*Research Evaluation*, volume 6, number 3, December 1996, pages 187–192, Beech Tree Publishing, 10 Watford Close, Guildford, Surrey GU1 2EP, England.

# Innovation indicators

## Innovation indicators for less developed countries

**Sandra Brisolla**

***Reliable indicators of innovation and innovative agents are even more necessary in developing countries, where scarce resource require even greater productivity in public investments, than in developed countries. A number of Latin American authors, and analysts at UNCTAD have proposed indicators, including impact indicators, that should assist developing nations to monitor their investments in S&T knowledge. This system needs to be codified and developed into a usable standard for these economies.***

Dr Sandra Brisolla teaches and coordinates a Labroatory of Science, Technology and Innovation Indicators at the Scientific and Technological Policy Department at the Universidade Estadual de Campinas, Caixa Postal 6152, Campinas, SP, Brazil. Tel: +55 19 8778272; Fax: +55 19 2391772; E-mail: brisolla@turing.unicamp.br.

THE FIRST POINT when discussing the construction of scientific, technological, and innovation indicators in Latin America is a philosophical one: is it possible to construct indicators reflecting the complex and rapidly evolving reality they are supposed to represent?

This question is similar to that raised by Keynes. Rather than considering the complexity of firm-level behavior, where businessmen take into account in their decisions the expected responses of each competitor and each customer, Keynes noted that it is impossible for any economic decision-maker to foresee all the possibilities of market evolution. In this sense, Keynesian uncertainty is understood as a structural uncertainty, inherent to the system. Similarly, it might be discussed whether the construction of S&T activity indicators is feasible — whether it is possible to conceive variables accurate enough to represent the wider social phenomenon of scientific development, technological advance, and innovation.

The second question is of a more practical nature, but is similar to the first. Is it worthwhile constructing indicators? In other words, in the present stage of development of statistical and data collection tools in Latin America, should we expect to obtain a set of measurements which meet the needs of policy-makers as well as of those who study S&T policies? Do today's indicators perform their role of 'indicating' the direction of S&T development?

Indicators would be an unnecessary device if S&T activities were immediately measurable:

> "Forms devised to yield indirect information on phenomena or events to which they are applied, are indicators, i.e., parameters offering

 0958-2029/96/030187-6 US$08.00  

> approximate notions of the concept we intend to assess." (Davyt, 1996, page 5)

On the other hand, immeasurability derives from the non-material character of such activities:

> "The product of science is knowledge, which is rather intangible and hence difficult to gauge." (Morita-Lou, 1985, page 11)

The development of scientometrics indicates that some qualitative aspects of S&T may be quantified. Even though publication and citation counts are problematic, statistical treatment of such information has yielded interesting results. Although these indicators cannot be considered accurate indications of the level attained by scientific training, they nevertheless allow the production of comparative analyses and time series, and at the same time offer an overview as valid as their supporting premises. Problems, if any, are mainly due to erroneous applications or out-of-context use.

For example, objections have been raised as to the use of the *Science Citation Index* (SCI) as the only source of information to measure scientific output in developing countries. In Latin America, there have been a number of studies critiquing this source due to its bias towards publications from English-speaking authors from industrialized nations, and the under-representation of journals from developing countries. Similarly, the use of patents as an indicator of technological output must be discounted in Latin America because a great deal of technological innovation is not officially recorded.

These considerations suggest that indicators should be specifically designed for the reality they intend to reflect.

> "Besides recognising differences between central and peripheral countries as relatively strong, the fact that S&T indicators are not neutral, assuming as they do many of the surrounding factors and conditions, should be highlighted." (Davyt, 1996, page 22)

## Indicators for economic integration

Given that a nation needs its own frame of reference if it is to have a set of efficient indicators, with the twofold purpose of supporting policies and enabling analyses of them, the problem lies in the construction of that specific group of specific variables. The first step towards this is to attain an understanding of the characteristics of national systems of innovation common to all Latin American countries.

Two points should be stressed when discussing the construction of a Latin American system of S&T information. The first refers to the nature of S&T activities: they are high-risk activities, for which there are no immediate returns from the investment and results are not proportional to the resources invested. In countries in which the national system of innovation is based on technology imports, returns on S&T investments are more doubtful. The level of long-term investment in this sector does not satisfy the need for solutions to alleviate social inequalities.

This challenge must be faced when discussing the future, especially when the social reality requires a concentration of human and material resources to solve existing problems. Ironically, the application of new technologies is precisely the most cost-effective way to overcome difficulties in social areas. Thus it is necessary to show governments and society as a whole the importance of S&T activities in reducing the costs of social problems in those countries.

