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TECHNICAL PAPER NO. 5

MEASURING R&D:
Challenges Faced by Developing Countries

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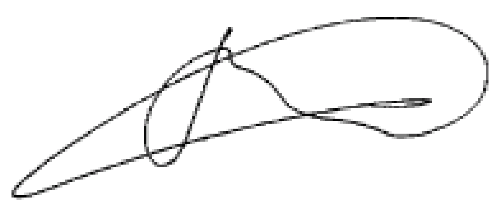
Foreword

The study of knowledge systems relies heavily on the use of Science, Technology and Innovation (STI) indicators to establish cross-national comparisons and to follow their evolution over time. Of the different types of STI indicators, research and experimental development (R&D) statistics are probably the most important. To produce R&D statistics, the methodology proposed by the Organisation for Economic Co-operation and Development (OECD) in the *Frascati Manual* (FM) is used extensively in developing countries despite the fact that it was originally written for R&D surveys in OECD member countries. This confirms the FM as the most widely accepted international standard practice for R&D surveys. In addition, the involvement of UNESCO and other international organizations has only served to further its development and diffusion.

However, the characteristics of research systems in developing countries differ significantly from the ones that gave rise to the current statistical standard. When producing statistics and indicators, the tension between prioritizing international comparability – embodied in the frequently uncritical application of the FM by developing countries – and producing policy-relevant results that reflect the particular characteristics of these countries becomes evident. The main challenge is in obtaining cross-nationally comparable indicators while at the same time adequately reflecting the characteristics of developing countries.

The UNESCO Institute for Statistics (UIS) has taken on the task of preparing an Annex to the FM that will provide guidance to developing countries on how to use the standards proposed in the Manual for measuring R&D. The Annex will provide suggestions on how the concepts in the FM should be interpreted to ensure that data better reflect the particular characteristics of R&D activity in developing countries while still maintaining international comparability.

This Technical Paper is a stand-alone document on measuring R&D in developing countries and will serve as the basis for an Annex to the FM. In addition to providing guidance on how the concepts in the FM should be interpreted, this guide also offers suggestions on how to strengthen STI statistical systems in developing countries. This document will also address and provide recommendations for specific situations that fall outside the framework of the FM. In time, some of the recommendations in this guide could serve as input for future revisions of the Manual.



Hendrik van der Pol
Director
UNESCO Institute for Statistics

Acknowledgements

This Technical Paper is the outcome of a process that spans over two years and that started with a Consultation Meeting in December 2007 in Montreal. At this first meeting, three documents were presented that served as an initial platform to draft the first version of this Technical Paper.

After several revisions, an Expert Meeting on Measuring R&D in Developing Countries was held in Windhoek, Namibia in September 2009. The experts present at this meeting provided valuable comments on the style and content of the draft version of this Paper. In addition, a global consultation of all Member States through the UNESCO National Commissions was undertaken in February and March 2010. The three lead papers from the Consultation Meeting, the agenda and the rapporteur's report of the Expert Meeting can be accessed on the UIS website (see http://www.uis.unesco.org/ev.php?ID=7854_201&ID2=DO_TOPIC).

Michael Kahn from South Africa was commissioned by the UIS to prepare the final version of this guide. He has also drawn from this Paper a shorter and more focused document for the OECD's National Experts on Science and Technology Indicators (NESTI) meeting in November 2010 as a proposal for an Annex to the FM.

This document has received input from a wide range of national statisticians and international experts through various regional workshops and expert meetings. The UIS would like to express its gratitude to everyone who contributed to this Paper. In particular, the UIS would like to thank the regional science networks of RICYT and NEPAD, as well as Eurostat, the OECD Secretariat and OECD's NESTI Working Party who have all been essential partners in the preparation of this document.

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In addition, thanks are due to the experts who provided the UIS with many valuable observations before, during and following the expert meeting in Namibia: Rodolfo Barrere, Claes Brundenius, Simon Ellis, Ernesto Fernández Polcuch, Jacques Gaillard, Changlin Gao, Fred Gault, Regina Gusmão, Dudi Hidayat, Michael Kahn, Alfred van Kent, Vladimir Lopez-Bassols, Philippe Mawoko, Hatem M'Henni, Rohan Pathirage, Laxman Prasad, Kitipong Promwong, Nabiel Saleh, Martin Schaaper, Lukovi Seke, Gert-Jan Stads, Lena Tsipouri, Gunnar Westholm and Igor Yegorov. Thanks go out as well to the Government of Namibia, particularly Alfred van Kent, Director of Research, Science and Technology at the Ministry of Education, for hosting the Expert Meeting.

The development of this document began at the UIS under the supervision of Ernesto Fernández Polcuch (now at UNESCO Windhoek) and Simon Ellis (now UIS Regional Advisor for Asia and the Pacific) and ended under the supervision of Martin Schaaper (Programme Specialist S&T Statistics, UIS). It has also benefitted from inputs from Rohan Pathirage (Assistant Programme Specialist S&T Statistics, UIS).

Finally, our thanks go out to Michael Kahn for acting as rapporteur at the Expert Meeting, aggregating all input received at the meeting and converting the draft of this Technical Paper into a coherent and well-structured document.

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Abbreviations

AU	African Union
FI	Foreign institution
FM	Frascati Manual
FTE	Full-time equivalent
GERD	Gross domestic expenditure on research and experimental development
GNERD	Gross national expenditure on research and experimental development
HE	Higher education
HEI	Higher education institution
HERD	Higher education expenditure on research and experimental development
ISCED	International Standard Classification of Education
MNC	Multinational corporation
NGO	Non-governmental organization
NEPAD	New Partnership for Africa's Development
NESTI	OECD Working Party of National Experts on Science and Technology Indicators
NIS	National Innovation System
NSO	National Statistical Office
OECD	Organisation for Economic Co-operation and Development
PNP	Private non-profit
R&D	Research and experimental development
RICYT	*Red de Indicadores de Ciencia y Tecnología Iberoamericana e Interamericana* (Ibero-American and Inter-American Network on Science and Technology Indicators)
S&T	Science and technology
SME	Small and medium-sized enterprise
SNA	System of national accounts
SOE	State-owned enterprise
SSH	Social sciences and humanities
STA	Science and technology activities
STET	Science and technology education and training
STI	Science, technology and innovation
STMIS	Science and technology management information system
STS	Science and technology services
TK	Traditional knowledge
UIS	UNESCO Institute for Statistics
UNESCO	United Nations Educational, Scientific and Cultural Organization

Executive Summary

Innovation is now universally regarded as an engine of economic growth in developing as well as developed countries – it is therefore an important driver of poverty alleviation. To set effective innovation policies, policy-makers need trustworthy indicators to benchmark and monitor these policies. Research and experimental development (R&D) is an important component of a country's national innovation system (NIS) and R&D statistics are among the most widely used indicators to monitor the NIS.

The methodology to measure R&D is detailed in the Frascati Manual (FM), which has been in use for almost fifty years. Despite this longevity, developing countries sometimes face problems when trying to apply the FM standards to the situation in their country. This Technical Paper provides guidance on a number of challenges that are relevant to developing countries and which may not be elaborated on clearly enough in the FM. The following situations that may present challenges to measuring R&D in developing countries are addressed in this document:

1) Developing countries are a heterogeneous group, extending from the least developed countries to emerging economies. Consequently, their innovation systems and associated R&D measurement systems exhibit wide variety both internally -- by institution, sector and region -- and internationally. In addition, despite the increasing presence of developing countries in global R&D, there is still a marked lack of demand for science, technology and innovation (STI) indicators from policy-makers in developing countries. Even if the demand does exists, there are often significant problems with compiling the data due to a lack of coordination at the national level, a lack of cooperation by research institutions, universities and businesses, and a generally weak statistical system in the country.

2) A concentration of innovation activities by sector or in a small set of institutes may lead to volatility and inconsistencies in statistics. The lower emphasis on R&D in the business sector may reflect the way R&D is organized. Business enterprises that cater mainly to the local market may experience reduced competitive pressure, making systematic R&D the exception rather than the rule. R&D may therefore be commissioned *ad hoc* to deal with production issues and is thus informal as well as difficult to capture.

3) In the higher education sector, the increasing number of private universities makes it useful to distinguish between public and private higher education and to further break up private higher education into government-dependent and independent private institutions. Further disaggregation into private-for-profit and private-not-for-profit higher education institutions should also be considered to track where most research is carried out.

4) The landscape of R&D expenditure is changing, which affects the collection of data. R&D used to be largely funded by the government but now new sources of funds are emerging – foundations, non-governmental organizations (NGOs) and especially foreign organizations play an important role. Although the FM recommends the collection of primary data through direct surveys, the use of secondary data from the national budget and the budgetary records of public R&D performing units has been a widely adopted practice for obtaining a rough estimate of R&D expenditure. However, using budget data may not reflect true R&D expenditure as it harbours the risk of double counting, especially when a mix of budget data and survey data is used.

