A Proposal for Measuring Science, Technology and Innovation Activities

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Introduction

For fifty years now, developed nations have measured their inventive and innovative efforts through statistical activities defined by precise methodological norms. The OECD manuals, such as the Frascati and Oslo Manuals, have developed influential indicators to this end. However, the methodological recommendations are concerned mainly, if not entirely, with the supply-side of invention and innovation. The Frascati Manual concentrates on organizations performing R&D. The Oslo Manual focuses on the innovating firm, with only residual concerns for the end-users. For example, diffusion is discussed from the side of the innovating firm, with no statistics from the users, be they customers, organizations other than a firm, or national systems of innovation as a whole.

The previous paper by Godin and Holbrook , "*Towards a New Concept of Scientific and Technological Activities*" suggested that indicators of use, of the formation of human capital, and demand should be added to supply-side indicators. As a matter of fact, there existed , for many decades, a whole literature on the demand side of STI (Schmookler, 1966), but it may not have been considered seriously until then (one exception is certainly J.-J. Salomon). To a certain extent, the recent concept of absorptive capacity (Cohen and Levinthal, 1990) is a reminder of the need to consider adoption seriously, not only invention or R&D. As a matter of fact, to many (except to strictly economic-oriented or commercially-minded people), innovation is both invention (and its commercialization) **AND** imitation (adoption, diffusion), and the two are considered as two equally valid strategies for firms (Nelson and Winter, 1982[1]; these authors use the term imitation).

The majority of UNESCO countries are first of all users of knowledge and technology produced elsewhere. Therefore, there is need to measure their efforts to absorb what comes from outside as much as their own inventive and innovative efforts. This means that the measurement should give equal attention to invention (and innovation) as to adoption. An argument has been made for some decades that in-house R&D is necessary to absorb what comes from outside. This is one reason why R&D must remain a central indicator in the developed countries statistical efforts. However, this is not the whole story. Firms (and countries) also need the basic elements to use or adopt what comes from elsewhere. Innovation is not just inventing and commercializing but also

[1] At least in measurement of, or in the development of indicators.

using and adopting new knowledge and technology, whatever its source. Instead measuring only scientific and technological activities (STA) as has been the practice of UNESCO in the past, it is argued that innovation must be included, and that the measurement universe should be that of science, technology and innovation activities (STIA) Thus the conceptual framework for measuring STIA proposed by Godin and Holbrook which consists of five elements;

- Human capital: how does a national system of innovation absorb knowledge and technology, both national and foreign?

- Infrastructure: what are the 'services' (institutions, programs, investments) supporting the adoption of knowledge and technology in a country?

- Diffusion and transfer: what, if any, and how many, are the users of knowledge and technology, what are the mechanisms through which knowledge and technology are transferred, what investments are made into supporting these mechanisms or activities?

- Innovation : How should innovation be measured in non-manufacturing economies? What is the role of communication and diffusion in spreading innovations within an economy and from one nation to the next?

- R&D. R&D is a subset of innovation – essential the development and application of knowledge that is new to the world. While R&D is more commonly found in developed nations with sufficient resources to devote to the activity, it is not absent elsewhere. While consistency demands that the same standards be applied as in the OECD (the Frascati Manual) are there other factors that need to be considered in nations with smaller R&D efforts?

Only if there is absorption of knowledge and technology into behaviors, practices and organizations, do outcomes coming from both R&D and innovation manifest themselves. Like indicators on R&D which need to be seconded with indicators on diffusion and transfer, the latter need to be seconded with indicators on impacts or outcomes. As a matter of fact, investments in R&D and innovation are made only because they are expected to lead to benefits (impacts). Not measuring this dimension is an act of faith in STI activities.

A Proposal: Indicators of Science, Technology and Innovation Activities (STIA)

The five major components of STIA are outlined above, These components can be broken down, roughly, into two categories: investment in S&T capital (human and infrastructure) and investment in innovation (R&D and national innovation activities). Diffusion and transfer of knowledge and technology is a consequence of these investments. All of these have economic and social impacts.

This suggests a new paradigm (Figure 1). Thus the proposed framework for the system of indictors of consists of the following:

- S&T Human capital (all employed personnel with S&T qualifications in ISCED 5a, 5b, and 6), subdivided by ISCED level and discipline (see the Frascati Manual, Annex 7, sections 41 - 48)
    - ISCED 5a, 5b and 6 gives STET (all post-secondary educational activities in S&T as per the Frascati definition of S&T, which includes the social sciences, including formal education overseas). The R&D activities of level 6 need to be separated out, so that their compensation can be included in GERD, under national R&D activities
    - Some educational activities are technology transfer and would be collected under that heading. Here the ISCED level 5b refers only to those that lead to a formal certificate
    - Levels of expatriate human capital

- S&T infrastructure, including:
    - Support activities for R&D, as per UNESCO guidelines for STS
    - Capital investment in technology-based equipment, particularly ICTs, (embedded knowledge).

