Problems in Adapting the Frascati Manual for Use in Resource-based Economies

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Background - S&T Indicators

During the period of reconstruction and economic reorganization that occurred after the Second World War, policy makers in Western Europe and the United States realized that S&T programs had a profound effect on the outcome of the war, and they wished to apply the benefits of national S&T programs to domestic civilian programs and to the Cold War arms race that has broken out. Today, policy makers in most economically stable nations realize the need for S&T indicators to assist them in making informed economic and social decisions for their countries.

S&T indicators fulfill several functions. According to Jan Van Steen (I), these include:

- signalling or monitoring: giving insight and calling attention to developments and trends in the S&T system and its environment;

- accountability, evaluation and allocation: setting and justifying S&T budgets and

> giving insight into the performance of the S&T system against the goals established by policymakers and planners;

- legitimisation; support for existing policies; and,

- awareness: providing information to set aside prejudices and incorrect perceptions of the performance of the S&T system

In the public sector, statistics on S&T inputs and outputs, and the consequent S&T budget, should support the following activities:

- formulation of S&T policy, in support of economic and social objectives;

- provision of advice to ministers and other senior officials;

- support for and justification of S&T program expenditures;

- information on scientific activities for elected officials, journalists and other stakeholders; and,

- analysis of the national system of innovation

Most nations have one or more governmental or not-for-profit agencies charged with collecting and analyzing S&T data. These are sometimes referred to as S&T observatories. Hernan Jararmillo, in writing about S&T observatories (2) noted that an observatory , as an agency for collecting and processing S&T indicators:

"...helps society to understandS&T development and the integration ofS&Tvariables with other measures of economic and social development. The resulting information becomes a public good and a necessary input for the development of society ".

Thirty years earlier, Chris Freeman, in a document published by the Organization for Economic Cooperation and Development (OECD) (3), noted:

"Trying to follow a science policy, to choose objectives and to count the cost of alternative objectives, without such statistics, is equivalent to trying to follow afull employment policy in the economy without statistics on investment or employment. It is an almost impossible undertaking. The chances of getting rational decision making are very low without such statistics"

The Frascati Manual

In the 1950's and 1960's S&T policy analysts demonstrated that the level of financial and human inputs to R&D activities were good indicators of national S&T development. In 1963 the OECD established a group of experts on S&T indicators, the National Experts on S&T Indicators (NESTI), which at a meeting at the Villa Falconari in Frascati, Italy, produced the first draft of" The Proposed Standard Practice for Surveys of Research and Experimental Development", or "Frascati Manual" as it is usually known[1]. This manual

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[1] Today the formal title of the Frascati Manual is still "Proposed Standard Practice for Surveys of Measurement of Research and Experimental Development"

(4) is now in its fifth edition, having been updated in 1993. As the foreword states explicitly:

"The Manual.... has been designed primarily to measure the R&D of OECD Member countries, which have rather similar economic systems ".

As such it was, and is, a document written by statisticians for statisticians. But the availability (or lack) of statistics can influence policy discussions. The ability of OECD countries to collect data on R&D activities has focused S&T policy in these countries on R&D performance.

However, in 1963, the OECD consisted of only 20 members, which with the exception of Canada and the US, were part of the European continent, including Turkey. Non-European members joined later - Japan being the first in 1964. Of the original members of the OECD, few could be described as "resource-based" and the largest resource-based economy, Canada, was generally thought of as being industrialized. Also the question of regional economic influences within member nations was ignored, since the OECD operates at the national level, aggregating its activities across internal boundaries within the member nations.

S&T Versus R&D in Resource-Based Economies

So how does this apply to other resource-based economies? Resource based economies are frequently, but not always, developing economies. This suggests that perhaps, the preferred approach should not be the automatic assumption that resource-based economies should attempt to move into manufacturing. After all, there is probably now a glut of manufacturing capacity in the global economy, and those Asian economies which recently invested heavily in manufacturing, are suffering. Perhaps national planners will want to re-examine their macro-economic directions and instead look to the development of service-based industries. These industries have many attractions: they are often labour-intensive, less-polluting, and usually consistent with the objectives of sustainable development.