5) Tallying the number of researchers in a given country presents further challenges. In certain cases, an underestimation occurs while in others, an overestimation is generated. In some developing countries, salaried researchers may not have research budgets or unpaid researchers may undertake research. In other scenarios, academic staff may hold part-time contracts at more than one university. Even if academic staff have contracts that specify the amount of time to be spent on conducting research, it is difficult to enforce especially where there is a lack of resources. Estimating the time spent on research and hence the calculation of the full-time equivalent (FTE) for research staff – particularly in the higher education sector – is fraught with difficulties. This directly impacts the calculation of R&D expenditure.

Likewise, capturing the time contributed to R&D by doctoral students and their tutors is a common problem. Researchers in foreign institutions present an additional challenge as their mode of working may differ from that of researchers in national institutions. Researchers may spend a considerable period working abroad but still retain their positions at home while visiting researchers (who normally work abroad and are visiting a particular country for a certain duration) fall into a different category and present yet another significant phenomenon to be taken into account.

R&D survey data need to be complemented with information from other sources. As such, the problem of accurately identifying researchers and the time they spend on research could be addressed in part through sensitive interviews by peers who understand local circumstances. When using secondary sources to calculate the number of researchers, however, it is necessary to verify the figures by surveying institutions in order to confirm coverage and avoid double counting.

6) Clinical trials are an area of growth in some developing countries. Identifying research personnel in the extended clinical trials value chain may be difficult as their involvement is occasional and harbours a risk of double counting (i.e. as personnel in the trial and as academic staff). The following convention should be used to account for the R&D personnel involved in clinical trials:

- Medical doctors and other professionals with at least ISCED 5A degrees (UNESCO, 2006) should be considered researchers;

- Nurses and other staff with qualifications below ISCED 5A should be categorized as technicians.

Involvement in clinical trials may be a part-time activity for doctors in their medical practice. As such, it is important to calculate the FTE of the staff involved. It is equally important to carefully attribute the expenditure and FTE to the correct sectors (i.e. higher education, business, private non-profit) as higher education researchers might be engaged in clinical trial supervision for a private company, for example.

7) A number of special types of activity warrant attention when measuring R&D as they rest on the borderline of what is considered R&D. The following are activities that are discussed in the Paper:

- In the case of traditional knowledge, it is important to set boundaries. Activities that establish an interface between traditional knowledge and R&D are considered R&D. However, the storage and communication of traditional knowledge in traditional ways is excluded.

- Reverse engineering is important in many developing countries. However, this generally falls outside the scope of R&D. Only if reverse engineering is carried out in the framework of an R&D project to develop a new (and different) product, should it be considered R&D.

- Minor or incremental changes are the most frequent type of innovation activity in emerging economies and developing countries. The activities leading to minor, incremental changes or adaptations should in principle not be counted as R&D activities unless they are part of, or result from, a formal R&D project in the firm.

- Surveys should measure R&D in the social sciences and humanities across all sectors. Development research and other social change projects should only be considered R&D so long as they are in a development and testing phase. Once the project goes to scale, it is no longer R&D. In some countries, research on religion has a particular importance. In principle, research on religion is a part of the humanities, thus institutions performing it should be included in R&D surveys.

- There are areas of growth and improvement in R&D measurement that should be addressed. Survey coverage should be extended to software development and system engineering R&D activities of leading firms in the financial services sector as well as small and medium sized enterprises in the R&D value chains of these leading firms.

8) Finally, given their importance in developing countries, it may be useful to create a foreign institutions (FI) sub-sector within each major sector of performance. In countries where the FI sector is deemed important and significantly impacts R&D statistics, it could be treated as a separate sector that ranks at the same level as other sectors of performance. If a country decides to establish an FI sector, it is recommended that this sector include foreign government institutes, foreign private non-profit (PNP) institutes and international organizations. Foreign companies, however, should remain in the business sector while foreign higher education institutes should remain in the higher education sector. Funding from this sector that helps finance other sectors should be labelled as funds from “abroad”.

STI statistical systems are often weak in developing countries. A number of recommendations are elaborated in this Paper to help strengthen these systems:

- Institutionalize R&D statistics;

- Establish registers;

- Demonstrate value and build support;

- Document survey procedures and estimations.

Lastly, there is a perceived need for further data and information beyond the FM definition of R&D to augment STI statistics with data on related S&T activities. These activities include scientific and technological services (STS) and scientific and technological education and training (STET).

1. Introduction

In recent years, innovation has moved centre stage as the main driver of economic growth – be it through incremental or radical innovation (UNCTAD, 2007). Innovation[1] activities include knowledge generation and transfer, the purchase of technologies, product commercialization as well as research and experimental development (R&D). As such, the ability to perform, commission, measure and manage R&D is an important facet of economic competitiveness and national development. There are several reasons for this:

- R&D is central to the capacity to adopt and adapt technologies through technology transfer.
- Local development problems require local solutions and perspectives. Technological solutions are socially and culturally embedded and, as such, must take indigenous knowledge systems into consideration. Culturally sensitive R&D that works alongside and collaborates with indigenous knowledge practitioners offers the potential to transform this R&D into various innovations.
- Highly qualified personnel are an important asset for development. Such human resources are trained and developed in higher education institutions (HEIs). The R&D carried out in HEIs is one of the drivers of quality in higher education.

R&D statistics are an important policy planning tool for industrialized countries, emerging economies and developing countries alike. The discussion in this Technical Paper seeks to reflect the different characteristics of economies and societies in a rapidly evolving "developing world" that encompasses the emerging economies as well. The group designated as "developing countries" is based on the UN classification of macro geographical (continental) regions, geographical sub-regions, and selected economic and other groupings -- it does not refer to a homogeneous set of countries.[2]

R&D intensity (i.e. national R&D expenditure as a percentage of the gross domestic product) is a sentinel indicator for economic policy as witnessed in the Lisbon Agenda of the European Union, the African Ministers of Science and Technology Consolidated Plan of Action, and the policy statements of the Organization of American States. Despite the value of R&D statistics as a relevant tool for evidence-based policy making, high-level demand for and the supply of these statistics is far from universal. There are instances where the importance of R&D has been diminished in the policy domain – notably, in the transition from central planning to the market economy, during fluctuations in the commodity cycle and, more recently, due to the global recession of 2008-2010.

In addition, developing countries differ in their production and dissemination of, and access to information, subsumed in the term "culture of information". This may manifest as a lack of demand for information by policy-makers and other users or an unwillingness or inability to provide information by research institutions, universities and businesses. If R&D is deemed unimportant for policy planning, its measurement is likely to be considered a low priority as well. Likewise, a weak measurement of R&D will also make it difficult to present a strong case for investing in R&D. This Technical Paper seeks to push for change in this state of affairs.

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[1] Innovation is the introduction into the market or an organization of a new or significantly improved product, process or marketing or organizational change. Innovation may be technological or non-technological in nature.

[2] United Nations Statistics Division, "Composition of macro geographical (continental) regions, geographical sub-regions, and selected economic and other groupings", http://unstats.un.org/unsd/methods/m49/m49regin.htm.

Currently, the availability of R&D statistics for developing countries is uneven and scarce (Gaillard, 2008; UIS, 2010). The existence of national survey champions of STI and R&D can help improve this situation. However, the task becomes more challenging due to the current lack of information as it weakens the political case for countries to dedicate resources to building R&D data. Breaking this negative cycle is further complicated if national statistical systems are weak and lack the technical competence to produce cross-nationally comparable R&D statistics.

The FM is the *de facto* standard for the internationally comparable measurement of R&D of the Organisation for Economic Co-operation and Development (OECD) Member States and associated observer states. The Manual embodies the collective wisdom regarding the measurement of R&D acquired over five decades of work in the industrialized countries (Godin, 2006). As such, this document follows the FM definition of R&D: “Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications” (FM para. 63).[3]

The aim of this Technical Paper is to help developing countries use the guidelines and standards of the FM to fulfil their own contextual needs. It addresses a number of issues of special relevance to emerging economies and developing countries. Bearing in mind that resources may be scarce, suggestions are also offered to reduce survey complexity and burden while maintaining international comparability.

The Paper begins by outlining key characteristics of R&D activities in emerging economies and developing countries, keeping in mind that these countries have different economic conditions and that science operates under a range of different institutional settings. Next, follows a description of the particular problems with measuring R&D that are relevant to these developing countries. Four sections respectively address measuring R&D expenditure, the R&D workforce and its mobility, specific types of R&D and the internationalization of R&D. This is followed by a section on setting up statistical systems in developing countries. Lastly, a brief section on thinking ahead completes the Technical Paper by outlining ideas that warrant further development.

