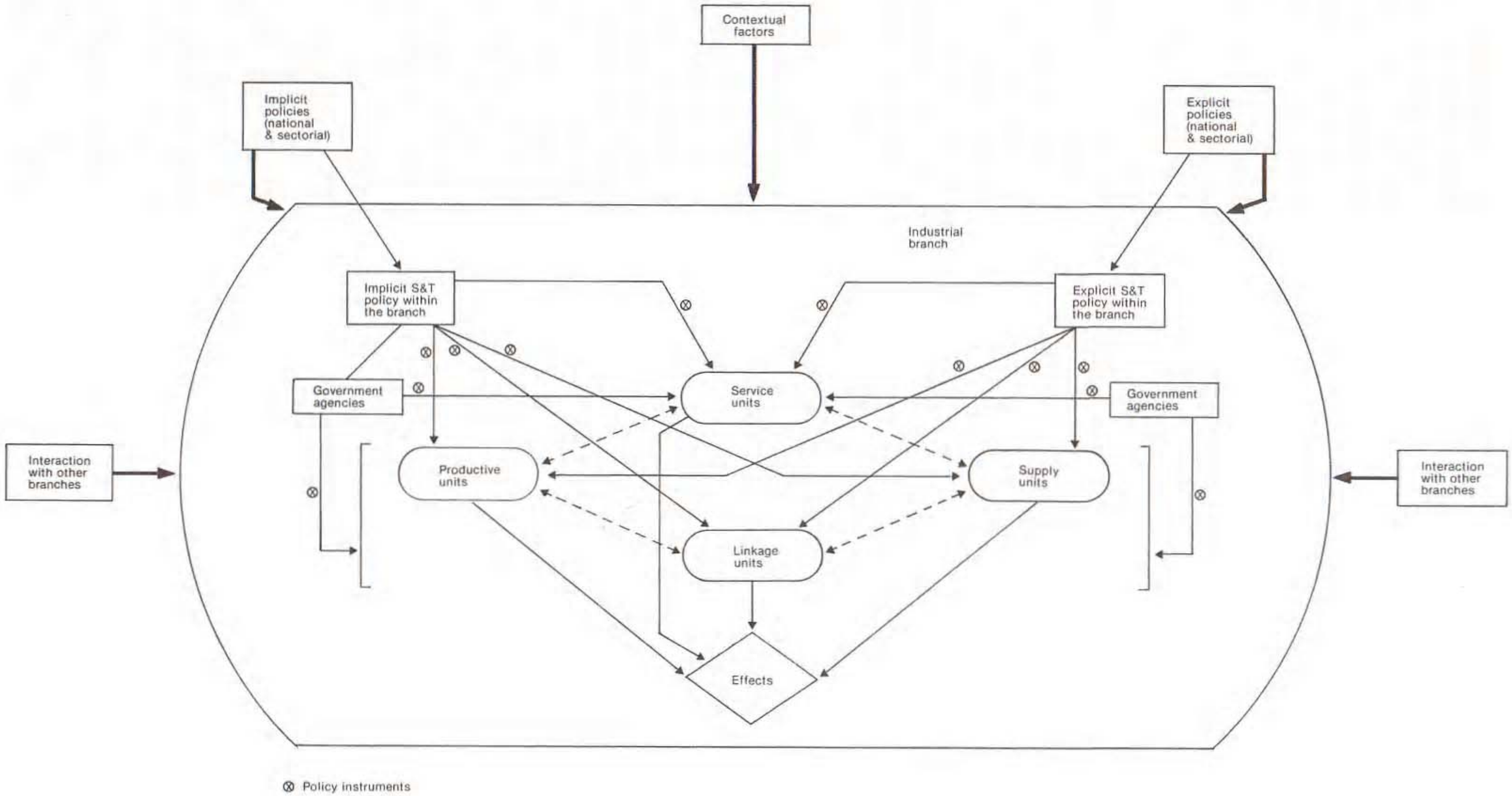


Fig. 10. The industrial branch as a unit of analysis for science and technology policies.

Another issue that arises when introducing the "branch" as a category of analysis mediating between the sector and the units, is the conceptualization of a hierarchy of technology policies. This hierarchy would require the definition of objectives and policies at different levels of analysis — national, sectorial, branch, subbranch, unit, operation — that move from the overall national level to the specific performance of activities within an enterprise. The formulation of an overall coherent set of policies at all levels remains a rational ideal that cannot be attained in practice. However, the interpretation of policies as components of a hierarchy permits study of their degree of coherence at different levels. Furthermore, it shows that the problem of conflict between individual and collective rationality does not appear only between productive units and the national economy. These conflicts appear at all levels, and require a constant process of negotiation and accommodation in which what becomes rational at one policy level may be irrational at the next one. Each category of analysis or policy level then becomes an intermediate link in a long chain of partial rationalities.

Technological behaviour at the level of the productive unit: study of the "demand" side in phase 3

The research approach in STPI postulates that the effectiveness of policies and policy instruments must ultimately be appraised in terms of their impact on productive units, where the basic elements of what constitutes technological development are fixed. This can only be done through data gathering efforts that will allow the research teams to examine what is actually happening with regard to technology, technology policies, and policy instruments used for implementing them.

The preceding section ended with some comments regarding the multiple levels of rationality for technology policy purposes. It is important to note that, at the "branch," sector, and national levels, it is rather difficult to identify clearly an entity that embodies the concept of rationality. In any of these levels, there are many agencies, individuals, and interest groups that make it rather difficult to focus sharply on a definition of "rational" behaviour from the technological point of view. This task may be comparatively easier at the level of the enterprise, for here the objectives, performance measures, and even individuals in charge of the organization are relatively easier to identify (although we may have the case of a very large enterprise that for all practical purposes behaves like a "branch"). Therefore, it is worthwhile to examine some of the principles that may govern rationality at the enterprise level and their potential conflict with rationality at higher levels in the hierarchy.

First, it is possible to state that the aims of policymakers at the "branch" and higher levels are to promote the demand for indigenous technology, to improve the absorption capacity in the productive units, to regulate the inflow of foreign technology, to promote the generation of indigenous technology, and in general, to develop technological capabilities and a capacity for autonomous decision-making in science and technology matters.

The aims of productive units may be different, and even conflicting with these, given the existing structure of policies (explicit and implicit) and the nature of contextual factors. Among the list of possible principles of rational behaviour from the productive unit's point of view we may have: profit maximization, cost minimization (these two are not necessarily equivalent), attaining a satisfactory level with regard to some performance measure (such as volume of output, profits, turnover, market penetration) maximizing output, maximizing the rate of growth (which is not necessarily equivalent to the former), maintaining long-term profitability and survival, penetrating markets to the fullest extent possible (search for monopolistic conditions), and so on. Any of these criteria, when examined from the point of view of their implications for technology policy may lead to some conflicts with the aims of policymakers.

However, there are many situations in which the removal of such potential conflict may be attainable, at least to some degree (which would lead to more or less "stable" alliances between policymakers and entrepreneurs). For example, the productive units may seek the help of policymakers to purchase technology from abroad and obtain better terms; to evaluate and choose among the available technologies; to obtain information with regard to alternative sources of technology; to adapt and modify existing technology to local conditions; to develop the enterprise's technical capabilities; and to manage more efficiently its own technical capabilities. In all of these cases it is possible to identify the convergence of interests between policymakers and entrepreneurs. However, it is important not to lose sight of the basic conflict between individual and collective rationality in which, broadly speaking, the enterprise's aim is to maximize (internalize) profits and to minimize (externalize) costs. This proposition is true not only in capitalist economies, but also in those socialist economies where short-term objectives prevail over long-term social goals.

In this context, "technological behaviour" is but one manifestation of a complex pattern of interactions between the enterprise and its environment, arising out of certain entrepreneurial decisions. These comprise issues such as financing, procurement, labour, market strategy, and the set of decisions that give rise to the technological behaviour of the enterprise, and are closely linked to all other decisions. Technology thus becomes the focus where the impact of many other decisions is felt.