Even in an OECD nation, regional S&T policies may mirror those of resource-based economies. For example, Canada looks like an industrialized country, but the two industrialized provinces; Ontario and Quebec account for two-thirds of all output. The rest of Canada is predominantly an agricultural and resource based economy dependent on sales of commodities on world markets. S&T policy makers in the provinces other than Ontario and Quebec, as well as federal policy-makers have to develop S&T policy within this paradigm. For example, British Columbia, which, on a per capita income basis is wealthy, is in the middle of an economic downturn caused by the simultaneous collapse of resource prices and its traditional markets in Asia, and the loss of its fishery due to over fishing. Even in the industrialized part of the country, the effects of a resource-based economy are felt, and thus there is a consequent need to understand S&T programs in the context of a resource-based economy as well as an industrialized economy.

Renato Dagnino and Heman Thomas (5), in their paper examining the relationship between S&T policymaking in Latin America and the measurement of S&T activities, have noted that there are many factors which differentiate Latin American S&T policy needs from those of the OECD. History, economics and social structure have all

influenced both the S&T needs of the region and the policies required to manage them. Not the least, the process of collecting and analyzing information on S&T activities must be "inclusive" rather than "exclusive", drawing in as many of the actors in the S&T system as possible. In their view, concentrating solely on measurements of R&D undermines this requirement. Indeed, the authors argue that a whole new metric for measuring S&T activities is required.

R&D is usually carried out as part of a national effort to develop knowledge to produce new products or processes. In a conventional national system of innovation (NSI), universities and government laboratories produce new knowledge to feed the manufacturing sector of the economy. The productive asset is the manufacturing base. In a service economy this is not so: the assets are human assets, and the strength of the services sector is dependent upon the ability of the national system of innovation to supply knowledge embedded in people, rather than in machinery. The Frascati Manual was written with the express purpose of providing a standard system for measuring R&D and hence the level of a nation's investment in innovation. It is, by design, a "performer-based" system, rather than a "funder-based" system. It is interesting to note that while the Frascati "system" works well for investment in civilian, productive, technologies, it fares less well in capturing levels of investment in military R&D and in R&D in the services sector, where the results are often intangible (such as software).

UNESCO has recognized that in a developing nation, the overall state of investment in S&T was more important that investment in R&D by itself. In 1978 UNESCO stated in its "Recommendations Concerning the International Standardization of Statistics on Science and Technology" (6) that scientific and technical activities comprise:

"...systematic activities which are closely concerned with the generation, advancement, dissemination and application of scientific and technical knowledge in all fields of science and technology. These include such activities as R&D, scientific and technical education and training (STET) and scientific and technological services (STS)"

In terms of S&T indicators, and the statistics that make up these indicators, one can state:

S&T indicators = R&D indicators + STET indicators + STS indicators.

In preparing indicators for policymakers in a developing nation, or even a nation where a national objective is to develop the services sector, S&T indicators comprise more than just those R&D indicators defined by the Frascati Manual2[2].

The Knowledge-Based Economy

The neo-classical view of the function of knowledge in an economic system is to include it as an input to productivity (along with raw materials, physical capital and labour) and attribute any increase in productivity above that which can be attributed to the non-knowledge based inputs, to the knowledge inputs. Richard Lipsey, in various papers on his structuralist theory, (see for example, Richard Lipsey and Ken Carlaw (7)), argues that the transformation of knowledge into incremental growth is more complex, and that

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[2] It should be noted that the Frascati Manual does give succinct definitions of STET and STS, by way of defining what is not part of R&D.

knowledge impacts on a variety of elements within what he calls "the facilitating structure". They are:

- plant and equipment that employ specific technologies human capital (knowledge embedded in people)