The Technical Paper complements the FM (OECD, 2002). It is not a blueprint for an R&D survey nor does it set out to provide a definitive list of STI indicators. Instead, it seeks to increase the participation of countries in surveys modelled using the FM, thereby improving local management of R&D and its comparability internationally. The ensuing interaction among STI statisticians in industrialized countries as well as emerging economies and developing countries may benefit future revisions of the FM, thus increasing its scope and relevance.

[3] The reference (FM para. ##) denotes the relevant paragraph number in the 6th edition of the *Frascati Manual* (OECD, 2002).

2. The nature of R&D activity in developing countries

2.1 The growing importance of R&D

From a global perspective, R&D is concentrated in the triad countries of the United States, the European Union and Japan. In the developing world, R&D expenditure and output are also concentrated in a relatively small group of countries in each region. Examples of these can be found in Gaillard (2008) and Arber et al. (2008) – particularly noteworthy is the rapid rise of R&D in China over the last decade.

R&D intensity, an indicator used to monitor resources devoted to STI worldwide, is conventionally measured as the ratio of gross domestic expenditure on R&D (GERD) to gross domestic product (GDP) expressed as a percentage. In 2007, the median GERD to GDP ratio for OECD Member States was 1.8% with six countries well below 1%. A shift in the global distribution of R&D is now under way – as reflected in the increases seen in GERD, the volume of internationally indexed scientific publications and patenting activity in developing countries.

The proportion of scientific publications in recognized bibliometric databases attributed to authors from developing countries has increased markedly. In 1973, developing countries as a whole accounted for 5% of the world's scientific publications and only India, South Africa and Argentina made the list of top 25 countries (Garfield, 1983). In 2006, scientific publications from developing countries accounted for 20% of the global share largely due to Asia (14.8%) and in particular to China (7%). China experienced a growth in publications of over 100% in the last decade while in Latin America, Brazil has increased its contribution to global publications by almost 50% during the same period (Gaillard, 2010).

As R&D activity increases so does interest in R&D statistics. It is commonly assumed that the main users of STI statistics at the national level are government, business and policy analysts but other players, such as the international donor community, multinational corporations and foreign higher education institutions, may also have important roles in local R&D and use these statistics as well. Although this increases demand for R&D statistics, it may also create pressure to generate user-specific data thereby jeopardizing international comparability.

R&D performers function within the specific context of a national social, cultural, political, financial and economic system, frequently carrying with them the legacies of colonial, postcolonial and other forms of governance. This analysis allows one to understand why in many cases it is government rather than the private sector that tends to dominate R&D in emerging economies (Kahn et al., 2008).

In many developing and emerging economies, the business sector performs much less R&D than the government and higher education (public) sectors. This is particularly evident in agricultural and natural environment research where there may be strong links between local research institutions established before independence with parent institutions abroad. In effect, this likely means that more 'R' than 'D' occurs. However, where there are large inflows of funds for health R&D – especially for clinical trials – it is more a case of less 'R' and more 'D'.

The lower emphasis on R&D in the business sector may reflect organizational issues. When business enterprises cater mainly to the local market, competitive pressure may be reduced so that systematic R&D would be the exception not the rule. R&D projects may therefore be commissioned ad hoc to deal with production issues making it, infrequent, informal and difficult to capture. This is quite a different issue to the (possibly rare) occurrence of R&D in the informal sector.

Informal or occasional R&D occurs in other sectors as well. One example is in academic teaching hospitals where research is a part of medical operations but may not be registered as a formal research activity or submitted for clearance by an ethics committee.

In some developing countries, measuring R&D activity in certain special fields may present methodological challenges. Capturing R&D in indigenous knowledge systems, traditional knowledge structures and religious research can be tricky. Other methodological problems arise when measuring the R&D component of clinical trials, software development, reverse engineering and minor technical adaptations, development research as well as other Social Sciences and Humanities research projects. These will all be elaborated in Section 5.

The systematic measurement of R&D presents new challenges to many emerging economies and developing countries. For one, survey staff is not as familiar with the technical definitions of R&D. Systematic training and supervision of data collection and survey staff is necessary to ensure that data will be comparable and consistent.

International experience shows that estimating the time spent on research and hence the calculation of the full-time equivalent (FTE) for research staff, particularly in the higher education sector, is fraught with difficulties. This directly impacts the calculation of GERD. Consistency in measuring time spent on R&D activities is key to the comparability of R&D statistics. This point will be elaborated further in Section 4.

2.2 Heterogeneity and concentration

R&D activities and their institutional framework have distinctive characteristics, depending on the country. This is a reflection of the heterogeneity of structures and the concentration of R&D by region, institution, sector and even project. Classification of activities into these distinct categories allows a first pass survey of the major R&D performers to be conducted.[4]

Understanding R&D within the context of political, economic, educational, scientific and social systems is an important adjunct to the surveys. This entails gaining knowledge of R&D performers, S&T institutions (academies, associations, trade unions, journals, invisible colleges[5], etc.), the working conditions facing researchers, the role of international donor and funding agencies, research outputs (publications, papers and patents) and scientific cooperation and agreements (Mouton and Waast, 2008).

Emerging economies and developing countries are a heterogeneous group, spanning the former centrally planned states, socialist countries and relatively young political formations. Their innovation systems and associated R&D measurement systems exhibit wide variety both internally – by institution, sector and region – and internationally. This variety encompasses an uneven concentration of R&D performers as well as an unequal capacity to measure R&D. Regional variation is the norm even if it is not regarded as the desired goal. There are countries with large and small land masses, as well as poorly

[4] For example, despite having 41 higher education institutions and six research centres, research in Lebanon is highly concentrated and is shared among three universities, accounting for 84% of the overall number of publications. In fact, more than 50% of the total number of publications originates from only one university, which was responsible for three quarters of the 58% increase in Lebanese publications from 1996 to 2003 (Gaillard, 2008).

[5] According to Lievrouw (1989), invisible colleges in a modern context were revived by Price (1963), who uses the term "to denote the informal affiliation of scientists with common interests who (are) already strongly embedded in other institutions (…) and who might live some distance from one another".

and well functioning innovation systems. In many countries, R&D activity is concentrated around an innovation hub with the remainder exhibiting a dispersed pattern from this hub. Recommendations for action should, where possible, take these variations and patterns into consideration.

Since these contextual factors will impact the conduct of R&D surveys, Arber et al. (2008) propose the following grouping of Latin American countries, according to three different sets of parameters (i.e. socio-economic development status, capacities of R&D systems and capacities of R&D statistical systems):

"Group A: countries with consolidated R&D systems and developed S&T statistics systems.

Group B: countries with consolidated R&D systems and less developed S&T statistics systems.

Group C: countries with incipient R&D systems."[6]

Some developing countries experience no major difficulties in applying FM concepts. In general, *Group A* countries are coping well with the challenges faced.

Group B countries have significant R&D activity but a limited history of gathering R&D statistics. These countries have functioning statistical systems and might be able to adopt most of the concepts in the FM. They have yet to develop legal frameworks for the conduct of R&D surveys and sustainably institutionalize these surveys.

Group C countries have produced occasional compendia of STI statistics without regular R&D surveys. These statistics do not cover all sectors and come mainly from administrative and other secondary sources – they are thus not necessarily compatible with FM standards. Group C R&D systems may be limited to a few government and university institutions. The participation of the business sector is almost absent. At the same time, these countries have very limited resources for STI policy and management, let alone STI statistics. An official whose other tasks include various STI management activities usually carries out the STI statistics function on a part-time basis. Under these conditions, countries might start to create a regular R&D statistical collection based on a key sector (often government or higher education) or a few major projects.

Developed countries with a strong national scientific function have a critical mass of relatively stable, well-resourced research and higher education institutes, and well-established science governance systems. The innovation systems in emerging economies and developing countries are more fluid, and, in some cases, depend on a relatively small number of very disparate institutions. If these institutions depend on foreign sources of funds, this may lead to volatility and inconsistency in statistics as the resources available to these establishments rise or fall and their focus shifts between projects and disciplines.

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[6] In the context of Latin America, Arber et al. classify the countries in the three groups as follows:

- Group A comprises Argentina, Brazil, Mexico and Chile;
- Group B comprises Colombia, Costa Rica, Cuba, Panama, Uruguay and Venezuela;
- Group C comprises Nicaragua, Peru, El Salvador, Paraguay, Guatemala, Bolivia, Ecuador, Dominican Republic and Honduras.