The component elements of technological behaviour at the enterprise level are thus the technological decisions. For analytical purposes, technological decisions can be broken down into primary and secondary decisions.

For a given socioeconomic activity (output mix of goods and services), *primary technological decisions* would be those that affect (a) the mix of inputs, that is, the quantity and quality of factors of production; and (b) the process of transforming the inputs and factors of production into the output mix.

There is a close interconnection between the choice of output mix and technological decisions, in the sense that technology imposes constraints on the selection of goods and services to be produced, and that a choice of output mix (quantity and quality) implies a range of technologies to be used. Therefore, to a significant degree, the choice of output mix can also be considered a primary technological decision.

For a given set of primary technological decisions, *secondary technological decisions* would be those that affect the capacity for transforming inputs into outputs, as well as the way in which this capacity is incorporated into the production process and utilized thereafter. Secondary technological decisions also refer to the organizational structure and management of the productive unit.

The following list identifies a few technological decisions for a productive unit:

Primary technological decisions:

- establishing the scale of production;
- choice of production processes (capital-labour ratio, modular technology to be used);
- choice of equipment and design;
- choice of raw materials to be used;
- decisions on the services to be employed (energy, water, etc.);
- decisions on hiring and training of technical personnel;
- decisions on equipment maintenance;
- decisions on technical assistance;
- choice of scientific and technological activities;
- (possible) choice of output mix.

Secondary technological decisions:

- choice of channels by which to acquire technology (equipment, blueprints, designs, etc.);
- decision on the construction and supply of equipment;
- decisions on plant construction and starting up;
- choice of suppliers of inputs and the conditions to purchase these inputs;
- quality control for processes of production and for products.

The effects of all types of decisions can be observed through the pattern of demand for technology and through the characteristics of the technology absorption capacity of the enterprise. The demand for technology refers to the knowledge needed by the enterprise for new (for the enterprise) products and processes and for improving on existing processes and products. It may originate from domestic or foreign sources and appear in a variety of forms as disembodied knowledge (proprietary and nonproprietary), embodied in capital goods, embodied in intermediate products, or embodied in technicians and experts.

The *demand for domestic technology* is the result of technological decisions that lead the enterprise to carry out scientific and technological activities or to orient its needs for knowledge toward research centres, consulting firms, engineering organizations, universities, etc., within the country. This would also comprise the technology available elsewhere in the country that is obtained free through the diffusion process. Considering that local manufacturers of equipment, processes, and intermediate products often incorporate locally generated knowledge into their productive activities, the technological decisions referring to the purchase of equipment, processes, and certain intermediate products may also be considered as a demand for local technology.

The *demand for foreign technology* would be the result of technological decisions that lead the enterprise to acquire the technical knowledge from sources abroad, not only through the purchase of equipment, processes, know-how, licences, and intermediate products, but also through the purchase of technical services and the reception of technical aid from foreign firms, governments, or multilateral agencies.

The characteristics of the *absorption capacity* will depend on a series of technological decisions regarding the scientific and technological activities undertaken by the enterprise, primarily those oriented toward assimilating and improving the technology already incorporated. It comprises decisions on research activities that would lead to plant optimization, product improvement and development, the adoption of quality control systems and standards, and trouble shooting. Another group of scientific and technological activities that affects the absorption capacity refers to the purchase of services to improve production processes.

Another way to examine the technological behaviour of the enterprise is through a conceptualization of the process that leads to the use of technology in the enterprise. Four stages may be distinguished in this process: (a) problem identification; (b) decision on the use of a particular technology; (c) incorporation of the technology into the productive process; and (d) utilization of the technology.

The *problem identification* stage would involve examining a general problem area for the enterprise in terms of one or more primary or secondary technological decisions that may lead to it. It is at this stage that the basic terms of reference for the solutions sought are established. The second stage involves the *decision-making process* where the choice of the technical solution is made. Then, once a particular technological solution has been chosen, the enterprise must *incorporate* it effectively within its productive processes. This involves a set of secondary technological decisions regarding the way in which the technological solution will become part of the ongoing operations of the enterprise. Finally, once it has been introduced into the productive process, the *utilization* stage involves not only the use of the technique to produce predetermined goods and services, but also the need to improve on it and make the modifications necessary to improve efficiency. Of course this is not a linear process, for there are many feedback loops at all stages, and also the incorporation and use of technology lead, in turn, to new problems.

The concepts of technological decisions, of demand and absorption of technology by the enterprise, and of the process of utilizing knowledge, provide some ideas for the analysis of the technological behaviour of enterprises. However, in order to observe the patterns of technological behaviour it is necessary to focus on specific parameters.

These parameters would be the things to look at when gathering empirical data from the enterprises. An illustrative list follows:

Characteristics of the product mix. As long as the choice of output mix is one of the main determinants of technological behaviour, this parameter would identify the characteristics of the product mix in terms of the market it is supposed to serve, the quality of the products, the price at which they are supplied, and so on. Distinctions may be made if products are directed to mass consumption or the consumption of an elite in the case of consumer goods, whether they are supposed to serve primarily as an input into other production processes, whether they are for export, or whether they are related to prestige or defence considerations.

Characteristics of the technology used. Here it would be useful to distinguish between modular and peripheral technologies, attending to the characteristics of each. Capital/labour and capital/output ratios should give an indication of the capital intensiveness of the technology. The engineering characteristics of the modular technology used (for example, discrete-continuous), would derive their implications for technological behaviour from, and compare the technical level of the enterprise with, world standards. The type of peripheral technologies employed would give an indication of the preference of the enterprise for local or foreign technology, and whether they could be provided by local sources. The scale of production and the degree of capacity utilization should also be considered in this category of parameters.

Origin of the technology used. This parameter may be broken down to differentiate the sources of capital equipment, licences, raw materials, intermediate products, assembly components, etc. A first distinction would be whether they are local or foreign. Then it could be refined to include whether the technology supplied locally comes from foreign subsidiaries, local enterprises working under licencing agreements, and so on.

Form in which the technology is acquired. There are many ways in which technology can be acquired by the enterprise. A first distinction would refer to whether the technology is obtained in the form of a turnkey plant or whether the technology package is assembled by the enterprise itself, considering all the gradations. Distinctions can also be made with respect to the acquisition of technology via the purchase of capital equipment, licences and know-how, technical assistance, etc. This group of parameters may be enlarged to include the conditions in which the technology is acquired. Finally, in this respect it is important to differentiate between new investments — the development of a new project — or the expansion of existing facilities.

Technical capabilities within the firm. This category would refer to the existence of organized technical skills within the enterprise. The capabilities in human resources, the distribution of skills among the labour force, the existence of a group in charge of R&D, the existence of teams in charge of examining ways of acquiring technology, the physical facilities for R&D, engineering and quality control, the experience accumulated through the design and development of production facilities, etc. This would also include the capabilities for carrying out "trouble-shooting" activities and the performance of maintenance services.

Additional sets of parameters could be identified to characterize the technological behaviour of the firm, such as the capacity of the firm to contract out and evaluate the result of scientific and technical activities and services, the attitudes of managers and directors toward technological innovation, their degree of confidence in local technical capabilities, the attitudes of the technical staff of the enterprise with regard to modifications in the design of products and processes, entrepreneurial attitudes toward risk and innovation, and the degree of dependence of the enterprise on foreign technical advisors.

These parameters would represent the issues to be examined when studying the technological behaviour of the enterprise.

They would provide the relevant information to be interpreted within the framework of the rationality of the enterprise, and the different schemes to classify technological decisions. The choice of parameters to employ is one of the team's most important tasks in phase 3.

Factors affecting technological behaviour of productive units

The STPI project is concerned with the study of the effectiveness of policy instruments for the implementation of science and technology policies. In the last analysis this effectiveness must be appraised through the changes in the technological behaviour of the enterprise induced by a particular instrument.

