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Science, technology and innovation indicators for policymaking in developing countries: an overview of experiences and lessons learned[1]

Note prepared by the UNCTAD secretariat

Executive summary

Measuring science, technology and innovation (STI) is fundamental for the formulation of national innovation strategies. The absence of relevant indicators is often a mayor obstacle for the design and implementation of STI policies in developing countries.

This paper analyses current work undertaken at the global and regional level regarding the definition, collection and use of STI indicators and shows the heterogeneous capacity that developing countries have to measure STI.

Some of the key issues to be considered to enhance the contribution that STI indicators can make to the design of national development strategies include the following:

(a) Developing a systemic approach to measure STI based on a better understanding of national innovation systems;

(b) Developing STI indicators at the international, regional, national and subnational level to fulfil the need for internationally comparable and nationally relevant indicators;

(c) Improving the measurement of linkages within the STI system and with development goals;

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[1] This paper has been prepared by by Gustavo Lugones and Diana Suarez (Universidad National de Quilmes/Centro REDES/ RICyT). It was commissioned by the Division of Technology and Logistics of UNCTAD to support the discussions of its Ad Hoc Expert Group Meeting on Science, Technology and Innovation Indicators, 19 January 2010. The opinions expressed in this paper do not necessarily represent the views of the UNCTAD secretariat or its member States.

(d) Developing and collecting innovation indicators that go beyond accounting innovation outputs;

(e) Understanding better the relationship between international trade and STI;

(f) Supporting the statistical catch-up of countries with limited STI statistical capacity; and

(g) Fostering dialogue between developing countries.

The core set of STI indicators presented in this note could help developing countries identify priorities in efforts to build up their basic STI statistical capabilities, foster the comparability of STI indicators and enhance their understanding of national innovation systems. The proposed set of STI indicators builds upon, and complements, current regional and international initiatives. It also takes into account the current and potential availability of STI data, the need for a systemic approach to measure STI and the trade-offs between international comparable and nationally relevant indicators.

Two key areas for action that build upon and complement ongoing efforts are proposed: (a) enlarging the collection of STI indicators by moving beyond collecting only traditional research and development (R&D) indicators, by assessing the governmental impact on the NSI and by further exploiting existing trade and patent databases; and (b) developing a strategy to create common innovation indicators.

Contents

Introduction

1. Measuring science, technology and innovation is fundamental for the formulation of national innovation strategies. The absence of relevant indicators is often a mayor obstacle for the design and implementation of science, technology and innovation (STI) policies in developing countries.

2. This paper provides an overview of the status of measuring STI in developing countries, with an emphasis on the definition, creation and use of indicators, an account of worldwide and regional initiatives for their collection, and the main limitations and potential uses of existing information.

3. Current sets of STI indicators consist of five accepted dimensions: research and development (R&D), human resources, patents, innovation and technology balance of payments (TBP). These dimensions have been exhaustively discussed and analysed by expert committees and the Frascati, Oslo, Canberra, Technological Balance of Payment and Patents Manuals published by the OECD provide the methodological guidelines for their collection and interpretation.

4. Despite the widespread acceptance of the aforementioned manuals, the availability of indicators varies among countries and regions. While several regional and international organizations have moved towards the creation of databases, there are still several obstacles to overcome before a worldwide STI indicator set can be said to exist. Moreover, although the methodological recommendations of the manuals are widely followed, their different practical implementation (e.g. the questionnaires differ among countries) -obeying to national pertinence objectives- has led to comparability mismatches among indicators.

5. In this context, moving towards a set of indicators capable of contributing to the design of a consistent STI policy that supports development strategies will demand two different yet complementary kinds of efforts. Some countries should concentrate their efforts on building basic STI statistical capabilities, other countries with longer experience in the collection and analysis of STI data will have to find ways to conciliate the local use of the information with the need for international comparability.