This classification could be extended to include countries from the rest of the world.

3. R&D expenditure

R&D used to be largely funded by the government but new sources of funds are emerging. Foundations, scientific associations, non-governmental organizations (NGOs), and particularly foreign organizations already play an important role. In addition, the contribution of private business is becoming more important and gaining more recognition in a wider range of developing countries. Many of these new sources of funding go directly to individuals and groups rather than institutions (Gaillard, 2008), and therefore remain unaccounted for and are seldom declared – including for statistical purposes.

The following situations also present challenges to the collection of data on R&D expenditure:

- Although the FM recommends the collection of primary data through direct surveys, the use of secondary data from national budgets and budgetary records of public R&D performing units has been a widely adopted practice to obtain a rough estimate of GERD. However, there is often a discrepancy between voted and allocated budgets. Furthermore, national research systems have a limited absorption capacity, which may leave funds unused in central accounts instead of being transferred to R&D performing institutions. Moreover, care needs to be taken to ensure that such transfers are not 'double counted' as expenditure of both the funding body and the R&D performing institution.

- A combination of budgetary records and annual reports from performing units, national budgets and national planning documents is used in some countries as a source to estimate GERD. When both sources are used, duplication might result due to the mixture of funding and performing units involved. A similar situation arises for projects involving many different institutions. In some countries, especially the former centrally planned economies, the sources of funds accounted for in the budget are incompatible with FM recommendations.

- The definitions used by finance ministries and other government institutions to establish "S&T budgets" may be *ad-hoc* and fail to distinguish between broad S&T and narrower R&D activities. There are also other definition, classification and data access problems. For example, national defence R&D data might be restricted. Furthermore, many institutions (universities in particular) do not compile a separate R&D budget, especially where research is a low institutional priority.

- R&D components in the national budget, especially capital expenditure, can be difficult to identify and may be aggregated under different headings. In addition, when R&D activities stretch over more than one financial year, it may not be easy to estimate the amount of resources used each year.

- The attribution by sector of R&D activities of state-owned enterprises, university-owned companies and national scientific academies will have a marked influence on the scale and distribution of GERD. The issue of production for the market is general and dealt with in FM para. 163-168. The choice of sector for state laboratories, however, is a matter of convention that depends on the country in question. So, for example, the Centre National de la Recherche Scientifique (CNRS) of France is considered part of the higher education (HE) sector in that country. On the other hand, the Russian Academy of Sciences, like many Eastern Europe academies, awards doctoral degrees and is recorded as part of the government sector under the 'academy' sector.

- In the HE sector, the increasing number of private universities is not always reflected in increasing R&D expenditure. It would be useful to distinguish between “public HE” and “private HE” to examine this phenomenon and other related issues in more detail (FM para. 227-228). Concerning “private HE”, it will be important to distinguish between “government-dependent private” and “independent private” institutions, according to the definitions used by the UIS for education statistics.[7] Further disaggregation into “private-for-profit” and “private-not-for-profit” HE institutions should also be considered.

- Surveys that cover all R&D performers should in principle all report for the same period. This is difficult to achieve since in many governments, higher education institutions and businesses do not necessarily report on the same time period – the business sector is generally most problematic. Also, not all countries follow the same calendar. As a solution, the recommendation that R&D performers report on the ‘financial year closest to the survey period’ may have to suffice.

- Information systems in government and higher education are often not set up to enable the extraction of data on R&D personnel and expenditure. Thus, accurate information on financial expenditure only becomes available a long time after completion of an activity. Unfortunately, ad hoc IT solutions to address these issues may also lead to errors and inconsistencies.

Whenever possible and where it is relevant, the discrepancies discussed above should be covered in the survey metadata.

[7] A “government-dependent private institution” is a private institution that receives at least 50% of its core funding from government agencies. Institutions should also be classified as government dependent if their teaching personnel are paid by a government agency, either via the institution or directly. See http://www.uis.unesco.org/ev.php?URL_ID=5750&URL_DO=DO_TOPIC&URL_SECTION=201.

4. Internal and international mobility of the R&D workforce

Determining the headcount of researchers, calculating FTEs and identifying the breakdown by occupation, qualification and gender for personnel in universities and research institutes is a general problem facing statistical agencies.

In some countries, academic staff contracts specify the amount of time to be spent on conducting research but this is difficult to enforce, especially where there are resource as well as other system and personnel constraints. Some staff members at universities (particularly research professors or *enseignant-chercheurs*) are required by contract to spend a specific amount of time on research activities. When reporting data for R&D surveys, universities are therefore required to count these professors as researchers and assign them an FTE, according to the requirements of their contract. This might distort the results of the survey in a significant way.

The time contribution of doctoral students and their tutors to R&D presents another common difficulty (FM para. 305; 316-324; 332). One problem that remains unresolved is accounting for Masters' students who perform R&D as the FM (para. 323) specifies that only ISCED level 6 students (i.e. doctoral students) should be included.

Further compounding the problem, as university systems expand, academic staff may hold part-time contracts to teach or conduct research at more than one university as "taxi-professors", or occasionally even pro bono. Estimating the FTE of "taxi-professors" might only be possible through interviews.

In some cases, the published researcher FTE is higher than the headcount. Such a situation may arise when researchers have multiple full-time or part-time research positions in various institutions, leading to overestimations. These cases are usually difficult to identify without detailed crosschecks or by contacting the institutions concerned.

One of the keys to a successful survey is a good estimate of labour costs that in turn depends on the estimation of the FTE. As a rough rule of thumb, modern organizations consider that the current expenditure associated with each labour unit is of the same order of magnitude as the cost of employment – the labour cost. The labour cost added to current expenditure plus capital expenditure then gives the total expenditure on R&D. However, in some developing countries, salaried researchers may not have research budgets or researchers are unpaid – low-income countries frequently rely on unpaid researchers for their R&D activities.

Determining the researcher FTE is especially difficult in the former centrally planned economies despite the fact that these countries have well-developed national statistical systems that collect data from all registered research institutions on a regular basis. Generally, 'double-counting' occurs because statistical agencies record the primary place of work of a researcher as the equivalent of a full-time job, counting this as 'one unit' while other occupations are then added on. In essence, information on employment is gathered institution by institution without reference to particular researchers. This leads to a situation where a researcher could be allocated a headcount more than once despite the fact that a primary place of work is usually fixed according to the legal systems of these states.

This problem could be solved by the introduction of a procedure where persons with extra jobs are counted in one (primary) place only. In the future, the shares of time devoted to different jobs could be distributed among those posts accordingly. Information on a secondary occupation could be reflected in special sections of the statistical forms of the ‘primary’ organization. Persons who are registered at a primary workplace but not on a full-time basis must be counted according to the corresponding diminishing proportion of time spent at this primary workplace. It is essential that the survey metadata provide a note to clarify the procedure that is followed.

In post-crisis or post-disaster situations, researchers might still hold “research positions” in various institutions without proper infrastructure, salaries or even adequate security standards to conduct research. It is proposed that in these particular situations, R&D surveys and R&D statistics are suspended until proper conditions resume. In cases where such inadequacy is confined to a province or specific region, this should be noted in the survey metadata.

Further adjustments to survey procedure are needed to account for different groups of highly-skilled personnel. Researchers in “foreign institutions” hold certain characteristics that might distinguish them from those in national institutions. “Visiting” researchers are yet another significant group that should be differentiated. Accounting for these distinct groups requires data on citizenship, residential status, country of birth as well as length of stay in the country to monitor flows and “brain circulation”.

The reverse situation occurs when researchers spend a considerable period of time working abroad while still retaining their position at home -- this includes situations where a leave of absence is taken. These cases carry a risk of double counting the person in their home and temporary foreign domicile. In theory, this issue could be resolved by referring to the domicile where they file their income tax to obtain a proper headcount and determine where research work was done. However, it is unlikely that such inquiries will be fruitful due to confidentiality and privacy issues.

The mobility of highly skilled human resources presents problems for innovation policy worldwide. Mobility includes movement across borders as well as among the regions of a given country and among its institutions. These flows play an important role. On the one hand, the circulation of researchers is a necessary and desirable part of knowledge transfer and career development. On the other, permanent brain drain is often deleterious.

The relationship between a ‘research diaspora’ and the home country is dynamic and unique to each situation. The growing internationalization of the labour market for the highly skilled has made physical movement easier and has enabled the global sharing of scientific knowledge. The full extent of such migration patterns, which can include ‘circulation’ through a number of intermediary countries (e.g. country A→B→C, and not just A→C) as well as both regional and global ‘circuits’, has yet to be established.