- the organization of production facilities

- managerial and financial organization of firms location and concentration of industries

- national infrastructure

- financial structure of the economy

There are technological inputs, to a greater or lesser degree, to all of these factors. It is worth noting here that the inputs are not just those from the natural sciences and engineering, but also include inputs from the social sciences. Where does this knowledge come from - that is to say, knowledge new to the economy, as opposed to investments of existing knowledge in new physical or human capital? Simply put, one can approximate the sources of knowledge new to the economy as:

Total knowledge inputs =
domestic R&D + intangible knowledge purchased + implicit knowledge purchased

Traditional manufacturing-based economies lean heavily on domestic R&D as their source of new knowledge for economic growth. Resource-based economies and developing nations import most of their knowledge, either as intangibles or embedded in capital equipment imports. Thus it is import to measure all of these factors, not just the national R&D effort.

Measuring Knowledge Inputs

Domestic R&D measurements: Here, of course, one does follow the Frascati Manual, particularly for measuring R&D in the public sector (government and universities). Measurements of R&D in the private sector are harder, often because firms find it difficult to distinguish between the development of new knowledge, and the adaptation of existing technologies to changing situations. Many of the gaps in national measurements of R&D occur in the private sector: for example, the Frascati manual specifically buries industrial R&D carried out in private-non profit institutes in overall business enterprise R&D, even though there is ample evidence that R&D consortia are cost effective mechanisms for pre-competitive research by industrial sectors within a nation. Usually, the only private non-profit institutes whose R&D efforts are captured are those that carry out pre-competitive research in support of social objectives, such as cancer research. Indeed, it is interesting to note that this area is poorly understood, yet, in developed nations, it represents one of the few areas where decisions made by private individuals, in the form of their donations to various medical charities, reflects the relative priority the public puts on different research programs.

Purchase of intangible knowledge: The purchase of intangible knowledge is more difficult to quantify, whether as patents or licenses or as expert advice on new

technologies. Often the value of the transactions does not match the inherent value of the information acquired. Domestic subsidiaries are often over-charged (or sometimes undercharged) for information brought by them from their multi-national parents. Purchases of technical expertise often go unrecorded if the purchase does not pass through the national banking system. The OECD has developed a Technological Balance of Payments Manual (8), but as yet, no one knows how successful it may be in tracking knowledge imports and exports in a national economy.

Purchase of knowledge embedded in capital goods. In one sense this is the easiest to measure, as imports of goods are usually closely monitored by Customs officials[3]. One can then assign a value of to the knowledge embedded on the basis of the R&D/revenues ratio of industrial sector from which the product comes. This is, of course, an approximation, but not unrealistic. For reference, some R&D/revenues ratios, based on Canadian statistics, are shown below:

Table 1: Selected R&D/Revenues for Canadian Industries, 1995

Industry	Estimated Revenues ($M)	R&D Expenditures ($M)	R&D Revenues Ratio (%)
Mining	17070	106	0.6
Crude Petroleum	12800	77	0.6
Food industries	45140	136	0.3
Plastics	1530	29	1.9
Textiles	3375	54	1.6
Wood	8000	24	0.3
Paper	33670	101	0.3
Primary metals - ferrous	6000	18	0.3
Primary metals - non-ferrous	12100	121	1.0
Fabricated metal	3750	75	2.0
Machinery	5970	173	2.9
Aircraft	8065	742	9.2
Motor vehicles	77500	155	0.2
Telecommunications equipment	6350	1379	21.7
Business machines (computers)	10730	322	3.0
Pharmaceuticals	7150	462	6.5
Scientific equipment	2210	84	3.8
Electrical power	28570	200	0.7
Computer services	3,135	464	14.8
Engineering services	6,560	676	10.3
Total all industries	478,690	7659	1.6

Source: Statistics Canada "Industrial R&D", catalogue #88-202-XPB

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[3] There are exceptions: as the elimination of tariff barriers takes effect under NAFT A, it will become progressively more difficult to track the movement of technology embedded in goods across the boundaries of the NAFTA nations.