6. The remainder of this document is structured as follows. Section 1 presents an overview of the current work on the definition of STI indicators and proposes a conceptual framework to reconcile the issues of international comparability with regional and national relevance. Section 2 discuses the strengths and weaknesses of different types of STI indicators and presents a core list of STI indicators aimed at characterizing the National Innovation System. This proposal builds upon and complements ongoing regional and international initiatives. In section 3, data availability at the international and regional level is analysed in order to assess the possibility of constructing the core list of STI indicators. Section 4 evaluates the main obstacles and limitations to using STI indicators for public policy. Finally, Section 5, outlines some key issues to be considered in order to improve the definition and collection of STI indicators and suggests a number of priority areas to collaborate and conduct research.

I. Overview of current work on the definition of STI indicators

A. Methodological background

7. In recent decades, the measurement of the production and application of new knowledge has become one of the most repeated demands from both public and private domains. The academic discussions responding to this demand have lead to the emergence

of a body of recommendations, methodologies and analysis that, with different degrees of diffusion (and application), shape the science, technology and innovation (STI) indicators available nowadays.

8. The collection of manuals published by the Organization for Economic Cooperation and Development (OECD) together with the contributions from other recognized international organizations (such as Eurostat, UNESCO or RICyT) should be acknowledged as the originators of the different methodologies. Interestingly, almost simultaneously to the rise in demand, the successive publication of specific manuals about different areas related to STI has shaped the set of subjects (and indicators) that accounts for the STI state-of-the-art at both the national and international levels.

9. In a stylized way, the resulting set of STI indicators cover by five dimensions: research and development (R&D), human resources, patents, innovation and technology balance of payments (TBP). Each dimension includes input and output indicators that, when analyzed jointly, provide a more or less complex image of the dynamics of the national, regional or local innovation system.

10. “Traditional” R&D indicators have their methodological basis on the Frascati Manual (OECD, 2002), first published in 1993 under the title “Proposed Standard Practice for Surveys of Research and Development. Frascati Manual”. Nowadays, the manual is in its sixth revision (published in 2002) and constitutes an *“effort to strengthen various methodological recommendations and guidelines, in particular for improving R&D statistics in the services sector and collecting more detailed data on human resources for R&D”*.

11. In an extremely synthetic way, the Frascati Manual goes beyond a simple list of which activities should be considered R&D (and which should not) to define also the unit under study, how data should be collected and the identification of the target universe. The proposed methodological approach divides R&D measurement regarding its institutional classification (the place where this activity is carried out and how it is financed) and the functional distribution (type of R&D performed).

12. The institutional classification characterizes the effort involved (monetary and human resources), the origin of the funds and the performing sector. With different degrees of disaggregation, these indicators capture the dynamics of R&D in different sectors (business enterprises, government, higher education, etc.), how R&D is financed (public or private sources) and the institutional belonging of the projects (manufacturing and services sector, science and technology (S&T) system and universities).

13. The functional classification distinguishes R&D indicators by type of activity (basic research, applied research and experimental development), by scientific field (natural, biological, medical, social, etc. sciences) and by socio-economic objective (defence, environment, human health, etc.).

14. The coverage of the Frascati Manual has been extended from R&D measurement to the measurement of other domains of S&T. For instance, human resources indicators are now covered by Frascati Manual and have been fully developed in the Canberra Manual.

15. The Canberra Manual (OECD, 1995), in contrast to the Frascati Manual, has not been revised (probably because of the predominant and inclusive role of the latter). The objective of the Canberra Manual is *“to provide guidelines for the measurement of Human Resources devoted to Science and Technology (HRST) and the analysis of such data”*. Following a similar logic than the Frascati Manual, it defines the study subject (what must be considered HRST), the statistical unit (people), how they must be approached, the stock and flow variables and the different institutional, regional and scientific fields classifications. Thus, there are indicators related to S&T and R&D personnel, which are

disaggregated as well in a similar way as R&D effort and output indicators (public or private sector, productive sectors, scientific field, etc.).