Developing countries have reacted to this movement in a variety of ways. A small group of countries that have seen relatively higher levels of growth – led by India and China – have started to attract back their scientists from abroad, by using very active STI policies. There are also counter examples where Indian and Chinese firms have established their own R&D laboratories abroad in hopes of employing their expatriate scientists.

Other countries have opted to organize the STI diaspora through "remote mobilisation" (Gaillard, 2008) – for example, by creating databases of expatriate scientists to mobilize, organize and reconnect their scientists abroad with the scientific community at home.

The intent is to encourage expatriate scientists to use foreign facilities and networks while creating channels through which their research output and skills can be used in their country of origin. The mixed fortunes of several STI diaspora – particularly in Latin America and Africa – remind us that however simple and enticing it may seem, members of the diaspora are not necessarily easy to engage (Gaillard and Gaillard, 2003).

Virtual collaboration is a related phenomenon that can be linked to the expansion of the internet to all countries in the world. During the last 20 years, the internationalization of science (measured in relative importance of foreign co-authorship) increased much faster in developing countries than in the rest of the world (Gaillard, 2008).[8]

By definition, GERD includes intramural R&D that occurs on home territory (FM para. 34). The internationalization of R&D whether through national scientists that are temporary migrants or the inclusion of national R&D facilities under the aegis of multinational corporations (MNCs) or public sector laboratories presents a universal challenge to this definition.

Recommendations

If accurately identifying researchers and the time they spent on research are of particular importance, this could be addressed in part through sensitive interviews by peers who understand local circumstances.

R&D survey data need to be complemented with information from other sources, such as databases of researchers or S&T management information systems (STMIS). If secondary sources are used to calculate the number of researchers, the figures should be verified by contacting the institutions in question to confirm the coverage and avoid double counting. Secondary sources of information (other than direct R&D surveys) include the following:

- Annual reports of R&D performers;

- Ethics clearance registers;

- Applications for anthropological research;

- Grant registers;

- Publication databases, both national and international;

- STMIS and other databases of researchers (including databases of expatriate researchers in the diaspora);

- Professional association registers (scientific, medical, legal, engineering, etc.);

- Clinical trials registers; agricultural field trials; trials of GMOs;

- Main foreign donor registers (i.e. those involved in funding R&D);

- University accreditation databases.

[8] The high percentage of international co-operation in developing countries' R&D presents new challenges regarding the relevance and impact of R&D. This nevertheless remains outside the scope of this document.

5. Specific fields of R&D activity

This section addresses a number of R&D fields of activity – most of which are already covered in the FM – but that deserve more attention when applied to developing countries.

5.1 Traditional knowledge

Traditional knowledge (TK) has a central role in discussions on sustainable socio-economic development and poverty alleviation in developing countries (Rahman, 2000). Its protection, promotion, complementarities and integration with scientific knowledge are key objectives for science policy in many emerging economies and developing countries. Some countries prefer the term "indigenous knowledge". [9]

TK is "a cumulative body of knowledge, know-how, practices and representations maintained and developed by peoples with extended histories of interaction with the natural environment. These sophisticated sets of understandings, interpretations and meanings are part and parcel of a cultural complex that encompasses language, naming and classification systems, resource use practices, ritual, spirituality and worldview" (ICSU and UNESCO, 2002). This knowledge frequently presents itself in a tacit form, in contrast to the explicit form of scientific knowledge (Rahman, 2000). In some cultures, TK is partially codified.

The term "traditional knowledge" is used "to differentiate the knowledge developed by a given community from the knowledge generated through universities, government research centres, and private industry (i.e. the international knowledge system, sometimes called the Western system)" (Warren, 1992 cited in Grenier, 1998).[10] For some authors, TK "can be termed science because it is generated and transformed through a systematic process of observation, experimentation, and adaptation" (Appleton et al., 1995).

According to Rahman (2000), a dichotomy between traditional and scientific knowledge systems may be made on the following grounds:

- substantive grounds – because of the differences in the subject matter and characteristics of traditional and scientific knowledge;
- methodological and epistemological grounds – because the two forms of knowledge employ different methods to investigate reality; and
- contextual grounds – because TK is more deeply rooted in its environment.

[9] "Indigenous knowledge" emphasizes attachment to a place and establishes a link with indigenous peoples. For some, however, this connection is problematic because it narrows the term's application and excludes certain populations who may not be officially recognized as 'indigenous people' by their respective governments, but who nevertheless possess sophisticated sets of knowledge about their natural environments. In contrast, terms such as "local knowledge" are easily applied to a variety of contexts, but suffer from a lack of specificity (ICSU and UNESCO, 2002). Therefore, for the purposes of this document, the term "traditional knowledge" will be used.

[10] This definition is particularly interesting because it points out that TK is not generated by any of the FM sectors of performance but by "a given community". This adds to the difficulty of measuring it in the framework of R&D surveys.

By the above definition, pure TK does not conform to the FM definition of R&D and is excluded. But when TK forms part of an R&D project, the effort (e.g. the use of finance and people) should be included.

However, “there are weak links between the formal R&D institutions and local communities that hold and use the (traditional) knowledge” (AMCOST, 2010). Different types of activities providing linkages between traditional and scientific knowledge can be identified as:

- The scientific approach to TK in disciplines such as ethno-science (ethno-botany, ethno-pedology, ethno-forestry, ethno-veterinary medicine, and ethno-ecology) or cognitive anthropology. This is “the study of traditional knowledge, in the sense of the study of people’s perceptions of their surroundings, an organized examination of thought across cultures” (International Rice Research Institute). This establishes TK as an object of scientific study.

- The application of scientific methods to TK, converting it into a source of scientific information, such as in biodiversity science or nature conservation. Examples include traditional health and pharmacopeia; agricultural, fisheries and food practices; and conservation and flavours with industrial potential (Foundation for Research, Science and Technology, 2007).

- The interaction between scientists and communities in participatory R&D using the traditional practices and TK of local populations as a starting point (ICSU and UNESCO, 2002).

Recommendations

It is important to establish boundaries for TK in terms of what qualifies as R&D according to the FM definition of R&D. The activities that establish an interface between TK and R&D are considered R&D. The storage and communication of TK in traditional ways, however, is excluded, according to the test of novelty (FM para. 144).

Some fields of activities in TK are trans-disciplinary (e.g. ethno-botany), making them difficult to map into the current Fields of Science classification scheme. Fields of activities as mentioned above may be diffuse and difficult to identify, but they should if possible be included in the R&D statistical survey.

5.2 Clinical trials

The internationalization and outsourcing of R&D, the decentralization of laboratories, activities of pharmaceutical companies, and their need to conduct clinical trials among a wide population of potential users, make clinical trials a major growth area worldwide.

The ethical procedures and results of clinical trials are of legitimate concern to trial participants, host governments and the promoters of the trials. Clinical trials (FM para. 130) in phases 1, 2 and 3 may involve a significant amount of resources relative to total R&D expenditure in developing countries. The R&D expenditure associated with clinical trials will be allocated among the applicable Fields of Science, but it may still be useful to display the efforts associated with clinical trials as a separate entity in the reporting of the R&D surveys.

In order to identify clinical trials occurring in a given country at a specific moment, R&D statisticians have access to various databases such as national registers of clinical trials.[11] One of the most comprehensive registers from the United States (http://clinicaltrials.gov/) includes a thorough guide to clinical trials by country. The World Health Organization (WHO) has established the International Clinical Trials Registry Platform (ICTRP), which aims to facilitate the registration of information on all clinical trials and public access to that information by integrating data from registers worldwide.

Funding for clinical trials in developing countries comes mostly from abroad (the headquarters of the pharmaceutical MNC) and is often thinly distributed among a number of local parties such as:

- the local subsidiary of the MNC;
- universities and university hospitals;
- government research institutes;
- individual medical practitioners and researchers;
- medical clinics;
- local PNPs;
- international PNPs.

Identifying all the research personnel involved in the extended research value chains that typify clinical trials may be difficult. The starting point could be the principal investigator who might be able to provide estimates. The occasional nature of the involvement of university researchers and medical practitioners (public and private), however, makes it difficult to determine precise headcounts and FTEs without the risk of double counting.

When no estimate of the research headcount beyond the core team is possible, the extended research value chain may be subsumed under the heading 'other current expenditure.' This results in an unavoidable underestimation of the researcher headcount.

[11] For example, the Australian New Zealand Clinical Trials Registry (ANZCTR) (http://www.anzctr.org.au/), the Chinese Clinical Trial Register (ChiCTR) (http://www.chictr.org/), Clinical Trials Registry - India (CTRI) (http://www.ctri.in/), ISRCTN.org (http://www.isrctn.org/), the Netherlands National Trial Register (NTR) (http://www.trialregister.nl/), the Sri Lanka Clinical Trials Registry (SLCTR) (http://www.slctr.lk/), all provide data to ICTRP. Other examples of registries are www.controlled-trials.com for Europe, the Latin American Ongoing Clinical Trials Register (LATINREC) http://www.latinrec.org/, and the South African National Clinical Trials Register (http://www.sanctr.gov.za/).