- National innovation activities. Conventional measurements based on the OECD Oslo Manual are difficult to replicate from one country to another, unless the nations have similar economies as in the European Union. It will be necessary to develop a more broadly based set of indicators (see, possibly, the "Bogota Manual" (2000)). Some elements of knowledge and technology transfer may be included here as well.

- National R&D programs, as per Frascati Manual guidelines.

- Diffusion and Transfer of S&T Knowledge and Technology
    - Patents, licenses, and other codified knowledge
    - Investment in on-the-job training (training that does not lead to a formal certificate from an educational institution)
    - Investment in other informal and non-certificated training of national S&T human capital, both domestically and from overseas
    - Note that this includes the acquisition of knowledge and technology directly from outside the country, such as the transfer of R&D results from another nation, and the knowledge associated with the procurement of technology-based equipment from outside the country.
    - This categories also includes S&T information and documentation activities (STID)
    - Measures of emigration and immigration of human capital
    - Outwards diffusion of knowledge and export of technology also occur. However these flows are not shown in Figure 1

Policy makers need to know the overall impacts of S&T activities on economic and social well-being, if only for cost/benefit purposes. Thus while general impact indicators, such as those indicators of specific activities that assist STIA activities, such as energy consumption, transportation, and ICT penetration (see also the Lisbon Manual, for ICT indicators), should be part of the information used by S&T policy makers, they will not be reviewed here, as they are of a more general nature, and are (usually) described by internationally accepted standards.

Figure 1: Science Technology and Innovation Activities

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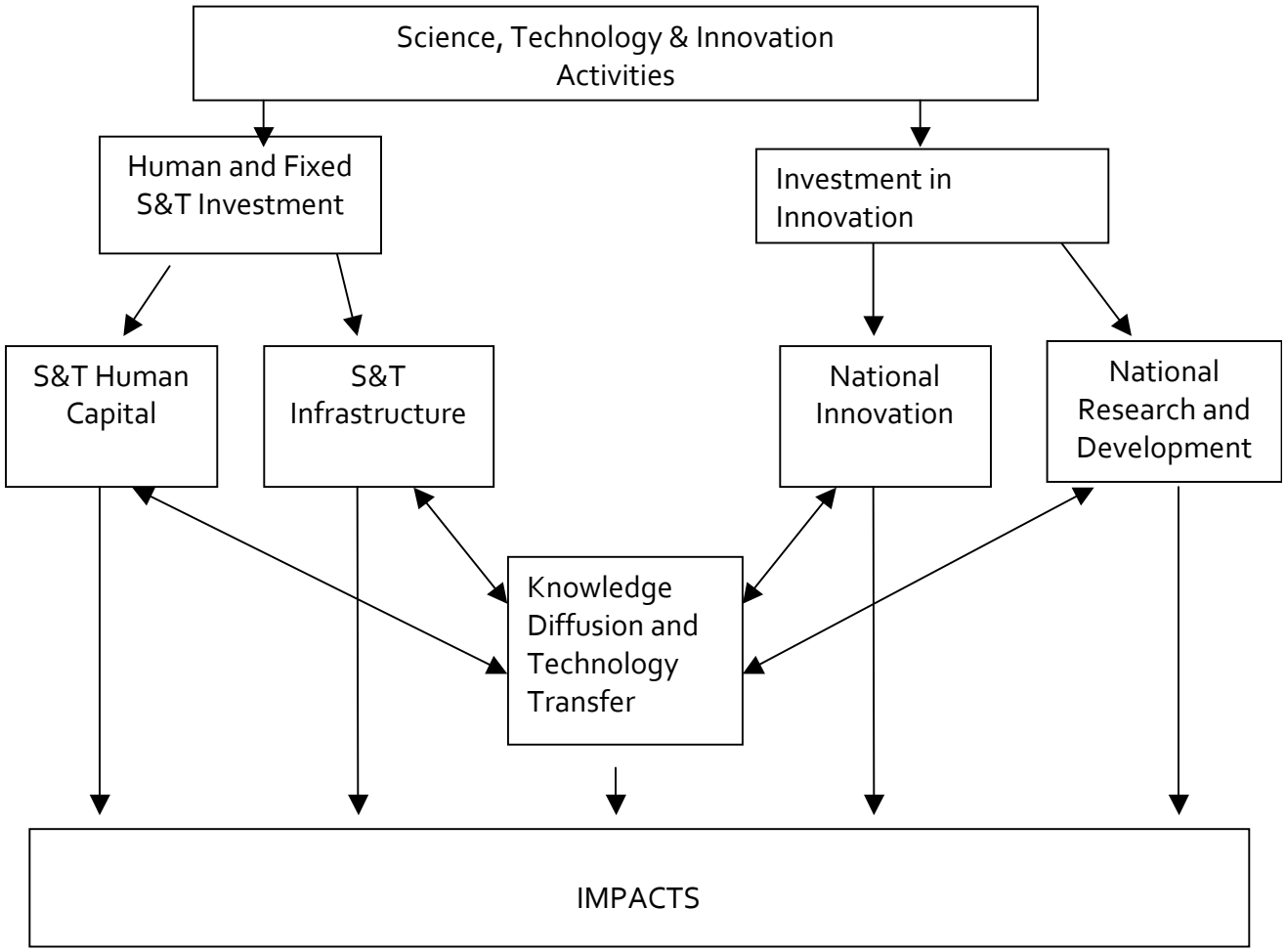