16. The Oslo Manual (OECD, 2005) constitutes the equivalent of the Frascati Manual for the measuring of innovative processes, particularly in the private sector. This manual, published for the first time in 1992 and available in its third revision in 2005, aims *"to provide guidelines for the collection and interpretation of data on innovation"*. In the same way as the other two manuals, it provides methodological recommendations related to the study unit, the frequency of the exercises, the institutional classifications and the key definitions (what innovation is or not). Based on its suggestions, and with different comparability levels, countries have developed innovation surveys to understand innovative efforts, innovative outputs, the role of human resources, the obstacles that hamper innovation, the sources of information and finance as well as the linkages with other actors.

17. The 2005 edition of the Oslo Manual brought two main novelties. First, it considered organizational innovations at the same level as other technological innovations (product of processes innovations). Secondly, it included an annex on the needs and use of STI indicators by developing counties. The diffusion of innovation surveys in developing countries –particularly in Latin America- had made evident the incompatibilities and shortcomings of using the Oslo Manual to characterize the innovative processes taking place in developing countries. Previously, the specificities of developing countries had led to the publication in 2001 of the Bogotá Manual by the Ibero-American Network on Science and Technology Indicators (RICyT; 2001). The Bogotá manual adapted the methodologies presented in the Oslo Manual to better measure the innovative processes of firms in developing countries.

18. Subsequent discussions at RICyT's workshops, latter revisions of the Manual and its diffusion among other developing countries – especially in the African continent- set the basis for the Annex of the Oslo Manual. As highlighted in the Oslo Manual, the importance and impact of the standard-setting work of the Bogotá Manual inspired the production of the Oslo Annex.

19. The Oslo and Bogotá Manual have inspired different indicators. Since neither one of these two manuals propose a questionnaire, their application has became contingent to the interpretation done in each country. Although based in the same manual, national innovation surveys can differ significantly and so the indicators derived from them[2]. Sections 2 and 3 will discuss further the application of the Manuals and the comparability of STI indicators.

20. Patent and Technology Balance of Payments indicators have also their own definitions and methodological recommendations in their respective manuals. The Patent Manual, published in 1994 (OECD, 2009) and currently in its second revision, aims *"to provide basic information about patent data used in the measurement of science and technology (S&T), the construction of indicators of technological activity, as well as guidelines for the compilation and interpretation of patent indicators"*. The Patent Manual constitutes a synthesis of the fundamentals of patent analysis (as inventive activity outputs) and provides a set of recommendations for the compilation and interpretation of patent indicators.

21. The Technology Balance of Payment (TBP) Manual was published in 1990 (OECD) with the objective of "*serve(ing) as a standard method for surveys and data collection for trade in disembodied technology between countries which continuous to be difficult to*

[2] For a more detailed analysis of the Oslo and Bogotá Manuals see: Lugones and Peirano (2006); Lugones et al. (2006); Anlló, Suárez and De Angelis (2009).

compare because of differences in the grouping of categories of data". Despite the absence of revisions, the Manual has set the ground for the classifications and considerations currently used to measure the international transfer of technology. The TBP Manual presents indicators that account for the incomes and expenses related to the exchange of technology. These indicators permit the measurement of pure international technology trade, the exchange of technological packages and more complex technology transactions[3].

22. To sum up, the development of methodologies to measure the processes of knowledge production and application has a long trajectory. The diffusion of the existent methodological background and the fact that it satisfies, to different extent, the demand for STI indicators demands has set a relatively comparable information system at the international level. However, and as it will be commented in the following section, difficulties in the effective construction of STI indicators and comparison persist, especially when the "traditional" STI indicators are applied in developing countries.

B. The manuals and the needs of developing countries

23. Even if we assume that the questions of *what* and *how* to measure in STI have been answered by the set of indicators described in the previous section (R&D, human resources, patents, innovation and TBP), we still have to ask *why* do we want to measure these phenomena in developing countries.