Recommendations

While principal investigators for a study are usually located abroad (in the sponsoring countries), local staff perform various functions, including that of researcher. As a rule of thumb, if the functions of the personnel involved are difficult to establish, the following convention should be used:

- Medical doctors and other professionals with at least ISCED 5A degrees should be considered researchers;

- Nurses and other staff with qualifications below ISCED 5A should be categorized as technicians.

It is important to calculate the FTE of the staff involved since clinical trials may be a part-time activity for doctors in their medical practice.

It is also important to carefully attribute the expenditure and FTE to the correct sectors (i.e. higher education, business, PNP) as HE researchers might be engaged in clinical trial supervision for a private company, for example.

5.3 Industrial activities: reverse engineering and incremental changes

As noted in Annex A of the Oslo Manual (OECD/Eurostat, 2005), developing countries display weak innovation systems and low R&D intensity in the business sector.

Innovation is mainly incremental and imitative. Reverse engineering, which is one such highly skilled innovation activity, can be defined as "the process of extracting the knowledge or design blueprints from anything man-made" (Eilam, 2005). The objectives of reverse engineering are usually to understand the structure and functioning of an object in order to make a new device or program. Thus, a similar object is created in a different way by copying it or improving on it.

Recommendations

If reverse engineering is carried out within the framework of an R&D project to develop a new (and different) product, it should be considered R&D. An example is reverse engineering to improve the interoperability of a new product, such as supporting undocumented file formats or undocumented hardware peripherals.

When reverse engineering is not conducted within the framework of an R&D project, it should be considered an innovation activity, other than R&D (Oslo Manual, para. 525) and not included in R&D surveys.

Minor or incremental changes are the most frequent type of innovation activity in emerging economies and developing countries (Oslo Manual, para. 499). Activities leading to minor, incremental changes or adaptations should in principle not be counted as R&D activities unless they are part of, or result from, a formal R&D project in the firm.

5.4 Social sciences and humanities research

Social sciences and humanities (SSH) research tends to be under-reported around the world. In regards to SSH, the FM (FM para. 143) applies the test of novelty: "… projects of a routine nature, in which social scientists bring established methodologies, principles and models of the social sciences to bear on a particular problem, cannot be classified as research." FM para. 144 provides examples of such excluded activities.

In addition, some countries specifically exclude R&D in SSH from their business sector surveys as well as from qualifying for tax incentives. This further downplays the perceived importance of R&D in SSH. As a result, R&D in SSH tends to be reported more in the higher education sector, government sector and PNPs. Among these, higher education tends to be the major performer.

The growing importance of the services sector and transition to the knowledge economy further strengthen the case for measuring R&D in SSH in the business sector. This situation is increasingly untenable in principle and in practice since successful technology transfer and community development depends on understanding human agency – a central aspect of R&D in SSH. In addition, development research, research on sustainable development and mitigation of climate change all rely on social innovation that often includes elements of R&D in SSH.

Recommendations

R&D surveys should measure R&D in the social sciences and humanities across all sectors.

Development research and other social change projects should be considered R&D only so long as they are in a *development and testing* phase. Projects at this stage could be categorized as applied R&D and allocated to the appropriate Field of Science, possibly but not necessarily in the Social Sciences (e.g. UNESCO, 1984).

Once the project goes to scale, it is no longer R&D. Evaluation and impact assessment may constitute R&D if it is part of the R&D project or passes the test of novelty.

In some countries, research on religion has a particular importance.[12] In principle, research on religion is a part of the humanities and institutions performing it should be included in R&D surveys.

R&D carried out by institutions associated with a particular religious affiliation should be accounted for in that sector, according to the applicable Field of Science. A decision to classify such institutions as a sub-sector remains a moot point.

[12] In the Middle East, religious research centres make significant contributions to R&D while in South and East Asia, there are Buddhist higher education institutions.

5.5 Software development and system engineering

The techno-economic paradigm that characterizes information technology has a global impact, especially in the growth of the services sector. This is particularly the case in post-industrial economies and is also true for commodity producers, emerging economies and many developing countries.

Capturing R&D in services is complex and incomplete the more so as much innovation in the services sector is driven by the social sciences and some countries do not measure R&D in the social sciences in the business sector.

R&D in information technology includes work on hardware, software development and system engineering – the latter two being widespread (Miles, 2000; Kahn and Hounwanou, 2008).

Many large financial services, retail and wholesale companies have divisions specializing in software development and system engineering. As such, the occasional R&D carried out in these divisions should be captured in R&D surveys. FM para. 133-142 and 256 provide guidance with respect to determining the R&D content of software development and system engineering.

Recommendation

Efforts should be made to extend survey coverage to the software development and system engineering R&D activities of leading firms in the financial services sector as well as the small and medium-sized enterprises (SMEs) in the R&D value chains of these firms.

6. Foreign and internationally controlled entities

National and international research institutions operate research facilities in many countries. These facilities are staffed by both local and foreign researchers and receive funding from diverse offshore and local sources. In fact, a high concentration of resources may be involved, directly impacting the uptake of R&D and R&D measurement. In small national STI systems, such facilities may dominate and distort national R&D indicators. Demarcating these as a separate sector of performance may be necessary lest the R&D statistics over-represent national characteristics.

FM para. 229 places international organizations in the "abroad" sector not as a sector of performance but as a source of funds. They are considered a source of funds when they give money to other institutions. However, if they are themselves conducting R&D activities, they might be included in a foreign institutions (FI) sector. Examples include:

- the Inter-American Institute for Cooperation on Agriculture (IICA), based in Costa Rica;
- *Institut Pasteur*;
- the Smithsonian Tropical Research Institute in Panama;
- Institut de la Recherche pour le Développement (IRD);
- Major foreign astronomical observatories, such as the European Southern Observatory in Chile;
- the International Rice Research Institute (IRRI), based in the Philippines;
- the International Potato Center (*Centro Internacional de la Papa* or CIP) based in Peru;
- the International Institute of Tropical Agriculture (IITA), based in Nigeria;
- the Consultative Group on International Agricultural Research (CGIAR)-supported research centres;
- International bilateral laboratories – or *Laboratoires Internationaux Associés* (LIA) in French – such as the ROCADE laboratory of the *Centre National de la Recherche Scientifique* (CNRS) in Hong Kong or the *Institut Franco-Uruguayen de Mathématiques* (LIA IFUM) in Uruguay.

Research labs set up abroad by MNCs may primarily cater to the R&D needs of the parent company with decision-making taking place outside the host country. The local innovation system may have very little involvement beyond the provision of highly qualified R&D personnel. These circumstances make it important for countries to distinguish such MNC-owned institutions within the business sector (FM para. 181).

Multilateral organizations may also play a significant role in R&D in a given country by involving local staff and addressing local issues. These organizations might also have a significant impact on the total GERD and should therefore be accounted for in the statistics.

The classification of such organizations as sources of funds is dealt with in FM Section 3.8. They are grouped into Government, Business Enterprise, Higher Education, Private

Non-Profit, and International Organisations. Following the System of National Accounts' (SNA) recommendation, the statistical unit for this sector is the legal entity. In some circumstances, a smaller statistical unit may be appropriate as in the case of "foreign company R&D labs". The criterion for classification is the sector to which the institution would be assigned in their country of origin. In cases where there is no specific country of origin, the institution would be classified as an International Organisation.

The globalization of higher education services is leading many universities from industrialized countries to operate campuses abroad. The precise relationship between these foreign universities and the host system will vary from country to country. Despite any dissimilarities between these foreign universities, every effort should be made to capture their R&D efforts and contribution to the local production of doctoral students. Since they operate on national territory with the agreement of the local education authorities, this effort should form part of higher education expenditure on R&D (HERD) and GERD. Examples of these entities include the:

Dubai International Academic City (DIAC), which hosts several foreign universities, including Michigan State University in Dubai, Middlesex University, Saint-Petersburg State University of Engineering and Economics, the University of Exeter, the University of Wollongong in Dubai and the University of Phoenix; University of Bologna campus in Buenos Aires; and Monash University in South Africa.

In light of this globalization, the conditions for R&D activities and the governance of research demonstrate volatility. R&D projects may be managed in a centralized way from headquarters, with researchers moving into the countries for short-term assignments, thereby making it difficult to account for R&D expenditure. The impact of this process on the orientation and scale of national R&D requires further investigation in order to develop adequate methodologies for its measurement.