Questions to be resolved

Given the STIA framework outlined above there are concepts of STA, and in particular concepts of STET and STS indicators, that need reviewing. For the moment, the concepts of innovation and of R&D remains unchanged, although there is substantial room for additional work in terms of application in emerging economies and societies (EES).

Many of the concepts and definitions have been developed by the OECD, and accepted for use by its member states. But today there are many large, developing manufacturing economies that fall outside the OECD, particularly when compared with some of the smaller economies within the OECD. Thus to say that there is an OECD universe, and a non-OECD universe is wrong. Nations such as China, India, Brazil and Russia have far more sophisticated S&T indicators programs than many of the OECD nations. The issue here is to develop an understanding of the measurement of STIA that is applicable to any nation, and, more particularly, to a nation that has limited resources for support for its STIA policy makers.

Thus this paper addresses:

A. S&T Human Capital: how should the concept of STET be modified?

- Which theoretical and practical problems exist with the current definition?
- Which parts of the definition need to be removed or modified?
- Are there activities that need to be added?
- What could be done to facilitate data collection?

B. S&T Infrastructure: how should the concept of STS be modified?

- Which theoretical and practical problems exist with the current definition?
- Which parts of the definition need to be removed or modified?
- Are there activities that need to be added?
- What could be done to facilitate data collection?

C. Should there be separate data collection guidelines for STIA expenditures and for STIA human capital?

D. How should the concepts of innovation (particularly as defined by the OECD through the OSLO Manual) be developed to understand the role of STA in national systems of innovation and in methods of measuring these systems. Indicators of innovation often include quantitative measures of STA, and thus STA definitions need to be reviewed in this context. As noted above R&D is a subset of overall innovation activities, and apart from suggestions relating to the areas of specific interest to non-OECD nations, should will be left to future review.

The following sections deal with each of these questions.

S&T Human Capital

Which theoretical and practical problems exist with the current definition of STET?

How should the concept of STET be modified? The concept of STET was originally established to support the measurement of R&D in the OECD nations. Simply put, it was recognized that national R&D activities required inputs of human capital, and that there should be standards for defining how S&T human capital was trained, and, more particularly the expenditures relating to this training. These were input costs, and in a developed economy represented part of the investment required to mount an R&D program.

But experience has shown that in many nations[2], S&T personnel come from many sources, including expatriate sources, and furthermore that most people (human capital) with S&T training are not involved in R&D or innovation on an ongoing basis. Yet their contributions are important: a secondary school teacher or a bank manager with S&T training may play an important role in developing STIA in a nation. Studies (Holbrook, et.al) have shown that individuals with research training (in its broadest sense – this included the social sciences, humanities and arts) are more likely to have higher salaries, and to contribute more to their societies than those who do not., regardless of whether they are actually engaged in STIA occupations.

In some nations there are acute shortages of human capital. In many cases expatriate human capital is imported. Clearly there are economic situations where this may be a rational use of resources, but policy makers do need to know the degree to which they are dependent on expatriate knowledge workers, and the potential their nation may have for developing national human capital to replace them.

- Which parts of the definition need to be removed or modified?
- Are there activities that need to be added?
- What could be done to facilitate data collection?

[2] We will tend to use the terms "country" , "nation", "economy" and "society" interchangeably, mainly for literary diversity.. We apologize, but for the most part they describe a single unit with a defined system of governance. Clearly there are instances where these three terms are not interchangeable, but it is not the role of this paper to enter into that debate.