The second point is of a more structural nature: it is the difference between the role of the scientific and technological system and that of the innovation system in industrialized countries and Latin American countries. This is unremarkable in countries where the historical relationship between science and its applications to industry is well understood, but it acquires a rather perverse nature in Latin American countries, where the dynamics of scientific activity are quite divorced from technical progress. Science and technology inputs in Latin America may be quite heterogeneous, but the dialogue between Latin American science and its peers from industrialized countries is usually held in English through vehicles (journals or scientific meetings) belonging to or organized by the first world.

Innovation is also carried out on the basis of the international state of the art, with little influence from domestic developments in products and processes. The truncated industrialization in Latin America, first described by Fernando Fajnzylber, imposed on technology-dependent economies a pattern of production and consumption characteristic of mature economies, where the problems of satisfying primary needs had already been overcome. This caused serious social problems in the less developed economies. The process was accompanied by a parallel distortion of scientific and technological training (Fajnzilber, 1983, chapter 3).

It can be argued that the political and economic stability of the state has played a role in the late industrialization of some developing countries. As an

**The usefulness of S&T indicators as such, rather than measures of the national system of innovation, as instruments for the analysis and adjustment of innovation policies, has been questioned in both Latin American and industrialized countries**

example, the awareness that expertise in conventional technologies and cottage industries is less important than formal education in preparing workers for new technologies has led to new educational policies in some Asian countries. Such policies can only be carried out through public investment. Consequently, in Latin America, governmental instabilities have had a negative effect on the development dynamics of some countries.

State intervention in Latin American industrialization has usually occurred in manufacturing and services enterprises where the required investment is too high for local entrepreneurs, and where foreign private companies show no interest. Normally the prevalent private-sector attitude in national enterprises is of avoiding risk, and this constitutes an impediment for innovation. It is therefore crucial to study and understand government policies, because the higher rates of application of technologies by state-owned enterprises may be a result of the state being such an important factor in Latin American economies.

## Current indicators

The usefulness of S&T indicators as such, rather than measures of the national system of innovation, as instruments for the analysis and adjustment of innovation policies, has been questioned in both Latin American and industrialized countries. Such concerns spurred the OECD (Organization for Economic Cooperation and Development) to develop the *Oslo Manual*, which sets guidelines for the measurement of innovation.

This initiative by international specialists supports the proposition that it is necessary to introduce innovation indicators specific to the Latin American S&T system as soon as possible, especially because of the weak relationship between the introduction of new technologies and their application in the region. The problem in establishing such an indicator system is that these countries also have the greatest difficulties in establishing specific indicators for the productive sector, because of their cost and the resistance of businessmen to providing statistical data.

This attitude reveals the distance between businessmen and the academic environment, a relationship which in industrialized countries has become closer through the growing industrial expansion in the post-war period. Michel Callon (1990) created a typology of several subclasses in innovative networks: convergent networks, sparse or integrated networks, long, short, or incomplete networks.

In the case of strongly convergent networks (as in leading industrialized countries) there is a close relationship between the different actors, and coordination may be highly formalized. Any actor within the network — researcher, engineer, seller, or user — is able to harness all the capabilities of the network without resorting to adaptations, translations, or costly decodification.

In the case of sparse networks (developing countries), the density of relationships among actors is low, conversions from science to technology are not yet consistently consolidated, and it is difficult for actors to fully exploit the remaining part of the net. Large networks in these countries are unusual. Most networks have missing links (usually as a result of the economic structure).

Chaining networks together, to form the classic 'chain-link' network is a challenge for technological training in developing countries. Indicators provide an important tool to identify problems in weaving this innovative fabric.

The main goal is to create a system of indicators aimed at identifying, from the very beginning, the obstacles posed to innovation dynamics. This does not mean, however, that information relative to the behavior of traditionally representative variables in the scientific and technological dynamics of these countries should not be collected. It means, simply, that such traditional variables should be accompanied by an attempt to collect information about innovative initiatives.

In this sense, the goal of constructing indicators is a first step towards raising awareness in S&T policymakers as to the characteristics of the S&T sector in these countries. There have already been some attempts to construct indicators comparable at the international level, through the application of concepts common to parallel statistics in developed countries. However, this effort should be restricted to certain key variables useful for outlining a first common statistical base for Latin America. The RICYT–CYTED (Red Iberoamericana de Indicadores en Ciencia y Tecnologia – Ciencia y Tecnologia para el Desarrollo) network is already compiling information to devise about a dozen indicators for their member countries to draw a first comparative and overall picture of S&T in the region.