The enterprise is subject to a variety of influences arising out of its internal characteristics and the environment in which it functions. One of such sources of influence is the set of policy instruments used for the implementation of technology policies. The task is therefore one of extricating the effect of the policy instruments, and separating it from other factors that affect the technological behaviour of the enterprise. In this task, it is possible to follow the general outline suggested in the guidelines for phases 1 and 2 for tracing the effect of sources of influence (explicit policies, contextual factors, and implicit policies) on science and technology functions and activities. The difference between the procedures established for the study of the economy and the industrial sector in phases 1 and 2 and those for the "branch" is that the process of tracing the effects of the different sources of influence will have the enterprise as the main focus, and that these effects can be examined through various parameters that characterize the technological behaviour of the enterprise.

The first source of influence would be the set of *contextual factors*, particularized at the level of the enterprise. These include the invariant contextual factors, such as geography, climate, etc. that probably do not affect the enterprise itself directly (but indirectly through its effect on the economy as a whole); the superstructural contextual factors that define the social and cultural milieu in which the enterprise operates (comprising aspects such as attitudes toward work, educational levels, degree of technical competence of the labour force, etc.); and the contextual factors resulting from cumulative policymaking over a long period of time (such as the relatively easy climate for the enterprise arising out of indiscriminate protection).

The second source of influence would arise out of *government policies* at the national, sectorial, and "branch" level. This would encompass both explicit and implicit policies for science and technology. Among the *explicit policies* all those referring to the promotion of scientific and technical activities, the performance of R&D in the enterprise, the control and regulation of the transfer of technology and so on, must be considered. The main sources of implicit policies would be the financial, labour, fiscal, pricing, location, and foreign investment policies that were mentioned earlier in the guidelines for phase 2.

There are two additional sources of influence affecting the technological behaviour of the enterprise, that do not follow directly out of the work of phases 1 and 2. First, there are the structure and characteristics of the "branch" to which the enterprise belongs. We have already seen the importance of the technological behaviour of the industrial "branch" as a unit of analysis and it is clear that its configuration, the degree of interaction among productive, supply, linkage, and service units, and its completeness will exert an influence on the way the enterprise behaves from the technological point of view.

The second source of influence would be the internal structure and characteristics of the firm itself, particularly with regard to its technical capabilities. The structure of the enterprise, comprising manpower and the organization, has an impact on the technological decisions made by the enterprise. Of particular importance is the existing stock of technology, embodied in capital equipment, for it would condition and limit the range of alternatives to choose from when making technological decisions. Other internal factors affecting the technological behaviour would be the existing capacity for technical problem-solving, quality control, research and development, adaptation, and the performance of related activities. Finally, the influence of characteristics such as ownership, composition and attitude of the board of directors, and the origin of managers, should not be neglected either.

Figure 11 shows some of the interactions between the sources of influence and the technological behaviour of the productive unit.

The methodological guidelines for phase 2 outlined a procedure for formulating hypotheses at the general level of the economy of the sector, and we have also discussed the formulation of hypotheses for the industrial "branch." The formulation of hypotheses at the productive unit level follows a similar process, except that the postulates refer to the impact of the sources of influence (contextual factors, explicit and implicit policy, characteristics of the "branch," and internal structure) on the technological behaviour of the productive unit.

In the corroboration of hypotheses several possible routes can be followed for gathering empirical data. A first distinction can be made between indirect and direct sources of information, the former referring to published or unpublished material containing data on enterprises. Of particular importance are the official surveys done by ministries and other government agencies, which individualize information by enterprise and are used for statistical purposes. Following this route it is possible to obtain information such as volume of sales, structure of imports, financial ratios, labour costs, etc. Generally the ministries of industry, of labour, and of finance have access to information of this type. A variant that may be used by teams having a wider access to government agencies would be to add some questions on technological behaviour to the questionnaires sent by government agencies.

Through these indirect means it is possible to obtain information about the basic characteristics of the enterprise — a "profile" of the productive unit. However, it is not sufficient to test the hypotheses. For this, the researchers would have to gather data directly through interviews and questionnaires. The preparation of a questionnaire or of interview guidelines would be greatly helped if the research team would have a profile of the enterprises to be visited at their disposal.

The second route involves visits to the enterprises. Here two approaches may be followed: the researcher leaves a questionnaire to be filled in by the staff of the enterprise, or he conducts extensive interviews with them. Of course, they are not mutually exclusive. From the experience acquired in the feasibility studies of the STPI project through the conduct of the research by some national teams and from other studies outside the STPI network, it appears that to follow the questionnaire route alone is not productive, and that a combined approach mixing extensive interviews with data gathering through questionnaires produces the best results. The extensive interviews may be preceded by a preliminary meeting with executives of the enterprise and by the preparation of a profile of the enterprise through indirect data gathering.

The third route involves the use of panels of experts. In some cases it is possible to identify consulting firms, government officials, professionals, or groups of experts who have an intimate knowledge of the workings of a particular industry, and who have at one stage or another visited most of the important enterprises. It may be possible to assemble such a group of experts, consulting them on some of the questions that refer to the technological behaviour of the enterprises they are familiar with.

Implicit in these arguments is the fact that most of the hypotheses generated would arise from the "top down" research approach discussed in the guidelines for phases 1 and 2. However, the process of obtaining data from the enterprises may lead to the formulation of new hypotheses, taking the point of view of the enterprise and examining the main sources of influence that affect its technological behaviour. This in fact, would imply an inversion of the matrix for generating hypotheses for one would move from the parameters that characterize the technological behaviour and from science and technology activities in the enterprise, to the sources