24. Developing countries are often characterized by a less diversified productive structure, where natural-resource-based goods and activities are dominant and, consequently, the export pattern is biased towards low and medium-low technological intensity goods. This, in turn, leads to lower levels of per capita income, combined with a more regressive distribution of income and inequality problems -poverty, unemployment and social exclusion.[4]

25. In this context, science, technology and innovation are tools that can contribute to move to a path of sustained development. Hence, indicators are expected to provide information that would allow successfully translating the activities and outputs of STI into development. In other words, indicators should be considered as inputs for the design and implementation of public policies. Their use as tools for monitoring and evaluation should be secondary. The international comparability of these indicators should focus on the appropriation of foreign learning curves rather than on the analysis of relative national positions and the assessment of successes and failures of other policies in countries with different development levels.

26. The lack of a fully developed and well-performing statistical system leads to the design and implementation of policies that simply try to emulate the results achieved in developed countries (i.e. to reach similar levels of R&D investment) without paying much attention to the special features present in each region. This can negatively affect the efficacy and efficiency of the policies, hampering future adjustments and re-designs. An illustrative example is the way in which public policies have tried to increase the rate of qualified personnel. The low rates of PhD-level human resources in developing countries have been tackled with policies based on PhD scholarships. Since neither the S&T system

[3] Sometimes, the border between the product, the service and the technology is almost impossible to trace (or identify) so indicators get under or over estimated. For further development of the limitations of TBP see Bianco and Porta (2006).

[4] See, for instance: Reinert (1996); Katz (2000); Edquist (2001); Lugones and Suárez (2006); Porta et al. (2007).

nor the private sector can absorb all these qualified personnel (because their demand is low), new postgraduates do not find a proper place to work. This policy, implemented in complete isolation and lack of consultation, results into *brain drain*, the overpopulation of existing institutions (reducing the budget per researcher) and/or the over-qualification of employees.

27. Secondly, in the context of developing countries we should mention the need and importance of producing statistical information at the sub-national level. The efforts of statistical offices have been concentrated on the measurement of traditional indicators (R&D, human resources and innovation) setting in a second level the regional (inside each country) dimension. With some exceptions, policymakers, particularly from larger but also middle countries, face serious difficulties to obtain information to nourish their local policy decisions.

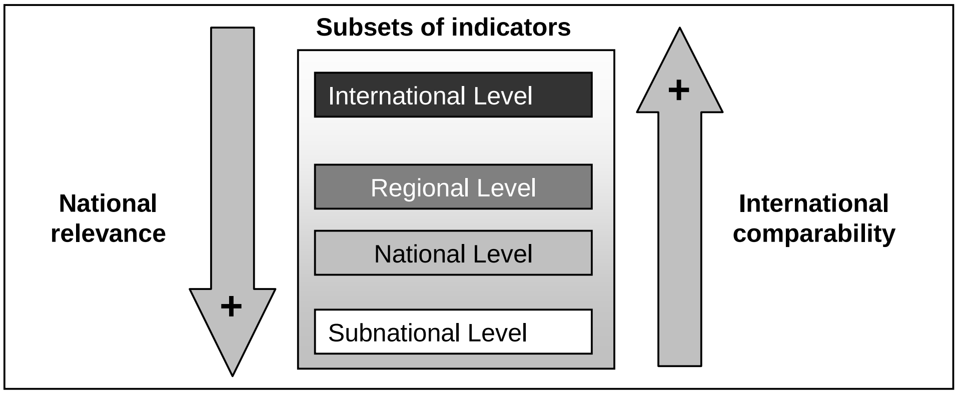
28. Thirdly, efforts have concentrated on the production of basic indicators and have not focused on the production of statistical information that accounts for the reality of key sectors in developing economies (such as the public sector, agriculture, informal sector, public health, etc). While it would be desirable to understand how STI can contribute to the development of these key sectors, many countries still lack the basic and traditional indicators. They hardly know the size of the S&T system, the amount of investments in knowledge creation, the availability of qualified human personnel and the characteristics of the knowledge supply and demand. Moreover, many of these indicators are still under intense discussion in statistical and academic agencies in developed countries. Even among those countries with a wider basis of information, the existing indicators can help in the design and implementation of those policies at the centre of the public agenda, namely fostering and supporting S&T institutions (to create knowledge), universities (to train human resources) and firms (to productively use that knowledge and employ that personnel).