The greatest difficulties concern variables representing the impact of S&T investment on the economy as a whole. There is an equally urgent need to reconcile scarce resource availability in Latin America with the need for up-to-date information with which to plan scientific and technological policies. The increasing non-material nature of technology, as well as its growing expression through non-tangible goods, training, and disembodied know-how makes measurement more difficult. Technologies are difficult to measure, even in countries where the appropriate departments within private corporations (R&D departments, corporate planners, financial officers) participate in the production of such statistics.

Technology is a social phenomenon. In capitalist societies, it is usually available for private appropriation under socially determined conditions. In these societies, such appropriation can be carried out through activities such as patent acquisition. In dealing with indicators in developing countries, however, there is a low correlation between patent acquisition and innovation initiatives. Technology being a social

phenomenon, its relationships with the environment within which it is implemented are of a complex nature. Transfer of technology to other countries requires changes in the immediate social environment (among them, training of staff belonging to the company that buys the technology), and also in general socio-cultural conditions, which frequently includes state-directed actions.

To construct indicators that are useful as a policy tool, efforts must be made to understand the mechanisms through which Latin American science may be helped in overcoming development problems. This will encourage the technological transformations needed to make these countries internationally competitive.

## Need for innovation indicators

The challenge to construct innovation indicators reflects the concern of specialists all over the world to find efficient tools to assist in the management of S&T policy for desirable outcomes from the economic, social, and cultural points of view. In less developed countries, technical progress appears as an external factor. Interrelationships between science, technology and society are less developed, resulting in deficiencies in statistical data, especially those associated with the impact of science and technology upon society (Konrad and Wahl, 1990).

It is precisely in these countries, where scarce resources press for greater productivity in public investment, that reliable indicators of innovative agents are even more necessary. The existing literature distinguishes the scientific and technological potential of a society (namely, its capacity to generate science and technology) from its capacity to receive and absorb science and technology solutions of domestic origin or acquired through technology transfer and transformed into social and economic innovations (see Konrad and Wahl, 1990).

Innovation indicators for developed countries have been systematized in the *Oslo Manual*, which deals with technological and industrial innovation and describes innovative changes at the firm level. In order to design a strategy aimed at understanding the innovative process in developing countries, it is important to have in mind the significant advances in the understanding of the very meaning of technology. In this sense, the task of working out concepts describing modern innovative processes requires a full understanding of the broader, and often unreported, economy in these nations. David Noble, for instance,

> "examines the concurrent emergence of modern technology and the rise of corporate capitalism as two sides of the same process of social production in America... technology is always more than information, logic, things. It is people themselves, undertaking their various activities in particular social and historical contexts... As Marcuse observed, 'We do not ask for the influence or effect of technology on the human individuals. For they are themselves an integral part and factor of technology, not only as the men who invent or attend to machinery, but also as the social groups which direct its application and utilization' (Marcuse, 1941, page 414)." (Noble, 1982, pages xxi, xxii)

Considering the characteristics of technical advance in less developed countries, there is a need for indicators reflecting innovation processes under such conditions. Some attempts have already been made in this direction, among them the work carried out at UNCTAD (UN Conference on Trade and Development):

> "Difficulties relative to data in less developed countries, with respect to the quality and availability of technologically relevant information, suggest that the range of technological indicators should be wider here than in developed countries. ...The importance of the different indicators and their interpretation, varies according to the level of development and to differences in economic policies among the less developed countries. An increasing flow in capital asset imports, or in direct foreign investment, may be read either as an increase in available technology or as higher dependence on existing technology." (UNCTAD, 1991)

The structure of technological indicators proposed by UNCTAD included:

Indicators of technological input:

- imported or transferred technology
- direct foreign investment
- capital goods imports
- copyright payments for technology and technical assistance.

Domestic inputs:

- national expenditure in science and technology
- expenditure on formal education and training
- investment in premises and equipment

Indicators of economic performance associated with technology:

- indicators of internal economic performance, such as increases in productivity and product innovation
- indicators of exports or trade performance (technological balance)
- increases in the market share of technology-intensive products
- technology exports

Indicators of technological performance:

- level of industrialization
- differences in GDP (gross domestic product) sectoral composition
- sectoral distribution of the workforce
- differences in internal output composition
- differences in trade composition

The UNCTAD approach proposes an analysis of economic variables that may reflect technological advance through impact indicators to be used in less developed countries. It also includes institutional variables which are fundamental for the implementation of the new technological paradigm.