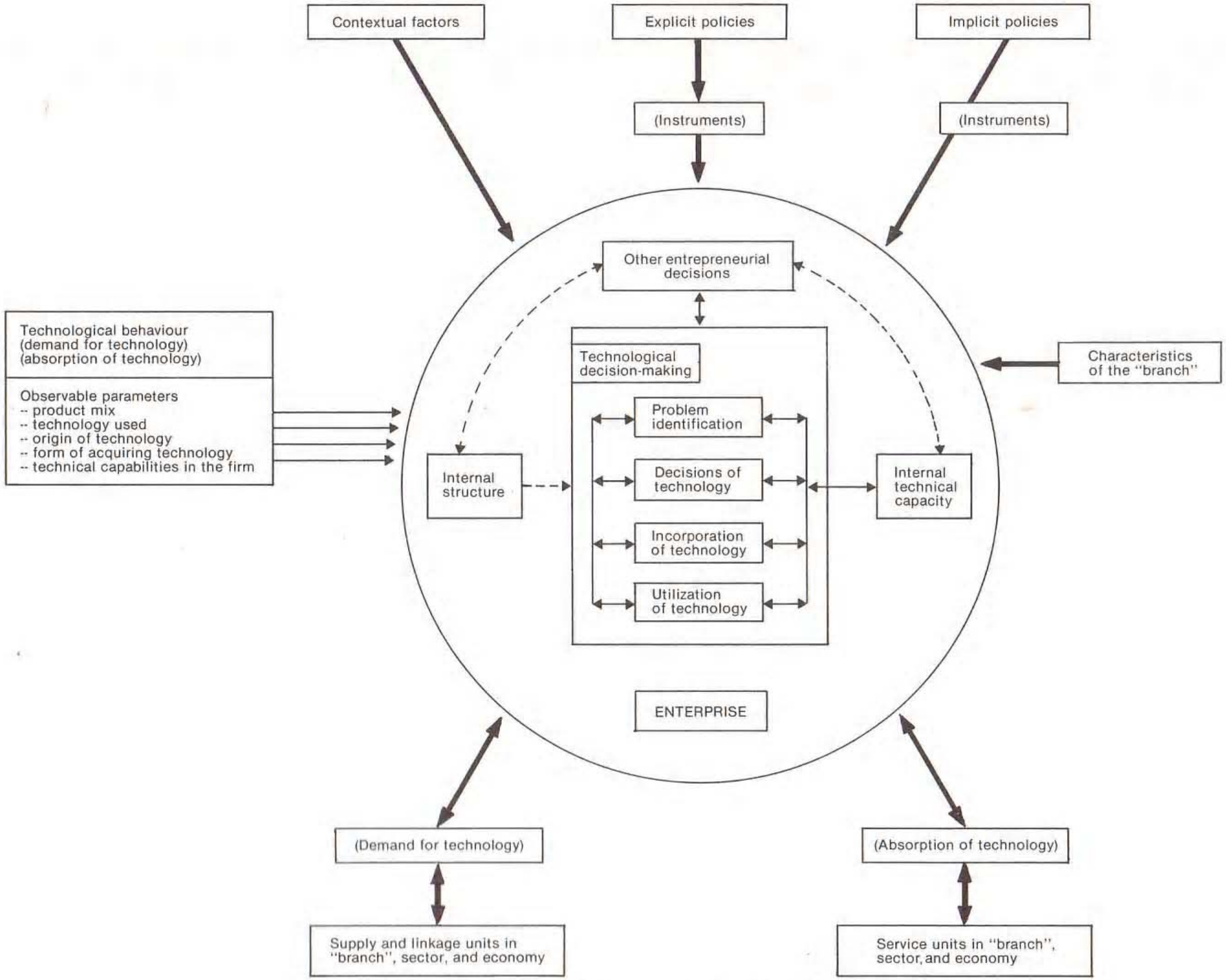


Fig. 11. Factors affecting technological behaviour of productive units.

of influence that are most likely to affect it.

At the end of phase 3 the team should have a set of statements that refer to the characteristics of the technological behaviour of the enterprise, the effect of the different sources of influence on it, and in particular to the influence and effectiveness of government policies and the policy instruments used for putting them into practice.

Technological behaviour of research institutes: the supply side in phase 4

The research in phase 4 of the STPI project aims at obtaining empirical evidence on the impact of policies and policy instruments on the supply of technical knowledge. In doing so the focus will be on the research institute as the typical entity in charge of technology supply.[12]

The concept of "research institute" covers a rather heterogeneous mix of organizations involved in many different ways in the supply of technical knowledge for industry. Three main categories can be identified:

(a) The research institute proper, which is generally an autonomous organization designed to generate technical knowledge through research, adaptation, development, and engineering activities. Research institutes may be financed from government funds, from contract work, or a combination of both. They may also be organized in the form of a "holding," with several laboratories attached to it.

(b) *University laboratories in science and engineering schools*. The main purpose of these organizations is to train professionals and researchers. The training process often involves active participation in research tasks and hence the need to establish research centres in the university. Frequently these centres are given a certain degree of autonomy to facilitate contacts with industry and obtain additional sources of finance.

(c) *Research laboratories within industry*. These are usually located in large state or private enterprises, or formed by an association of enterprises (what is called a "research association"). Their main function is to provide technical and "trouble-shooting" services to industry, and is wholly subordinated to the needs of their parent organizations. They work primarily in the improvement and adaptation of technologies used by enterprises.

The types of organizational forms that the research institutes adopt are not limited to these three, and it is possible to find agencies that do research and at the same time manage a research fund, channeling money to other centres and laboratories. Other functions of research institutes include the screening of foreign technology, the preparation of technical norms and standards, activities related to patents and industrial property, technical advisory services, and so on. Several of these functions would belong to the service units in the "branch." Therefore, the study of research institutions that supply technical knowledge must begin with an identification of the functions performed by the organizations under consideration. If it combines several of these, it may be necessary to segment the functions of the organization to examine only those dealing with the technology production aspects.

Research institutes are subjected to the same type of pressures and influences as enterprises, in the sense that contextual factors, policy instruments (for explicit and implicit policies), the characteristics of the "branch" in which they are inserted, and their internal characteristics condition their behaviour. The behaviour of a research institute would result from aggregating the technological decisions that have to do with the identification, formulation, approval, performance, monitoring, and evaluation of research projects. In this case it is not necessary to differentiate between "technological" and "other" decisions.

For the purpose of assessing the impact that different policy instruments have on the

[12] The supply of foreign technology is not considered in these guidelines, for there is another report prepared at the field coordinator's office of the STPI project dealing exclusively with this subject. See the report by Carlos Contreras, *Technology Transfer: A survey and some policy proposals.*

behaviour of research institutes, it is convenient to pose a set of questions on the evolution and functioning of the organization. We shall leave aside the questions that refer to the influence of contextual factors and policy instruments, for they are similar to the concepts analyzed in the guidelines for phases 2 and 3. Instead, questions shall be directed toward an understanding of the functioning of the research institute.

The first group of issues refers to the historical evolution of the institute. The question of "life, passion and death," of research institutions has important implications for the design of policies. Many organizations never reach maturity and after a few years wane away, others appear to be in a constant state of crisis but manage to survive for many years. The historical perspective should provide a ground base for understanding the behaviour of research institutes and the role they play. Of particular interest is the evolution of objectives for the institutions and their relation to the different stages of industrial growth, that is, the relation between the technological behaviour of enterprises and "branches" on the one hand, and the behaviour of the research institute on the other, both in relation to the evolution of industry and of industrialization policies.

This would lead naturally to a discussion of the research institute's objectives. Here it is of interest to analyze the relation between objectives of the institute and the needs of industry. From this a preliminary appreciation of the degree of isolation or of effective coupling of the institute with industry will emerge. Closely related to the objectives are the institute's strategies in terms of patterns of resource allocation, deployment of manpower, sequence of fields to enter in, disciplines to be incorporated, and so on.

The next group of issues to examine refers to the nature of the demand for the institute's activities. The first question is: does an effective demand exist, and if so , how is it manifested? A distinction must be drawn between demands imposed by the internal dynamics of the institution itself, and those generated by clients of the organization. The operational mechanisms for the formulation and translation of demands into research activities need to be described, as well as the institute's activities in the promotion of demand for its own services.

A critical issue in the study of research institutes is that of financing patterns. This refers to the sources and uses of funds, including the procedures used for resource allocation. The pattern of financing of research institutes usually changes with time, and a historical perspective becomes necessary for understanding them. Another important issue refers to whether the institute has a stable source of funds, relatively independent from its actual performance; whether it receives funds from government transfers, and therefore is subject to the vagaries of annual budgetary negotiations; or whether it is financed by contract research, and therefore subject to the fluctuations of industrial performance.

Research institutes are best characterized by the quality of their executive and technical staff. This is what determines their technical excellence. In consequence preferential attention should be given to the policies with regard to hiring, training, deployment, promotion, and evaluation of technical staff. This is also one of the issues that can be affected directly by policy measures, such as government provisions regulating the activities of technical personnel, including salary structures. The degree of excellence of the institute is to a very large extent the aggregation of the quality levels of its research groups, and these in turn are conditioned by the quality of individual staff.

Another issue to consider is the internal organization of the research institute, comprising the definition of research areas and priorities, the capabilities for research planning and programing, the procedures for selecting projects, the operational control, the criteria for evaluation and, in general, the philosophy of research administration. The structure and quality of services for research, including information and documentation facilities, equipment and materiels procurement and the physical plant, should also be included here.

Finally, the institutional self-perception and the degree of identification of the research staff with the objectives should also be analyzed. This includes differential perceptions by executives and technical staff, as well as the degree of coincidence between these and the perception of clients and policy-makers.

The list of issues to examine regarding the technological behaviour of research institutes could be greatly expanded. As an example of the questions and categories of analysis used by other researchers, Appendix E contains a set of questions extracted from a paper by Dr Robert Anderson. There is a substantial degree of overlap with the issues raised in the preceding paragraphs, particularly in the third group of questions posed by Dr Anderson.

The behaviour of units in the linkage area: relating the research of phases 3 and 4

After having studied the technological behaviour of productive units and of research institutes as two of the main constituent elements of an industrial "branch," the linkage mechanisms, as defined in the initial sections of the guidelines, need to be studied. Without attempting to develop a complete set of concepts regarding the "linkage area," we formulate a definition as a first approach to delimit the subject of research.