29. Fourthly, the heterogeneity amongst (and within) developing countries has also to be considered in the use and development of relevant STI indicators. For example, in the case of agriculture, while in Argentina agricultural problems are related to the need of moving forward to higher hierarchy positions in the global value chains, in China the problems are related to the necessity of moving towards the convergence among rural zones (mainly subsistence economies) and urban areas. In the first case, indicators have to be able to characterize the knowledge content of activities within the same value chain; in the latter, they should allow to monitor the internal technological divide.

30. A fifth matter is related to the expected international comparability of indicators. Manufacturing firms placed in Senegal, El Salvador or Nepal can hardly found their benchmarking in the German or Canadian manufacturing structure. The same applies to other sectors: the Mexican government can possibly found more interesting and replicable achievements in the dynamic of the Brazilian government (and vice versa) than in the dynamics of the Swiss or Austrian ones. For this reason, the establishment of a set of indicators comparable at a regional level seems a more pertinent strategy. The measurement of STI should allow the description of environments with problems that are common among countries. Indicators should be able to account for the special features of STI in a particular country. Although international comparability is an essential requisite for statistical systems, national relevance must be the fundamental factor in the design of STI indicators. STI indicator must be able to describe the causes, impact levels and interaction spaces. For the decision-making in the public area, one or two points of GDP in Science and Technology say little about the needs in STI, about how to improve this ratio (or even if that should be the objective of the policy) or the impact it might have on the rest of society. In other words, STI indicators should be able to capture processes not just goals.

31. Taking the aforementioned points, it is clear that developing countries require a set of indicators that combine the best practices of developed countries with their specific features. Figure 1 presents such set of statistical information based on the combination of four different levels of analysis: a national/ subnational set of indicators, allowing national comparability, a set of regionally comparable indicators (to learn from the successes and failures of similar countries) and a set of internationally comparable indicators (which mark the international technological border). The different levels of comparability would allow countries to think in terms of national demands and international requirements. The international subset of indicators should consist of a minimum set of indicators; otherwise, its extension would undermine the real possibility of its implementation. The regional and national sub-sets of indicators would rest on more specific principles of relevance, providing a set of indicators that combine the needs of local policies with the importance of monitoring and establishing relative positions at the world level.

Figure 1. The structure of STI information system



C. An internationally comparable set of STI indicators

32. Following the previous discussion, it is necessary to characterize the type of indicators that should be placed at the international level. First, it should be clear that these should be a set of indicators and not a single composite indicator.

33. A composite indicator, that is, an indicator that aggregates multiple indicators (weighted or not), synthesizes the situation of each country in terms of its science, technology and innovation reality and can help understand the gap dynamics between developed and developing countries. The design of a composite indicator must have in mind the individual indicators used for its construction and the structure of weights behind it. These may include an analysis of the importance attached to each indicator or of the variables that should be incorporated, including those variables that can be influencing the system dynamics but are not STI indicators in a strict sense.

34. When the same weights are used for all countries, the aggregation of indicators implies that a similar treatment to an array of variables that can operate differently in each country is being given. For example, the role of foreign direct investment the dynamics of the productive structure or the manner in which STI projects are financed and performed is different in Central America than the southern Latin American countries. As a consequence, the obtained indicator and the emergent ranking can hide the key issues of each country. If different weights are applied taking into account individual aggregations (by country, region or continent) then the degree of knowledge required for its construction would demand individual analysis of the index. In other words, whenever extra knowledge is used to build a complex indicator, this knowledge will also be required to interpret it.

