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Data Requirements for the Establishment of STMIS in Developing Countries*

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In most of the Less Developed Countries (LDCs) today, the basis for science and technology (S&T) resource management and decision-making remains one of adopting main categories of S&T similar to those indicators commonly used in industrialized countries. S&T management information systems (STMIS) in the LDCs and the data necessary to produce such S&T indicators for decision-making therefore essentially follow those adopted by the major industrialized countries.

In these systems, major S&T input indicators are based predominantly, if not exclusively, on investment in research and development (R&D) activities, namely:

- expenditure on R&D
- R&D personnel
- R&D infrastructure

This is clearly reflected by the main indicators produced by the Organization for Economic Cooperation and Development (OECD) which include variations in gross domestic expenditure on R&D (or GERD); expenditure on R&D in the business enterprise sector (or BERD); expenditure on R&D in the higher education sector (or HERD); government budget appropriations or outlays for R&D (or GBAORD); total full-time equivalent on R&D (or FTE); and the number of R&D research scientists and engineers (or RSE).[1]

Correspondingly, output indicators are constructed to measure what is achieved by investment in S&T systems. Major output indicators are based on two categories:

- Bibliometric indicators that measure the volume of S&T publications in mainstream scientific and technical literature
- Socioeconomic indicators, as in the number of patents, copyrights, license agreements, etc.

Examples of socioeconomic indicators used by the OECD are various types of patent application statistics, technological balance of payments, and export-to-import ratios.

WHY ARE CONVENTIONAL S&T MANAGEMENT INFORMATION SYSTEMS INADEQUATE FOR LDCS?

While S&T input and output indicators have been effective tools for S&T management and policy making among the industrialized countries, their effectiveness among LDCs is questionable.[2] The main reason for this stems from the basic differences in R&D structures between the developed and less developed countries, as seen in Figure 1, Figure 2 and Figure 3.

In the developed countries, R&D systems are coupled with an economy's production systems. In other words, research activities generate the new knowledge that leads to new technology development and product/process inventions. Industrial companies are then able to commercialize the resulting technological developments and inventions, reaping the economic returns to finance further R&D activities. It should be noted that industry spends more on R&D than does the public sector.

Though R&D structures among NICs have not reached the mature and self-reinforcing stage of the developed countries, they are nonetheless capable of undertaking technology and product development for commercialization that generate economic return to finance further technology and product development. Massive investments in R&D infrastructure and personnel over the past 20 years have lifted their status in the S&T structure closer to that of the developed countries. However, LDCs are unable as yet to produce frontier basic research, nor are they able to effectively apply the basic research conducted mainly by academic institutes into the productive systems.

In the case of LDCs, R&D activities and systems are basically weak. Thailand, for example, spends a mere 0.2 percent of GNP on R&D. The scarce research and development activities that *are* being carried out are separated from one another and are often not commercialized, either because of the quality of the research, which is mainly done in public sector institutions, or the inability of the productive sector to further develop them for commercialization. Even many relatively simple engineering activities are presently isolated from the productive systems. Therefore, the current state of the R&D structure in most LDCs inherently renders the conventional S&T indicators in use ineffective or even misleading.

WHAT KINDS OF S&T MANAGEMENT INFORMATION SYSTEMS WOULD WORK FOR LDCS?

While there is no universal set of S&T input and output indicators applicable for all LDCs, it is obvious that some attempt ought to be made to overcome the present deficiency in S&T indicators, based mainly on investment in R&D as input, and publications and patents as output indicators. Such a set of meaningful S&T indicators may vary from country to country, depending on each one's prevailing social and economic conditions.

It is proposed in this paper that the following additional S&T indicators could be considered for constructing a more meaningful national management information systems among LDCs.

Input Indicators

Expenditure Indicators

Data on expenditure should extend beyond those spent on R&D to include all major S&T activities such as quality control, standards, testing and certification services, calibration services, design, engineering and consultancy services.

These S&T activities, other than R&D, by far play a much bigger role than R&D in the S&T structure of most LDCs. They are important promotional agents for technological progress and therefore provide a good basis for judging the state of technological capability and a better instrument for deciding the appropriate course of S&T development.

In addition, expenditure on R&D should be further classified into R&D expenditures for the two options to either buy or make technology, specifically:

- adoption and adaptation of imported technology
- generation of new technology locally

Human Resources Indicators

Apart from S&T human resource indicators, other useful indicators would include expenditure on S&T-related education, both formal and informal. Formal education would include data on the number of S&T graduates each year, in what disciplines and at what expense. Informal education involves training by both public educational institutes and private-sector companies. Data should include the number of people trained, the number and types of training courses offered, and the amount spent on in-house and public training courses, workshops, and seminars.

What is important here is not merely a question of how many trained people an LDC has in R&D, but the total number in the whole S&T structure. More importantly, are existing and future S&T personnel given the needed opportunities to upgrade their skills? Given the ever-widening technology gap between the developed countries and the LDCs, this question is vital.

In addition to the number of people in S&T, it may be useful to observe the skills represented within a given industrial sector. Such a structure could include the following classifications according to functions performed:

- inventors and innovators
- managers and trainers
- engineers and designers
- technicians and supervisors
- skilled and unskilled workers

Infrastructure Indicators

In the developed countries, the emphasis on this category of indicator is on the number of R&D laboratories and the investment in R&D equipment for generating and commercializing technology on a "make some - buy some" policy (see Figure 4).[3] It is, however, more appropriate for the LDCs to concentrate on the "buy some" aspect.