We understand as the "linkage area" the collection of all those institutions and mechanisms that relate productive units with the units engaged in the supply of technology, and eventually with the service units. Essentially, these institutions and mechanisms perform a two-way function:

A. From the productive units to the technology-supply units, they serve as the interpreters of the needs and problems of the first in order to transform them into a technological problem whose solution can be found, provided the solution is already available, and if not, to define the problem in such terms that the solution can be searched and developed within the technology-supply units; and

B. From the technology-supply units to the productive units, they serve as the interpreters of the activities of the first in order to transform them into technological solutions and technologies that can be effectively incorporated to the productive units.

The linkage area therefore deals with functions and activities that relate, in practical and economic terms, the demand and supply sides of technology units and productive units. As underdeveloped countries are mainly technology importers, the functions of the linkage institutions are not limited to national sources but also include foreign sources, and therefore the institutions that control the flow of imported technology.

The key importance of the linkage area lies precisely in the fact that it is often the missing element in the structure of the industrial "branch" and that if left to spontaneous development, it can even become a barrier to communication between productive units and units that supply technology. In effect, linkage institutions may selectively block local technological developments to favour imported technologies whose characteristics make them easier to transmit to the product system.

The universe of institutions and mechanisms of the linkage area are thus rather complex and wide. The most representative type of unit in this area, though certainly not the only type, is clearly the engineering firm. Below we provide a preliminary list of the institutions that have mostly the functions of linkage units. They are classified into the two main types of functions mentioned above, the A and B type, though many institutions combine these types of functions.

A-type institutions:

- development, production management, trouble-shooting, technical and procurement departments of industrial firms,
- service, design, and consulting engineering firms,
- plant or project engineering firms and departments,
- agencies that regulate technology imports.

B-type institutions:

- sales, repairs, maintenance, and extension services of research and engineering units (liaison units of R&D organizations),

- cooperative research associations or programs (public or private),
- private or public extension service units and technical assistance units,
- "productivity centres" of hardware and organizational technology,
- information systems (documentation centres),
- advisory committees (for research units) with representatives of industry.

The mechanisms through which these institutions operate vary greatly, and could be broadly classified in the same terms as the institutions as follows:

A-type mechanisms:

- techno-economic feasibility studies,
- assembly of industrial projects,
- choice of technologies for industrial projects,
- selection and contracting of engineering services,
- equipment, supplies, and personnel,
- research and development contracts,
- applications for technical information.

B-type mechanisms:

- surveys to identify technological problems in industry,
- joint research programing with industry's personnel,
- training of industrial personnel for research,
- consultations through visits, mail, conferences, meetings, etc.
- exchange of personnel with industry (loans of personnel),
- demonstration plans for new technology,
- follow-up services,
- information services,
- technical publications.

Taking this into account, the research on the linkage area should cover basically the following themes:

— a survey of the *linkage institutions*, describing their features, functions, relationships, and capabilities in a historical perspective.

— a survey of the *operational mechanisms* put into operation by the linkage institutions, with particular reference to the engineering units, describing them from a functional and structural point of view, studying the magnitude, frequency, and quality of communication flows, and the degree of integration with supply and productive units. This includes an evaluation of the effectiveness of linkages and their technical and economic significance.

— an evaluation of the impact of *foreign firms* and organizations that perform linkage functions and their relations with local engineering firms in particular.

— a study of the influence and effectiveness of the body of implicit and explicit policies and policy instruments that affect the creation, growth, development, and functioning of the linkage institutions.

In the case of the engineering firm, it is possible to differentiate three types, even though these are often present in a single firm. There are the *consulting engineering firms*, which deal mostly with the economic feasibility of industrial, mining, finance, or trade ventures. They may even go to the level of preassembling an industrial project, putting together the definition of products, basic technological layout, and capacity selection, omitting only the actual engineering work. This is usually performed by the *design engineering firms*, which make the basic and detailed design of the industrial plant that is to be established. The third category, *the service engineering firm*, has a wide variety of functions related mostly to the implementation of projects: choice and negotiation of technology, selection and contracting of engineering work, selection and purchase of equipment, selection and contracting of personnel, administration of the industrial project, supervision of subcontracted work, and start-up management.

The most important of the three types of engineering firms is probably the service engineering firm, often associated or integrated with the design engineering firm. The critical capabilities of the different kinds of engineering firms are determined by their specific functions. The consulting engineering firm needs skilled economists with experience and knowledge about a wide variety of technologies. The design engineering firm requires above all specialized engineers, and the service engineering firm requires a wide variety of specialized engineers and administrative personnel with an intimate knowledge of the actual problems of industry.

The key problems of engineering firms have been identified as the limited and fluctuating markets where they have to operate in the underdeveloped countries, the scarcity of suitable project leaders and technical staff and the difficulties involved in their training, and the strength of foreign competitors with not only large and experienced staff, but often also solid financial backing. These problems present difficulties for the creation and sustained growth of local engineering firms, particularly the third type, because the user of engineering services in the productive units usually prefers the experienced foreign firms and thus orients its demand toward them.

Finally, we mention the importance for engineering firms, and for the linkage area in general, of the professionals in enterprises that constitute the "first step" in the linkage process. They are the ones that identify problem areas requiring technical solutions and orient the enterprises' demand for technological knowledge in the direction of their preference. This is closely related to the development of the absorption capacity of the enterprise.

Chapter 5
Concluding Remarks

The concepts and ideas put forward in the preceding pages provide a general framework within which to place the research tasks of the STPI project. As already mentioned, they are not expected to provide a detailed blueprint for the activities of all the participating teams. Rather, they constitute a set of coordinates that would allow placing and relating the activities of the country teams, as well as comparing their results.

Consistent with the approach of the STPI project, the guidelines have attempted to deal with the complex reality of science and technology policy formulation and implementation on its own terms, without reducing this problem area to small, more manageable, subproblems that can be handled individually. The intention was to provide a network of concepts that would lead to a progressive systematization of the problem area and that may orient the research tasks of teams operating in a variety of contexts of underdevelopment. Following the action-oriented nature of the research, this would enable the teams to generate knowledge to help policymakers and planners in putting science and technology to the service of development objectives.

The concepts and ideas contained in these guidelines must be considered only as the starting point for the work of the national teams. The action-oriented research process is highly dynamic and cannot be forced into a straight-jacket of *a priori* conceptualizations. The partial results obtained will suggest new directions and impose modifications in the sequence and orientation of the research. Therefore, the network of concepts presented in the guidelines will have to be constantly revised as the work proceeds.

The dynamics inherent in action-oriented research make it rather difficult to venture detailed suggestions on how the synthesis could be carried out in phase 5 at the end of the project. This applies equally to the content of the national synthesis and to the international comparative aspects of the synthesis effort of the STPI project. With regard to the content of the national synthesis, where each team is supposed to put together the most relevant results it has obtained, very little can be said, except that the report should pay attention both to direct inputs to policymakers, and to contributions to expanding the frontiers of knowledge.

Regarding the comparative synthesis, it is clear that no single report can contain all the relevant results produced by the national teams and the material provided by consultants and the field coordinator's office. There will probably be several synthesis reports each covering a portion of the ample ground explored in STPI. These reports will be the result of a collective effort by the coordinators of the national teams, prepared on the basis of drafts that the field coordinator's office will submit. The reports will have to deal with two main subjects: first, a comparison of national strategies and policies to put science and technology to the service of development objectives, examining their implications for the use of policy instruments and taking into account the international context of underdevelopment; second, the characteristics and impact of alternative policy instruments, following the general ideas put forward in the guidelines. Finally, these two types of reports should be complemented with specific thematic reports in areas the teams have studied in depth. The thematic reports should be organized around the issues found most relevant and important in the research by the national teams and the field coordinator's office.

In this way it may be possible to obtain a wide range of published results that would be available to researchers and policymakers of developing countries other than those directly involved in STPI. Hopefully, this will stimulate thinking on the subject and may possibly influence the design and operation of science and technology policy instruments. The STPI project was designed as a temporary exercise to be completed in a relatively short period of time. This does not imply that definite answers and conclusions will be found at the end of the project, but rather that the groundwork will be laid for researchers and policymakers, whether involved directly or not in the STPI international network, to continue to explore ways of putting science and technology to the service of development objectives long after the STPI project is over.