These various patterns of foreign involvement in a country may mean that considerable R&D activity (i.e. decisions on expenditure and personnel) is beyond the control and influence of national R&D policy or even the strategic R&D decisions of companies in the country. How then can a country reach national spending targets if the underlying expenditure is basically immune to policy decisions at the national level? This poses important challenges to STI policy-makers and R&D statisticians in developing countries.

Solutions for these issues are compatible with the current guidance provided in the FM but require more detailed data collection and analysis in developing countries to ensure that the characteristics of R&D are captured and consistent policy-relevant statistical indicators produced. Some of these recommendations are equally valid for OECD countries and could be taken into consideration in a future revision of the FM.

Recommendations

Given their importance in developing countries, it may be useful to create a foreign institutions (FIs) sub-sector within each major sector of performance.

In countries where FIs are deemed important and they have a significant impact on R&D statistics, they could be treated as a distinct sector that is on par with other sectors of performance. If a country decides to establish a separate FI sector, it is recommended that this sector encompasses foreign government institutes, foreign PNP institutes and international organizations. Foreign companies should remain in the business sector while foreign higher education institutes should remain in the HE sector.

Countries might initially choose to include the institutions belonging to the FI sector in one of the existing sectors, particularly the PNP sector. Countries may also chose to specify the gross national expenditure on R&D" (GNERD) as well as GERD.

Funding from the FI sector used to finance other sectors should be labelled as funds from "abroad", according to FM Section 3.8.

In the business sector, the FI sub-sector follows the FM para. 181 descriptor that "foreign entails more than 50% ownership and voting power, either directly or indirectly through subsidiaries."

Where foreign control and funded R&D is extensive, a specific questionnaire for the FI sector could be designed to address the particular characteristics of these institutions. This questionnaire should cover the demographic characteristics of researchers (particularly, nationality, country of birth and other parameters related to the internationalization of R&D) as well as the linkages between these institutions and the national innovation system.

7. Strengthening R&D statistical systems

The Annex to the Oslo Manual, "Innovation Surveys in Developing Countries" (OECD/Eurostat, 2005: para. 527), notes that there are relative weaknesses in their statistical systems. In particular, business registers may be incomplete or absent – a problem that is not unique to developing countries. These limitations are equally applicable to the process of setting up R&D statistical systems – or, more broadly, STI statistical systems – designing data collection procedures and producing analytical outputs based on the resulting data.

7.1 Institutionalizing R&D statistics

Establishing a sound and sustainable R&D statistical system requires dedicated political support as well as a predictable budget, infrastructure, a stable staff complement and provision for continuous training. Ideally, the responsibility for the surveys should remain vested with a dedicated agency for periods in excess of five years so that methodological stability may be attained. Migration of responsibility for the survey carries the risk of inconsistency.

Naturally, the existence of a survey champion would be an asset. The integrity and credibility of the survey may be built and protected through the establishment of a representative committee to oversee the process. The national survey champion for STI and R&D must be empowered to make the case for science policy based on the readily available data.

Irrespective of where responsibility for the survey is vested, the necessary legal framework to ensure survey participation and the confidentiality of data must be enacted.

Another potential problem to look out for is high staff turnover, which weakens institutions and reduces the quality of data. Sustained training and capacity building based on a fully documented training programme will assist in minimizing the affect of staff turnover on data quality. Codification of survey procedures, routines and the way in which exceptions are dealt with is an important part of organizational learning and knowledge management, and is pivotal to the handover of responsibility from exiting staff to newcomers. It is also important to strive for consistency in the training approach.

7.2 Establishing registers

It is important to set the scope of the survey at the outset. A register of government departments, research institutes and statutory bodies serves to identify the possible R&D performers in the government sector, while a list of accredited higher education institutions will suffice for the higher education sector. In principle, a census should be conducted to reveal the R&D performed in these two largely public sectors. The register could be designed with R&D statistical reporting in mind. Using FM definitions from the start will create more cross-comparability of data.

In the early stages of conducting R&D surveys, there will necessarily be trade-offs among factors such as cost, coverage and accuracy. The identification of large R&D performers and successfully capturing their R&D characteristics represent 'quick wins' for the survey. Identifying the possibly more numerous but smaller performers and collecting their data almost always follows the law of diminishing returns.

Surveying the business and PNP sectors presents different problems since business registers tend to be unavailable and will not generally reveal where R&D is being conducted. Where business registers are found, care should be taken as they tend to be insensitive to volatile sectors such as small enterprises and the PNP sector, hindering the construction of the framework and the estimation of missing data.

A good starting point is to approach the largest firms, both MNC and local and to meet with the Chief Financial Officer or Chief Technology Officer, as available. Such an approach would be informed by industrial structure and the concentration of firms. It should be noted that insight into the location of main value adding activities will be important. Missing a large firm when identifying R&D performers might result in significant error.

In many countries, interviews confirm that R&D activity is concentrated in large firms, but – as in the case of identifying researchers – “detective work” is needed (Kahn et al., 2008). Survey staff should invest time in interviewing key firms to understand their R&D function and obtain a clear picture of their activity. The R&D survey is thus a labour intensive exercise. Close cooperation between the survey and government departments responsible for R&D tax incentives, import facilitation, export promotion and price controls may also assist in identifying other R&D performers.

Chambers of Commerce and trade associations may be another useful source of information. Depending on the relationship between government funding agencies, higher education and business, it might be possible to identify R&D performers from the databases of grant makers. Other sources of information could be academic and learned societies; STI services institutions; registers or databases of scientists and engineers; and databases of scientific publications, patents and other intellectual property documents.

The identification of a core group of knowledgeable respondents will yield valuable information over time. In this way, the register of likely R&D performers may be built up to form the basis for a purposive survey. This register will expand over time as gaps are filled. One might expect that saturation will be attained after three survey rounds.

In some domains, a science and technology management information system (STMIS) may exist and thus provide an overview of the research system and a framework for establishing registers as sample frames for R&D surveys.

Identifying the R&D performers among the many PNPs presents similar problems to that in the business sector. Once again ‘size matters’ and a careful purposive survey must suffice. It might even be that public sector R&D completely overshadows that of the business sector. In this case, it would perhaps be appropriate for a first survey to concentrate on the former.

7.3 Classification issues

As described above, the globalization of production and the R&D function creates structural imbalances within national systems of innovation. For this reason, it might assist the evidence base for policy if the R&D expenditure of foreign-controlled entities is captured as a distinct sub-sector.

State-owned enterprises (SOEs), both for profit and not-for-profit play a major role in R&D in some industrialized countries and many emerging economies and developing countries. The precise relationship of SOEs with government is complex, their shareholding may be opaque and their reporting standards vary from country to country.

All these factors make sectoral location and comparability difficult. Where SOEs form an identifiable group, they might be reported as a sub-sector of the business sector.

In some developing countries, large public enterprises in different sectors that intensively develop research activities dominate R&D expenditure. In some cases, these enterprises may create "independent" R&D institutes where research efforts are undertaken in an autonomous way with significant R&D budgets. They have their own financial resources, receive funding directly from supporting agencies and may enter into their own contractual arrangements. This sub-sector includes state utilities both at the national and secondary level that are registered as enterprises. They are 'corporatized' with a single shareholder and also operate independent research centres or R&D departments as cost centres that may receive funding agency support.

FM para. 165 uses the test of "production for the market" to decide in which sector to classify R&D performers. Application of this test suggests that the R&D investments of public firms must be classified as "enterprises in the R&D sector" though some confusion or distortion can occur in relation to the public sector. In some developing countries, entities bearing the juridical status of "enterprises" act as typical governmental research institutions. For example, EMBRAPA (*Empresa Brasileira de Pesquisa Agropecuária* or the Brazilian Agricultural Research Corporation) is classified as a federal research institute in national data sources and official statistics, and is consequently included in governmental R&D expenditures.

In some countries[13], the national research council may have centres that might be stand-alone, joint with a university, or joint with other government institutions, which makes it difficult to assign them to the proper sector of performance.

Institutions in the PNP sector may make a significant contribution to R&D, such as new initiatives in agricultural R&D or in infectious and insect-borne diseases. As another example, producer organizations play an important role in conducting research on tea (Kenya, Malawi, Tanzania), coffee (Colombia, Kenya, Tanzania, Uganda), sugar (Colombia, Mauritius, South Africa) and other crops. Thus, large-scale phase 2 and 3 clinical trials conducted through PNPs that may start and end within the space of one to two years makes R&D expenditure in the PNP sector very volatile and difficult to capture.

Given the strong linkages between PNPs and government, it is not always clear in which sector a particular PNP might best be classified. This problem is recognized in the FM note stating that "sector definition cannot be precise" (FM para. 160) and that the appropriate sector location should be determined by "who is being served" (FM para. 167-8).