## Less-developed country paradigm

Avalos and Viana (1985) pioneered discussions on the specific features of less developed countries affecting the production of indicators in the region. Among recent works on innovation and technology indicators, Konrad and Wahl (1990) show an original approach. According to them, the underdeveloped relationships among science, technology, and society are responsible for difficulties in translating S&T potentials into a capacity to absorb new results. The authors suggest three groups of indicators:

> "one group of indicators for the scientific and technological potential of the countries, a second group of indicators for their ability to generate such capacities (generativity) and a third group for the capability to receive, to absorb scientific knowledge and technological solutions created in the country or acquired by technology transfer and to transform them into economic and social innovations (receptivity)." (Konrad and Wahl, 1990, page 246).

The main indicators of S&T inputs (indicators of S&T expenditure and human resources) are included among indicators of S&T potential. The structural and functional aspects are covered by relative indicators such as researchers per million inhabitants, and expenditure in R&D/GDP per inhabitant or per researcher including expenditure on R&D in the private sector. Konrad and Wahl found no correlation between the concentration of resources in the private sector, the R&D potential of a country, and its overall level of development:

> "It becomes obvious that this concentration is necessary but is not a sufficient condition for social efficiency of national R&D... The assimilation, adaptation and modification of the available science and technology results are a priority task of the R&D capacities in these countries which takes second place to the creation of new results..." (Konrad and Wahl, 1990, pages 249, 251).

To measure the capacity to generate S&T, the indicators included were mainly comparative economic and social variables, such as manufacturing output as a percentage of GNP, *per capita* GNP and its growth rate, the percentage of the national budget spent on education, urbanization level, purchasing power of exports, as well as some absolute values, such as gainfully employed labor force, fixed capital formation rate (or gross inward investment).

Social indicators, especially those referring to education, must be included because:

> "social and technical innovations presuppose a general education in science and technology as well as a requisite motivation of the working people." (Konrad and Wahl, 1990, page 260).

A general conclusion of their study is that receptivity appears to be the bottleneck of scientific and technological progress in the third world. Structural problems pose the most severe restrictions, both for oil exporting countries and countries with a high indebtedness in Latin America. They also conclude that there is a low correlation between bibliometric indicators and those associated with structural aspects. This supports the suggestion that publications are not a useful indicator for decision-making in scientific and technological areas in less developed countries.

Coutinho and Ferraz' work (1994) developed a wider set of competitiveness indicators, which could be the base for further studies in this direction. They classified indicators into: performance indicators; efficiency indicators; and training indicators. Each category, in its turn, contained three subclasses: systemic indicators; sectoral indicators; and enterprise indicators. One of the benefits of this type of classification is that the influence of competitive factors from outside the enterprise, and even from outside the industrial sector, are explicitly captured.

## Conclusion

This review shows the possibilities of work based on available indicators to measure the impact of S&T activities on technological innovation in less developed countries. The use of social and economic indicators to this end seems effective. Competitiveness may be analyzed in the existing socio-economic context through the explicit consideration of systemic indicators. In the case of Brazil, sectoral conditions could be effectively characterized by combining indicators; this suggests elements for policies to correct main systemic and sectoral distortions.

## References

Ignacio Avalos and Horacio Viana (1985), "Bases para la elaboracion de Indicadores de Medicion de la Capacidad Tecnologica", UNICAMP, mimeo.

Michel Callon, P Lareto and V Rabeharisoa (1990), *The Management and Evaluation of Technological Programs and the*

*Dynamics of Techno-Economic Networks: The Case of the Agence Française de la Maitrise de l'Energie (AFME)* (Centre de Sociologie de l'Innovation, Ecole des Mines de Paris).

Luciano Coutinho and João Carlos Ferraz (coordinators of the study) (1994), *Estudo da Competitividade da Industria Brasileira* (Editora da UNICAMP, Papirus Editora & Ministerio da Ciencia e da Tecnologia).

Amilcar Davyt (1996), "Cuantificando la ciencia: una revision critica sobre indicadores bibliometricos (1960–1995)", mimeo.

Fernando Fajnzylber (editor) (1983), *La Industrializacion Trunca de America Latina* (Editorial Nueva Imagen, México, Caracas, Buenos Aires).

N Konrad and D Wahl (1990), "Science, technology and development indicators for third world countries — possibilities for analysis and grouping", *Scientometrics*, 19(3–4), pages 245–270.

Herbert Marcuse, (1941) "Some social implications of modern technology", *Studies in Philosophy and Social Science*, IX.

Hirolo Morita-Lou (editor) (1985), *Science and Technology Indicators for Development* (Westview Press, Boulder, Colorado).

D F Noble (1982), *America by Design — Science, Technology and the Rise of Corporate Capitalism* (Alfred A Knopf, New York, 1982, chapter 1).

UNCTAD (1991), "Los Indicadores Tecnologicos y los Paises en Desarrollo", UNCTAD/ITP/TEC/19, United Nations Conference on Trade and Development.