The Question of Infrastructure

As Lipsey' s list of factors in the economic "facilitating structure" shows, simple inputs of knowledge are not enough. The existence of a well-educated labour force, capable of using the knowledge-based inputs, and the services required to support the use of knowledge-based inputs is required. Thus the STET and STS elements of the UNESCO system, which are outside the Frascati system, for S&T indicators are equally important.

Scientific and Technical Education and Training (STET): Decisions affecting national investments in STET require adequate information on numbers of students, both entering the tertiary levels of education, and leaving it. Indeed, given the widespread use of many technologies today, some knowledge of STET at the secondary level (and perhaps, in the case of computer literacy, at the primary level) is required. Inventories of highly qualified personnel, by level and field of study, and the rates at which individuals enter and leave the inventory are necessary. Studies in this area also need to address issues relating to emigration and immigration of highly qualified personnel.

Attempts have been made by the National Science Foundation in the US to develop an accounting procedure to track the total volumes of S&T personnel. It has proven to be very difficult; simply because individuals enter and leave the S&T labour force, but stay within the economy. Indeed, it is widely suspected that most economies have a reservoir of S&T talent, which is underutilized. Yet, in developing economies it is precisely this reservoir of talent that must be exploited to make optimal use of existing investments in STET .

Scientific and Technical Services (STS): Just as measurements of expenditures on R&D are necessary for adequate economic policy formulation, so too, are indicators of investment in STS. The indicators themselves are often similar (expenditures, number of employees, etc.). The Frascati Manual lists STS by category; Statistics Canada, in its publication on federal government S&T expenditures (9) gives a more thorough set of definitions and descriptions for STS in the natural and social sciences. These include:

- libraries and museums
- translation and editing of S&T materials surveying and prospecting
- socio-economic data collection
- testing, standards, quality control
- client counseling: agricultural and industrial

STS in the private sector is rarely, if ever, measured. It is difficult, in a short survey to assign values to STS activities in a firm, and the role of private non-profit STS providers is not clearly delineated, yet it is often in provision of STS, that (for example) industrial associations playa major role on supporting the collective needs of industry (as in standards).

The National System of Innovation

However, given the complexity of Lipsey's model, it is often difficult to attribute a particular output (say, increase in productivity) to investment in anyone factor. There have been many attempts to measure outputs and link them to specific S&T inputs, but they are doomed to failure because of the interconnectedness of the factors within a

national economic system. This is one reason that analysts look to the models of national systems of innovation in attempt to derive indicators of the stocks and flows of knowledge among the various elements of a national economy. As Charles Edquist noted in the introduction to his book "Systems of Innovation"(10):

- innovations are new creations of economic significance

- innovation processes occur over time and are influenced by many factors

- the behaviour of firms is also shaped by institutions that constitute constraints or incentives for innovation

- the actors as well as these contextual factors are all elements of systems for the creation and use of knowledge for economic purposes.

Thus:

"*If we want to describe, understand; explain - and perhaps influence - processes of innovation we must take all important factors shaping and influencing innovation into account* ".

The OECD has analyzed national systems of innovation (11) and has concluded:

 "The study of national systems of innovation (NSI) offers new rationales for government technology policies. Government policies in the past have focused on <u>market-failures;</u> studies of NSI make it possible to study <u>systemic failures.</u>

The report goes on to argue that analyses of NSI help to identify networks and areas where networking can be of benefit, and improving policies which enhance the innovative capacities of firms. The report admits that studies of NSI are hampered by difficulties in measuring the flows of knowledge: the Frascati manual measures only a part of those flows, and thus supplemental information is required.