Suitable input indicators would be the amount spent on technology from abroad, and output indicators would be the extent of technology assimilation and innovation, to be discussed later.

Figure 4 and Figure 5 provide lists of promotional agents which form the basic infrastructure for the development of all four components of technology (i.e., physical facilities, human-abilities, documented facts, and organizational frameworks). It is very important to ascertain that the strength of each of the promotional agents is satisfactory in that there should be a minimum critical mass (both human and physical resources) for effective operation. Furthermore, it may be an important consideration to ensure continuity of each of the development chains.

Output Indicators

Bibliometric Indicators

This category of output indicator would need local databases for information on national and grey literature as a measurement of S&T performance.

Socioeconomic Indicators

In addition to the indicators commonly adopted by the developed countries, possible relevant output indicators could be established, based on:

- Manufactured exports evolution
- GDP evolution in manufactured outputs
- S&T activities

Manufactured Exports Evolution

Based on data on manufactured exports over time, useful indicators may be constructed from the *structural shift in manufactured exports* to see if and how much exports have moved in terms of percentage shares from resource- and labor-intensive industries toward being more S&T-intensive as in differentiated and science-based manufactured exports.

Based on the classification taken from OECD, 1988 (see Dahlman and Brimble 1990), the different manufacturing sectors may be grouped into five types. They are: resource intensive, labor intensive, scale intensive, differentiated, and science based. Resource-intensive industries are ISIC categories 31, 323, 331, 3411, 353-4, 369 and 372. Labor-intensive industries are 321-2, 324, 332, 380-81, and 39. Scale-intensive industries are 34, 351, 355-6, 361-2, 371, 384. Differentiated goods are 3821-4, 3829, 383, and 3852-3. Science-based industries are 352, 3825, 3851, and 3845.

GDP Evolution in Manufactured Output

A similar indicator to the one described above is based on a country's aggregate structure of manufacturing production, with the manufacturing sectors grouped into the same five types of industries using these OECD classification. Here *the change in the shares and the rates of change* over time of the five types of industries again can provide output S&T indicators among developing countries.

Output Indicators for Other S&T Activities

Most of the indicators considered so far are based primarily on aggregate data at the "macro" level. Since most industries in the LDCs are in the infancy stage of development, they usually have only a small number of companies engaged in S&T activities. Even these are poor in technological capability. Therefore, some indicators at the "micro" level can be developed into useful decision-making instruments. Some possible indicators could be designed to gauge the extent of technology transfer as measured by the activities going on in searching and purchasing technology among companies; the success of technology assimilation as measured by the maintenance performed, replication of imported technology, adaptation of technology; and finally the degree of technological innovation found in improving or even creating new technology, products, or processes (see Figure 4).

The methodology to create suitable "micro" level S&T indicators as outlined above, would most naturally be a company survey among the major industrial sectors of a particular country. An example is the attempt by the Thailand Development Research Institute (TDRI) to assess the technological capability of Thai industries by conducting a survey of 119 companies in the areas of biotechnology, materials and electronics (see Kopr Kritayakirana et al. 1989). The technological capabilities of production companies were categorized into four types: acquisitive, operative, adaptive and innovative. Acquisitive capability includes a companies' ability to search, assess, negotiate and procure relevant technology. The transfer of operation know-how, as well as installation and start-up of production facilities, were also included in the acquisitive category. Operative capability includes the ability to efficiently operate and control machinery and other equipment, as well as its maintenance, skill development (training), general management, production planning and quality control. Adaptive capability is the ability to learn technology, understand new technology and the ability to carry out minor product and process modifications. Innovative capability includes the ability to carry out in-house research and development, new product and process modifications, new or major changes and new products and/or process inventions.

Although this TDRI Exercise yielded a good overview of Thailand's technological capability, it took 18 months and many researchers, plus a sizable budget. Therefore, some other methodology should be developed to speed up the process, even if it means eliminating some information.

We would like to propose here a concise questionnaire which not only makes a rough estimate of various capabilities, but also tries to assess relative weaknesses in equipment, manpower, information and organization. A model questionnaire for conducting such a proposed survey is attached as an annex.

Data obtained from this questionnaire would be useful in producing a set of industry capability/productivity improvement indicators. The evaluation of the status of technology in a given industry and its comparison with the state-of-the-art would also be useful.

CONCLUSION

We have attempted to show why the S&T indicators currently in use in the developed countries are of little relevance to the LDCs, even though they are often blindly adopted.

On input indicators, we have proposed that expenditure indicators should include all S&T activities, and not merely R&D. Such activities are, for example, all types of technical services, human resource development, and technology purchases. Possible useful output indicators, may be national and grey literature bibliometric indicators, manufactured exports evolution and GDP evolution in manufactured output indicators, and a number of S&T activities output indicators.

These suggestions are by no means exhaustive. They should be considered as possible tools a country's decision-makers might use. The specific S&T indicators, and the corresponding data requirements for a particular STMIS, can only be identified following a detailed study into the user's needs and the prevailing social and economic conditions of a given country.

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