Appendix A

Approach and Objectives of the STPI Project*

Approach

The research approach and the philosophy behind STPI can be summarized as follows:

(a) The research is *action-oriented* in the sense that it aims at producing knowledge that would feed directly into policymaking, decision-making, and planning activities. It should also generate a learning process shared by all the participants that would lead to better implementation (and formulation) of technology policies. This implies leaving aside the more traditional concept of academic social science research and replacing it with an action-oriented research approach into the problem domain of science and technology policy implementation.

(b) The research will not focus on the policy formation process at the macro level, or on the individual processes of technology decision-making at the micro level (productive unit, government agency, research institute, etc.), but rather on the *interrelations* between these two. The idea is to examine the instruments and mechanisms that mediate between the macro and the micro decisions. One of the main aspects to study will be the divorce — or coincidence — of individual rationality at the micro level and of collective rationality at the macro level, always in relation to science and technology policies, plans, and decisions.

(c) The research will be both *interdisciplinary* and *interinstitutional* in each participating country. Mediating instruments and mechanisms will be studied by teams consisting of lawyers, economists, administrators, and engineers. They should jointly identify and characterize instruments, assessing their relative effects. The research will also require participation from government agencies, private enterprises, and research organizations. Not all of these will be directly involved in carrying out the research, but their collaboration to supply information and to feed their points of view into the project will be necessary.

(d) The research will be *contextual* in the sense that it postulates that instruments and mechanisms to implement science and technology policies cannot be adequately studied without taking into account the specific context of underdevelopment in which they operate. Moreover, it also postulates that the interactions among different government policies play an important role in shaping scientific and technological behaviour. This requires that, starting from the point of view of technology and science policies, the interrelations with the main economic, educational, and social policies be worked out to uncover the overall resultant policies for science and technology. The same applies to the instruments and mechanisms that are employed to implement these policies.

(e) These considerations lead to a comparative research project with a common approach and a shared conceptual framework, but which at the same time is decentralized, flexible, and organized on a national basis. Each participating coun-

* Extracted from *The Science and Technology Policy Instrument Project,* IDRC-050e, 1975.

try would agree to exchange a minimum level of information on all phases of the project, but this does not imply that all countries must share all the information they acquire through their own research efforts or that any country could not study in greater depth some specific aspect of the project in which it is particularly interested. Ultimately the project should lead to the establishment of a network of interrelated researchers in the Third World, who would learn from each other and who would hopefully remain in contact long after the instruments project is over.

Furthermore, the first phase of the project, which deals with the role of the scientific and technological system in each participating country, gives an opportunity to describe and discuss the political orientations of the participants and of the project teams. In comparative social science research among the Third World countries there is nothing to be gained by shying away from these issues. One last issue that must be raised refers to the political and ideological content of the project. Clearly it is not possible to leave aside considerations of this type when organizing a comparative research project on the instruments and mechanisms used for implementing science and technology policies, for these are greatly affected by political and ideological considerations. The point to be made is that the autonomy of national teams and the agreement to exchange a minimum level of information on all phases of the project would permit a constructive dialogue among all participants, regardless of their political views.

Objectives

The general purpose of the project is to gather, analyze, evaluate, and generate information that would help policymakers, planners, and decision-makers in developing countries to specify the ways and means for orienting science and technology toward the achievement of development objectives. In particular the project should help to:

- develop indigenous capabilities in science and technology appropriate to the countries' needs;
- better utilize these capabilities in the productive sector and other areas of socioeconomic activity;
- improve the process of importing technology in such a way as to maximize its beneficial effects and minimize its detrimental effects;
- absorb and adapt the imported technology linking it to the indigenous scientific and technical activities.

The realization of these general objectives will require the project to focus on:

(a) Identifying the general role that science and technology play in attaining development goals in different socioeconomic and political systems. This involves an analysis of the functioning of the scientific and technological system and its relation to the national economy and development objectives in each of the participating countries;

(b) Identifying major instruments and mechanisms that are most likely to be effective in implementing science and technology in a given context. This will involve an analysis of the use of both direct and indirect policy instruments on the technological behaviour of government agencies and productive units;

(c) Identifying and analyzing key factors that affect the technological behaviour of enterprises in selected sectors of the economy. The purpose is to examine the effectiveness of policy mechanisms and instruments from the perspective of the manager or entrepreneur who makes technological decisions in the productive unit;

(d) Examining the major controls, practices, and procedures followed by government agencies and departments that make policy decisions for science and technology. This implies examining the factors that affect the behaviour of government officials with regard to administrative controls that refer directly or indirectly to science and technology policies;

(e) Exploring and identifying the policy instruments, including those in other areas of government policy, that are likely to have a significant effect in promoting the development of an indigenous scientific and technological capacity geared to the needs of development;

(f) Carrying out comparative analyses of the effect that different instruments are likely to have in diverse environmental conditions.

As a result of these comparisons it should be possible for policymakers concerned with applying science and technology to the achievement of development objectives to identify the mechanisms and instruments that are most likely to have the desired effects. Other subsidiary objectives would be to develop and sustain an international network of Third World researchers in this field and also to advance the state of the art of science and technology policy research.

Appendix B

Background Documents Prepared for the STPI Project
(Up to January 1973)

Amadeo, E., *Conceptual Scheme for a Feasibility Study on Scientific and Technological Policy Instruments*, OAS/UCA, Buenos Aires, Argentina, January 1973.

Aráoz, A., *Instruments for the Implementation of Technological Policy*, IDRC, Buenos Aires, Argentina, December 1972.

Flores, G. and Flit, I., *Results of the Interviews Among Industrial Enterprises to Study their Technological Behaviour, OAS, Lima, Peru, December 1972.*

Flores, G. and Flit, I., *The Technological Policy Implicit in the Industrial Development Plan, the General Law of Industries and the General Law of Mining of Peru*, OAS, Lima, Peru, December 1972.

Jones, G., *Science Policy Instruments*, R. T. Z. Consultants Ltd., London, England, November 1972.

O'Donnell, G., *Some sociologically-oriented suggestions for cross-national research of technological policy instruments*, Instituto Torcuato Di Tella, Buenos Aires, Argentina, December 1972.

Roulet, E., *Analysis of Instruments for Scientific and Technological Policy*, OAS, Buenos Aires, Argentina, January 1973.

Sagasti, F. and Medina, D., *Structure and Operation of Scientific and Technological Policy Institutions in Peru*, Lima, Peru, November 1972.

Sagasti, F., *Notes on the Background, the Approach, and on Definitions for the Project on Instruments to Implement Science and Technology Policies in Underdeveloped Countries*, Lima, Peru, January 1973.

Sagasti, F., *A Study of Instruments for Science and Technology Policies in Underdeveloped Countries*, Lima, Peru, November 1972.

Appendix C

Examples of Instrument Description

Here we present brief analyses of three different policy instruments. Note that in the third case "policy" is defined at the level of an individual organization that does not have a broad mandate for policy making, and the legal device is a contractual arrangement.

Case 1. Disaggregation of imported technology

Policy issue:
excessive imported technology in new investment projects, much of it in turnkey plants.

Policy purpose:
- (a) to increase bargaining power;
- (b) to identify components for local production;
- (c) to facilitate technology absorption in the productive unit.