The implications are clear. Any (and every) economy has an NSI. Knowledge is transferred among the components as intellectual property, embedded knowledge or people. Thus policymakers need to understand the relationships among the components of the NSI. Data have to be collected on all elements of the NSI and warehoused in an institution, an observatory, to enable their timely analysis and processing. Figure 1 gives an example of an NSI for a developed, federal country (Canada) while Figure 2 shows an NSI for an emerging economy that has recently undergone economic liberalization (Argentina).
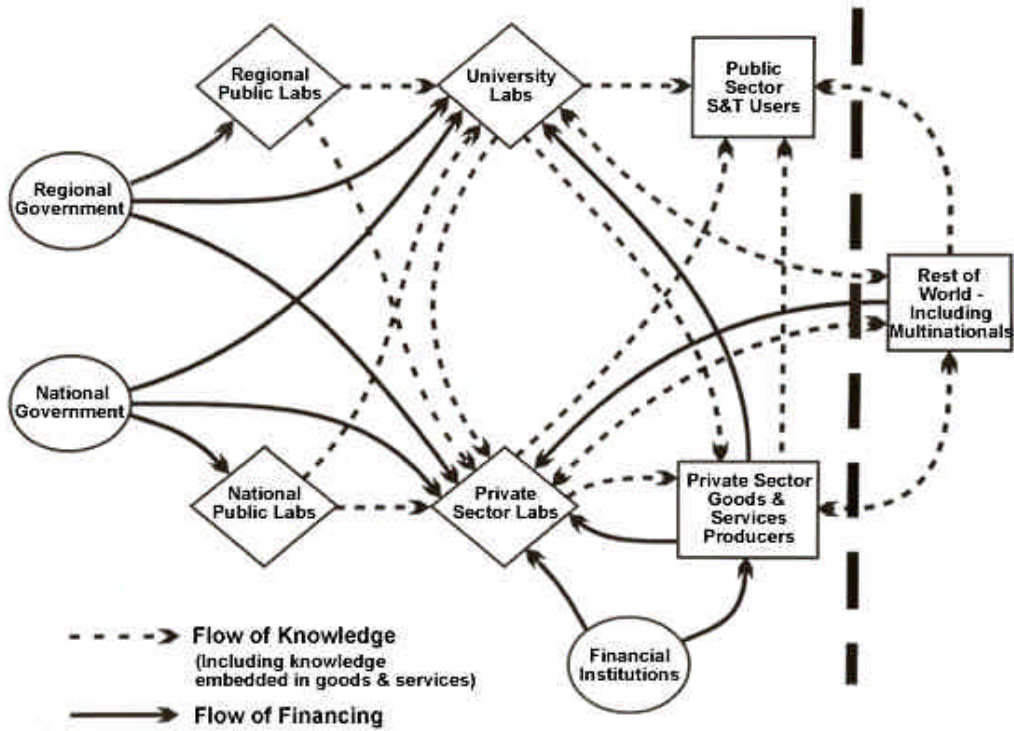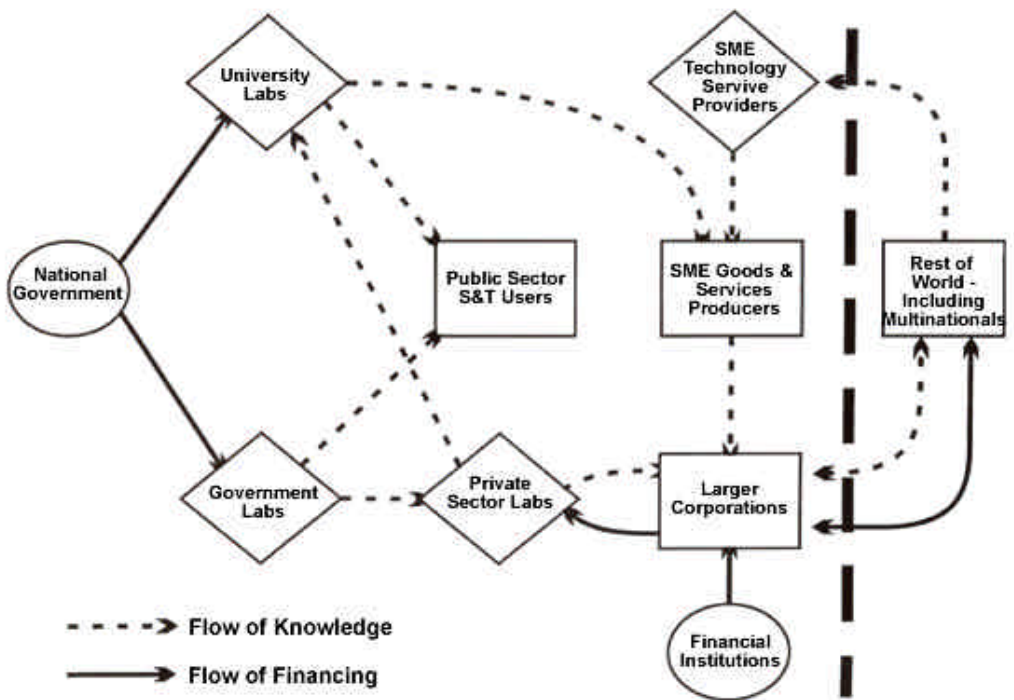
Figure 1