7.4 Demonstrating value and building support

A first survey based on a short questionnaire may present a 'quick win' for the national survey champion, the intended user of the survey results as well as the team involved. The survey instrument must carefully balance the need for comprehensive information against the cost of the survey. Producing a valid survey in a short space of time presents a challenge but also an opportunity to mobilize interest and support.

[13] CONICET (*Consejo Nacional de Investigaciones Científicas y Técnicas)* in Argentina is a case in point.

Survey coverage and the response rate are important to data quality and survey integrity. In order to improve the support of respondents, close communication should be maintained with them throughout the survey cycle and especially in the follow-up when the results are disseminated. Consideration could be given to setting up a forum that brings together data users and other stakeholders. Identifying and maintaining contact with knowledgeable respondents within the major R&D performers is useful as they are well positioned to assist in identifying other – perhaps smaller – R&D performers, essentially acting as a mirror group.

In some countries, universities are autonomous and might be reluctant to provide information to the government. Accordingly, the support of university leadership must be obtained as a precursor to the survey fieldwork.

The above considerations thus demand hands-on fieldwork in addition to the use of postal or electronic survey methods. Partnering with business associations or conducting face-to-face visits with leaders may increase the probabilities of a successful survey, both in terms of response rates and data quality.

If possible, the protection of data confidentiality should be settled before launching a first survey. When the survey takes place under the aegis of a national statistics office (NSO), this principle is usually in place but if an independent agency carries out the survey, the approval and support of the NSO is essential.

Thorough training of interviewers is required so that they understand, and can explain to non-specialists, the technical definitions and concepts involved in R&D, innovation and other science statistics. This will increase response rates and the quality of the data received.

Subsequent surveys will include more detailed questions to inform the science policy planning process. These might cover matters such as the FTE by field of science, data on migration and data on R&D collaboration.

Ultimately, the value of creating and maintaining a survey time series lies in its use as the evidence base for formulating and monitoring science policy. One-off surveys have some value but a series is necessary to identify trends.

Communicating the results of the survey to government and other stakeholders should be given high priority.

Countries might also institute a separate survey module to collect data on barriers to R&D, such as lack of resources, out-of-date equipment or lack of internet access. This would provide more information on the problems faced by researchers and, while not addressing the accuracy of data on time spent on research, would allow policy-makers to address the barriers that prevent researchers from focussing on their work.

7.5 Survey procedures and estimation

Questionnaire design deserves particular attention as well as the frequency of surveys. The use of other countries' survey questionnaires may be a good starting point but beyond the most basic items, questionnaires need to be adapted to local situations, both in terms of specific language issues as well as the circumstances in which surveys take place (e.g. structure of institutions, roles of respondents, etc.).

In general, the expertise of the NSO can be a key resource in this process though it should be recognized that the R&D survey is labour intensive and may require graduate field staff to maintain accuracy. Such resources may not be readily available in the NSO.

Depending on the resources available and complexity of the different sectors, unique questionnaires might be designed for each sector. Once the first designs are approved, the questionnaires should be piloted as the first step towards larger dissemination.

While the use of combined R&D and innovation surveys (or other surveys, such as industrial or labour surveys) to obtain business enterprise R&D data could be cost effective, the low occurrence of R&D in businesses needs to be taken into account. The standard approach for conducting innovation surveys involves stratified random sampling from a representative business register. In general, R&D tends to be concentrated in large firms so that the coverage of this stratum may have to be close to a census lest important R&D performers are excluded.

An essential aspect of survey procedure is to ensure full documentation of the life history of each survey return through detailed annotation. These records might be in paper or electronic form and should include notes on queries, their resolution, the date of the incident, reasons for interpolation or extrapolation of data, and the methods of imputation. Proper document management lays the basis for a smooth handover to new staff as they are inducted into the survey methodology.

Once a valid and reliable first survey has been conducted, it becomes feasible to use this data set to inform the imputation and extrapolation of data items in subsequent surveys.

Appropriate procedures need to be developed for estimating missing data, particularly in the first few survey rounds when no previous information is available and data quality can still be low or difficult to assess.

8. Thinking ahead

The measurement of R&D and construction of associated indicators is dynamic, the more so in the rapidly growing emerging economies and developing countries. The 2006 OECD "Blue Sky II" conference on Science, Technology and Innovation (STI) indicators (OECD, 2006) convened to examine the need for new STI indicators going forward.

Considerable work on R&D indicator measurement is taking place in Latin America (*Red de Indicadores de Ciencia y Tecnología Iberoamericana e Interamericana* or RICYT) and in Africa (S&T Secretariat of the African Union - New Partnership for Africa's Development or AU-NEPAD). In fact, there is scope to set up or even revitalize similar regional bodies in Eastern Europe and Asia.

This Paper is thus a work in progress and the ideas and principles laid out here need to be broadly tested. It has drawn on the experience of R&D survey practitioners and users from a host of industrialized countries, emerging economies and developing countries. The Paper will inform future revisions of the Annex to the FM. At the same time, some of the issues raised are of universal relevance and may influence the main body of the FM in future revisions.

The heterogeneous nature of country R&D systems points to the need for further data and information beyond the FM definition of R&D to augment STI statistics with data on related S&T activities (STAs). STAs are currently excluded from R&D (FM Section 2.2.2). Many countries in Latin America compile data on related STAs and R&D (RICYT, 2010) – as does Canada, for example. There is therefore a need to develop and standardize more policy-relevant indicators on STAs alongside the R&D indicators. China collects data on the activities leading to commercialization under the heading "non-R&D result application." Likewise, the FM (FM para. 79-80) suggests that these activities are to be excluded from R&D.

STAs include scientific and technological services (STS) and scientific and technological education and training (STET). Two decades ago, UNESCO attempted to standardize the attributes of STS and STET (UNESCO, 1978) but problems with the definitions remain, especially regarding the STET tertiary level and classification of scientific and technical personnel.

In some countries, higher education statistics could be a source of data for the R&D survey thereby reducing respondent fatigue. However, care should be taken to ensure definitional consistency: "academic staff" is not the same as "researcher". The subject field classifications of national higher education statistics may also differ from the international fields of science.

As mentioned in Section 4, the substantive contribution of diaspora R&D networks to countries of origin, both in terms of R&D activity and their broader impact on economic development is moot. Addressing these issues will require new methodological approaches and might bear consequences for FM-type methodologies.

A strong case could be made that all countries want to construct a database of their PhD graduates that includes basic demographic data on gender as well as the most recent known place of employment and e-mail addresses.[14] Such databases potentially allow for the tracking of the ebbs and flows of the national stock of high-level human resources.

[14] The Careers of Doctorate Holders (CDH) Project is an example of a methodological approach that could supply this data, although it only provides a partial solution.

The sharing of expertise to conduct R&D and associated surveys might be well served through the development of a UIS interactive website with “wiki” features.

There is also a perceived need in developing countries for more hands-on guidance on how to set up and carry out an R&D survey. Such guidance could be developed by the UIS in cooperation with other relevant agencies and could include topics such as questionnaire design, pilot testing, survey procedures, imputation methods and non-response analysis. In addition, a model questionnaire could be developed that would include a module on barriers such as those alluded to earlier in this document.

While this Paper has adhered to the FM definition of R&D, it is clear that the nature of innovation is in a rapid state of flux. These changes may in turn lead to adjustments of the definition and scope of what counts as R&D.

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Research and experimental development (R&D) plays an important role in innovation, which, in recent years, has taken centre stage as one of the main drivers of economic growth and poverty alleviation. Policy-makers, in turn, can help spread the benefits of innovation through policies that encourage growth in the areas of science, technology and innovation.

To inform effective innovation policies, up-to-date, internationally comparable science, technology and innovation (STI) indicators are needed. Of the full set of STI indicators, R&D statistics form an important subset. To produce R&D statistics, the methodology proposed by the Organisation for Economic Co-operation and Development (OECD) in the *Frascati Manual* (FM) is used extensively in developing countries – despite the fact that it was originally written for R&D surveys in OECD countries.

However, the characteristics of research systems in developing countries differ significantly from the ones that gave rise to the current statistical standard. This Technical Paper, which will serve as the basis for an Annex to the FM, aims to provide guidance to developing countries on how to adapt the standards proposed in the FM to suit their own unique situations when measuring R&D. It provides suggestions on how the concepts in the FM should be interpreted to ensure that data better reflect the particular characteristics of R&D activity in developing countries while still maintaining international comparability. In addition, this guide also provides recommendations for specific situations that fall outside the framework of the FM and offers suggestions on how to strengthen STI statistical systems in developing countries as well.

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