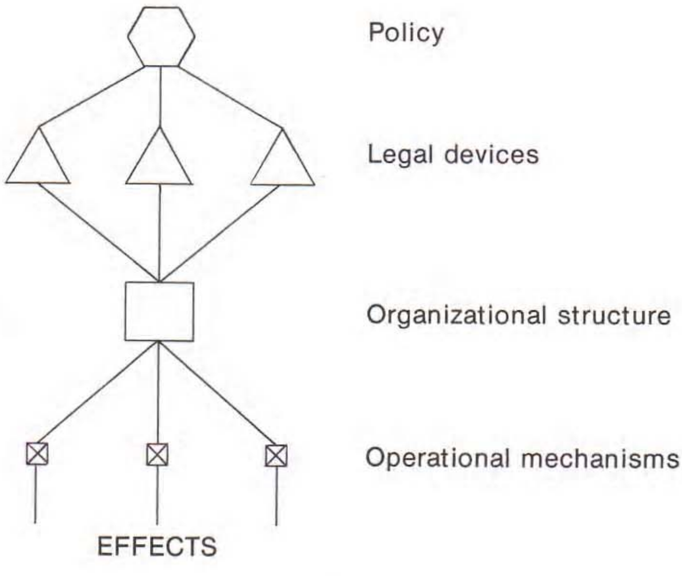
Legal device:
one or more regulations, such as:
- (a) prohibition on importing turnkey plants;
- (b) model contracts with suppliers.

Organizational structure:
a special government engineering organization to handle all large investment projects, with the support of a network of other institutions.

Operational mechanisms:
- (a) approval, or not, of a certain contract. Effect: improvement of bargaining power.
- (b) direct action through engineering activities. Effect: local purchase of inputs of goods and services not previously bought locally.
- (c) technical support and advice to productive units; stimulation to enterprise for disaggregation. Effect: facilitates technology absorption.

Final effect:
improvements in the importation of technology.

Structure of the instrument



Case 2. State research contracts

Policy issue:

lack of research and development oriented toward development problems.

Policy purposes:

(a) promote socially useful R&D in existing science system;
(b) promote the expansion of R&D capacity;
(c) solve specific problems.

Legal device:

general law with norms instituting a system of state research contracts.

Organizational structure:

(a) department of a ministry;
(b) R&D office in a state organization;
(c) special organization (like FINEP in Brazil);
(d) the structured procedures for:
— getting contracts going
— controlling project's advance
— evaluating final results of projects

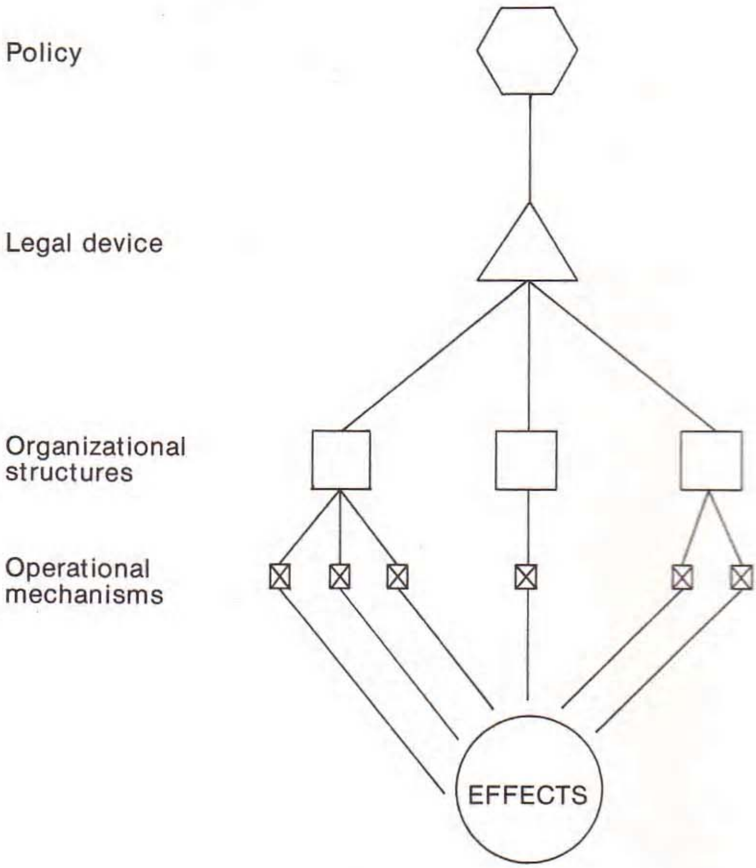
Operational mechanisms:

(a) definition of topics for R&D and terms of reference;
(b) selection of R&D contractors based on established priorities and using procedures of the organizational structure;
(c) establishment of deadlines and budgets;
(d) R&D contracts;
(e) periodic review and control of projects;
(f) final evaluation of results of projects.

Final effect:

the production of specific knowledge oriented toward the clarification or the solution of certain problems.

Structure of the instrument



Case 3. Linkage science-industry: analysis of the "service of technical assistance to industry" (SATI) of the metallurgical laboratory, Atomic Energy Commission of Argentina

Policy issue:
: little use by industry of laboratory's capabilities.

Policy purpose:
: to supply industry with R&D and technical services in areas in which the laboratory is active.

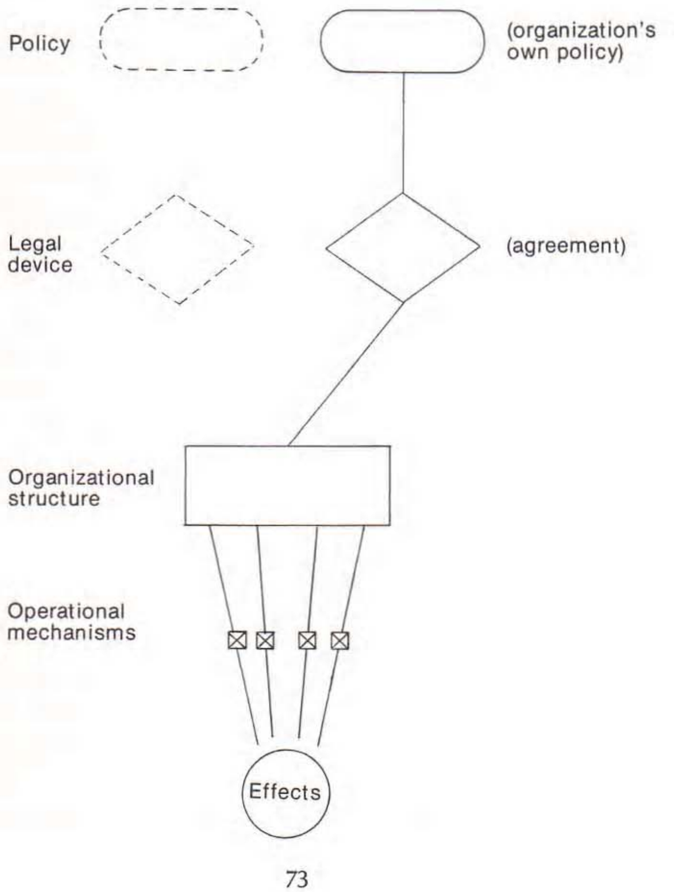
Legal device:
: agreement with the Metallurgical Industry Association setting up SATI, and establishing its purposes and bylaws.

Organizational structure:
: SATI and its technical staff.

Operational mechanisms:
- (a) information to industry;
- (b) training for industrial personnel;
- (c) publications;
- (d) visits to industry;
- (e) organization and execution of technical assistance, technical services, and R&D through contracts.

Final effect:
- (a) a reorientation of the laboratory's science and technology activities toward industry needs;
- (b) the supply of significant science and technology inputs to industry.

Structure of the instrument



Appendix D

Basic Outline for the Report on Phase 1 of the STPI Project

1. Description of the main characteristics of the human and economic geography of the country (size, population, distribution of natural resources, geographical regions, etc.).

2. Brief description of the political and economic evolution of the country. Stages in the process of development, outline of the main economic policies followed during the last 30 years, rates of growth of the different sectors of the economy, evolution of employment, structure of foreign trade, etc.

3. Governmental structure:
   a. Division of powers between the executive, legislative, and judiciary branches.
   b. Description of the system for passing laws and general regulations.
   c. Degree of discretionary power of government agencies with regard to bylaws, decrees, and interpretation of legal instruments.
   d. Administrative structure of the government, description of key ministries, outline of main government agencies and their functions, governmental decision-making procedures, degree of participation of the different sectors of the population in government decision-making, etc.
   e. Structure of the political system, role of political parties, electoral processes, etc.