Flow of Knowledge
(Including knowledge
embedded in goods & services)

Flow of Financing

Figure 2

Flow of Knowledge

Flow of Financing

The measurements required to understand an NSI include measurements of the stocks of knowledge and the flows of knowledge among the elements of the NSI. Each element has a capital stock of human capital, of intangible knowledge stored in some archival manner (libraries, patent and license documents, etc), and a series of linkages to other elements of the NSI over which these stocks of knowledge flow. People move from element to element, knowledge is transferred in intangible forms (electronic, paper, etc.) and in tangible forms (the transfer or purchase of equipment). As policymakers learn where the constraints on movement of knowledge are, they can develop, as the OECD noted, policies to mitigate the conditions that cause these constraints.

An Example - The Canadian S&T Framework

In an attempt to place S&T indicators into a logical system within a national system of innovation, equivalent to the System of National Accounts that is widely used for economic indicators, the S&T Statistics Advisory Committee to Statistics Canada has developed a framework that places existing indicators in a logical sequence. In so doing it has also identified potential gaps in the data collected and the resulting S&T indicators. The framework (12) is based on addressing a generalized question that might be asked by any senior public official or policy maker.

Traditionally S&T statistics have been indirect indicators, but for a better interpretation of their meaning, these indicators must systematically related to each other in accordance with a model with tracks how knowledge is generated, transmitted and used in society.

The framework consists of three parts:

- the classification of statistics needed to describe S&T activities;

- the systematic relating of those statistics to S&T policy analytical questions; and,

- the selection of appropriate indicators measure the outcomes of S&T activities.

The framework for S&T statistics is similar, but not identical to the System of National Accounts (SNA). The SNA is an integrated and systematic classification of all monetary transactions which result in a change in the asset position of an economic agent, whether it be a household, business, or a government. The framework for S&T statistics overlaps the SNA - form instance, resources are consumed in the production of knowledge - but the SNA is concerned only with the monetary transactions. The S&T framework differs in that:

- the object of measurement is not monetary , but knowledge

- the unit may be used simultaneously by many without depreciation

- the increase in knowledge may not necessarily be connected to monetary economic "value"

The table below shows how the structure is set up:

Table 2: Proposed S&T Statistical Framework	
Activities	
Who?	Who are the actors involved in an S&T activity (by sector and occupation)?
What?	What is the nature of the activity?
Where?	Where is the activity taking place (both in geographic terms and sectoral terms)?
Why?	What are the objectives (economic growth, social progress, advancement of knowledge)?
Linkages	
How Much?	What resources have been committed to the activity (money, human capital, materials)? Where do the resources come from?
How connected?	What are the social organizations, supporting infrastructures, etc. linking the actors involved?
Outcomes	
What result?	When the activity is implemented, what are the outcomes (articles published, patents, new products)?