4. Main social features. Population growth, urban migration, standards of living and their evolution, social class structures and their relative power, labour mobility, etc.

5. Structure of the educational system, literacy rates, proportion of students in the school system, description of the university system, distribution of students by discipline, the brain drain problem, etc.

6. Cultural patterns and their evolution. Impact of modern technology upon society, value structures, attitudes and norms, particularly regarding manual labour, industrial activities, and science and technology.

7. Description of the industrial sector:
   a. Importance of the industrial activity for the national economy.
   b. Relative importance of the branches chosen for study in the industrial sector and the national economy.
   c. Outline of the historical evolution of the sectors chosen for study.
   d. Classification of enterprises according to the origin of capital, and to whether they are state owned, privately owned or mixed enterprises, cooperatives, self-managed organizations, etc.
   e. Main sources of financing for industrial development, particularly in the sectors chosen for study. Structure of the system for capital accumulation and its influence on industrial growth.
   f. Brief outline of the sources of technology used in the sectors chosen for study.

8. Description of the science and technology system:
   a. Human resources. The higher education system, number of students in technical professions, appraisal of the quality of students and teachers, evolution of the student population in different technical fields, importance of the education abroad, relation of the

subjects of study to national needs, attitudes, and motivations of foreign-trained graduates, etc.

b. Use of highly qualified personnel. Employment of graduates, distribution of professionals in industry, government, and science; wage and salary structures; career possibilities; importance of part-time employment for scientists, etc.

c. Financial resources for science and technology. Gross expenditure in science and technology for the whole country, percentages of the GNP in comparison with other countries, expenditures in science and technology services. Main sources of funds (government, university, private, foreign, etc.). Uses of the funds according to capital and current expenditures; breakdown of current expenditures into basic research, applied research, development, and other science and technology activities; breakdown of current expenditures by main fields of application, etc.

d. Main issues of technology transfer. Expenditures in technology transfer and their relation to total research and development expenditures, distribution by main branches of industry, importance of multinational corporations, importance of licensing agreements and of the import of capital goods, technical assistance from other countries and from international organizations, etc.

e. Installed capacity for science and technology. Basic data and brief description of institutions that are involved in research and development, human resources, funds, physical assets, etc., related to research organizations; use of the installed capacity in research and development.

f. The environment for science. Support received by researchers, financial problems, administrative and bureaucratic problems, structure, and cohesion of the national scientific community and the international science system, social recognition, prestige, and status of researchers. Recognition of the value of research by government, industries, and various social groups, outline of the image of science and of scientists.

g. Linkages between the science system and society. Survey of extension activities, analysis of engineering design groups, contacts between the scientific institutions and the users of their work, popularization of science, etc.

h. Importance of scientific and technological activities in the government and productive sectors. Level of consciousness attained by industry as regards the importance of research and development. Performance of science and technology activities by industrial enterprises and by governmental agencies.

i. Organization of science policy. Decision-making in science and technology matters, brief description of national research councils, universities, ministries, and other public agencies. Participation of scientists and of users of research in the policymaking process.

9. Key issues in science and technology development. Problem areas of importance in the development of science and technology (e.g. transfer of technology, productivity of research institutions, relation of research and development to the planning process, interaction between technology and employment, etc.). Critical evaluation of the role of science and technology in the development of the country, and relevance of the key issues singled out.

10. Main obstacles for the efficient functioning of the science and technology system and its contribution to development. Policies and objectives for science and technology that can be derived from these.

Annexes

A. Statistical summary regarding the structure of the economy, of industry, and of the branches chosen for study, quantitative description of the science and technology system, human resources, etc.

B. Principal legal dispositions regarding the functioning and operation of the science and technology system, as well as the organization of structure for science and technology policymaking and planning.

Appendix E

Questions for a Comparative Study of Research Institutions*

Individuals

A. — How do the institutes inculcate or generate in newcomers the dispositions and intentions appropriate to research?

— What becomes of the idea of individual responsibility and personal achievement in group research?

— What dreams of success, fears or failure, or adaptations to mediocrity are prevalent among active workers in these institutes?

— What are the prevalent pictures or models of a proper atmosphere, of how research is supposed to be organized and of how judgments of standard are expected to be made?

— What is the difference in reaction between active researchers, administrative personnel and inactive researchers when these pictures/models conflict with experience?

— In accounting for migration of research workers between institutes how are the conditions (for work, etc.) judged by these people?

— What form does self-regulation take if conditions in institutes are not felt to be conducive to active research?

B. — What are the meanings to individuals of the coexistence of the life of scientific research with the domestic, political, and cultural life outside the institute?

— What are the relations between these two systems of thought in their own lives?

— Why does someone enter a life of research instead of becoming a housewife, plumber, or painter?

— What is the status or value of their positions and work in the eyes of other sectors of society — military, youth, business, political parties?

Research groups

A. — How is socialization of new members carried out in research groups?

— What implications and consequences do relations between individuals have for the relations between groups?

— Are there hierarchies of groups within these institutions?

— How do these hierarchies affect relations between individuals?

— What are the criteria for this ranking of groups? (the quality of their published work?, the length of time in existence?, their finances?, their access to political processes outside the institute?, their participation in governing the institute?, their role in teaching?).

— What are the relations between groups working on more abstract and theoretical lines, and groups organized more instrumentally around technologies?

B. — What are the patterns of communication and cooperation within these groups?

— How does competition with others in research seem to affect these patterns?

— How differently can groups be organized to approach similar work?

— What are the variations in the division of labour within groups?

* Extracted from a paper by Dr Robert Anderson, *An anthropologist observing research institutions*, mimeo. 1973.

— Do special relations exist between some research groups and the technical or administrative services labelled as common facilities?
— How is recognition awarded in group projects?
— What concerns do individual workers have for the relation between their personal reputations and the group's reputation?
— Do some types of research result in an identity of these two kinds of reputation?
— Does this apparent identity attract some people and repel others?

Institutes

A. — When the founders were establishing these institutes, what were the conditions in the scientific and technical community at the time, both nationally and internationally?
— What were the founders' strategies for the creation and maintenance of these institutes?
— What is the role of the memory of the founders at this time, most particularly in the conduct of research?
— How have conditions in the scientific and technical community changed since the institutes were established?
— What role did the institutes play in those changes?
— Did the founders have international reputations for research in their disciplines or were they local entrepreneurs?

B. — What are the sources of influence on the life of the institutes, particularly from federal/central or state government?
— What type of relations exist between the institutes /and their surrounding cities, universities, defence organizations, industries, labour unions, etc.? Are these relations productive, symbolic, unavoidable?
— What are the effects (if any) of national policies that are expected to stimulate or regulate the conduct of research, or any other aspect of the institutes?
— What are the reactions in the institutes to national policies?
— What are the common ideas about protection of the institutes from outside intrusion or influence? Are these congruent with the strategies of the founders?

C. — What is the structure of the governments of these institutes?
— What are the roles of the directors?
— What are the roles of "tenured faculty" or their equivalents?
— What are the roles of governing councils, boards, etc.?
— What are the degrees and types of participation in government of the institutes by members of active research groups?
— If there is access to the files — what is the relation between oral and remembered histories of events and the documents in the bureaucratic memory?
— What relations exist between the governments of the institutes and the conduct of research, including the development of ideas?
— How do individuals' pictures of how research is supposed to be organized differ from those of the governments of these institutes?

D. — Given the external conditions in the economy, and given the structure of the governments of the institutes, how is research work financed?
— Is the history of financing research more stable in some groups than in others?
— Is the process of deciding how to finance the overhead costs of running the institutes separated from the decision about funding specific research groups?
— What is the process involved in dividing funds between research groups, and what criteria are used?
— What is the participation of members of research groups?
— Do people involved in the process agree on these criteria?
— What do people who are not involved think is going on?
— How do the processes of financing research seem to affect the dispositions and intentions of active researchers?

— What are the ingredients of the state of morale in these institutes?
— Are these the same ingredients as in the rest of the scientific and technical community in the same country? in other institutes in other countries?