Time as a duration, or as a frequency can be used to qualify any variable in the network.

By way of a general example, the above can be formulated as a sentence, outlining a policy question:

For **an actor** (who) to perform an **activity** (what), in a **location** (where), in order to achieve an **objective** (why), what are the **costs** (how much), the **linkages and incentives** (how connected), in order to produce an **outcome** (what result)?

A specific example would be:

ARC Limited (who) conducted R&D in nanoconductors (what), at its research facilities in Kanata (where), in order to increase its market share of semi-conductors (why), and spent $10 million (how much), in conjunction with the Physics Department at Carleton University, but recouped half of the costs because of the R&D tax credit program (how connected), as the manufacturing process developed was environmentally cleaner (what result).

The framework tries to distinguish between outcomes and impacts. Outcomes of S&T activities are usually discernable results of that activity, while impacts are those consequences for the economic, social, political and environmental system which take longer to emerge, and which are often difficult to impute back to their origins. Impacts can be divided into those that affect the socio-economic system and result from an innovation, and those that affect the environment surrounding the S&T activity and result from changes in social, economic or political organization. While the framework, as outlined above, deals specifically with outcomes, one of its benefits is that it can be used to tie outcomes, later in time, to specific impacts.

With this framework in place, analysts can then propose analytical questions and hypotheses, design data acquisition systems and identify specific data gaps. With data, they can then formulate priorities and challenge myths about the S&T system. Hopefully this will lead them to be able to provide information to assist policymakers to comprehend the complexities of assessing social benefits and detriments of the evolution of S&T and appreciate the need for caution and criticism in establishing S&T policies.

Conclusion: The Social Policy Challenge

As Eduardo Martinez and Mario Albornoz (13) have noted, the social benefits of S&T programs indicators are usually confused with the economic benefits of S&T programs. Economic growth is widely assumed to be a social benefit, and that growth in knowledge and technological inputs must inevitably result in social progress, and that indicators of S&T economic impacts are transferable as indicators of social progress. This is not necessarily the case. A government could decide that it must tackle social problems at the price of slower economic progress.

At a recent workshop sponsored by the Red Iberoamericana de Indicadores de Ciencia y Tecnologia (RICYT) and the Organization of American States (OAS) in Mar del Plata, Argentina, the linkages between S&T indicators and social impacts were explored. Two useful paradigms were discussed:

$$\frac{\text{indicators of social impact}}{\text{indicators of S\&T inputs}} = \text{indicators of results and justification for S\&T investments}$$

and,

$$\frac{\text{indicators of S\&T inputs}}{\text{indicators of social impact}} = \text{planning indicators}$$

The first paradigm is an output measure: it gives a measurable result that is based on a measured social impact which is the (presumed) result of an S&T input. It gives a result that can be used to justify the allocation of S&T resources. The second, the inverse of the first, is a forecasting tool. It enables planners to predict what might occur if incremental S&T resources are allocated (always assuming that there is a direct relationship between the S&T resource input and the expected social impact). These paradigms are time-dependent: unlike economic impacts social benefits often increase as time increases after the input of S&T resources.

Latin America is uniquely placed to explore the relationship between social benefits and S&T programs. Although most Latin American economies have undergone economic liberalization *(apertura),* many of the economic and social impacts of S&T have yet to be measured. There is much room for research on the social impacts of S&T, and as Dagnino and Thomas have suggested for the development of entirely new indicators specific to Latin American S&T policy needs. This work will be of immense importance to policy makers in the majority of the world's nations which are not industrialized. By virtue of being linked to S&T in resource-based (or under-industrialized) economies, a social impact S&T indicators system could be developed to meet the direct needs of the nations concerned, rather than adapting a system that was originally developed for another type of economy.

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