35. A second issue is the contribution that composite indicators can make to the development and implementation of public policies. Although the relative positioning of a country can contribute to the establishment of starting points and, possibly, to the impact assessment of specific policies, it is not possible to identify which national aspects require to be strengthened or could be exploited. In this regard, from the perspective of policymakers and analysts, an aggregated indicator (an ordinal number) says little about the potentialities and weaknesses of a country or region. There is the risk of trying to achieve a higher positioning by improving the level of indicators that are consequence and not a cause of the underdeveloped process of knowledge creation. For example, in many developing countries the ratio between qualified human resources and economically active population is far below the average of developed countries. A sectoral analysis can show that firms absorb a low proportion of qualified human resources because their activities concentrate on the production of goods with low knowledge content. Consequently, much of the resources trained with great efforts are “redundant” to the actual productive structure and have to be incorporated into the public system (over-sizing the stock of researchers) or they end up enlarging the “brain drain”. In other words, an aggressive policy for the generation of qualified human resources without a coherent productive policy may be sterile or even worsen the initial situation (brain drain or over-sizing the public science and technology system).

36. For all the reasons argued before, a list of core indicators seems closer to the needs of developing countries, where information is required for both the design and the implementation of policies. Having a set of key indicators that allow international and inter-temporal comparability may be particularly relevant for those countries with little experience in the use of indicators.

37. The measurement of the STI phenomena should be approached starting from the construction of a core set of indicators, which can be expanded in order to move characterize the processes that take place within each country. The measurement/characterization of the dynamics, potentiality and impacts should enable the identification of spaces for improvement, the establishment of cause-consequence relations and the characterization of complementary potentials.

II. Strengths and weaknesses of different sets of STI indicators

A. Main sets of STI indicators

38. What would be, then, the guidelines for the production of a set of indicators about science, technology and innovation? First, STI indicators have to be able to capture the processes of generation, dissemination and appropriation of knowledge. Based on the concept of a National Innovation System (NIS)[5], STI indicators should be able to provide information about the different agents of a national innovation system and their interaction. In its simplified version, a national innovation system is composed of three types of agents directly related to STI: (a) agents that constitutes the science and technology system, included higher education institutions; (b) agents that are grouped under the label “firms”, including in this group all the productive sectors and (c) the public administration, including the different governmental levels. Moreover, these agents operate in a particular environment where other actors and institutions (such as, the financial system, the legal

[5] For a more extended description of the National Innovation System approach see: Lundvall (1992), Arocena and Sutz (2002) and Chiaminade et al. (2009).

framework, the characteristics of the demand) also affect the process of generation, dissemination and appropriation of knowledge.

39. A second criterion to select STI indicators is the availability of information. The variables currently available, which in many cases have been generated for over two decades, must be taken into account. Any scheme intended to contribute to the decision-making process cannot ignore the learning reached and the consensus achieved on the existing indicators.

40. Based on these two criteria, four sets of indicators that conform the STI information schema can be identified:

(a) Indicators describing the science and technology system (that is, the “supply” of knowledge). Indicators regarding R&D, human resources and technology are the fundamental inputs to characterize the science and technology system. This would include indicators related to inputs (expenditures), outputs (results), stocks (the available institutions and human resources) and flows (the formation of human resources and the retirement of the working force). However, to understand the dynamics of this group of actors, these indicators ought to be related. In other words, it is also necessary to understand how efforts in technology generate spillovers. This will require, for example, information about the interaction with the demand for knowledge;

(b) A set of indicators describing the innovation activities of firms. In this case, indicators related to efforts (human resources and expenditures), linkages, outputs and impacts seem to be more appropriate for measuring the innovative dynamic inside the firm. The trajectory of some countries in measuring innovation at the firm level has allowed the analysis of innovation at the micro level and research has provided sufficient evidence to support that the conducts of innovative firms are heterogeneous. These different types of behaviours can be identified based on the particular combination of efforts (embodied or disembodied technologies, intramural or extramural R&D, etc.), the absorptive capacities and the endogenous competences (human resources, quality assurance, training efforts), which lead –in turn- to different types of outputs (related to product, process or organization) and different impacts regarding productivity and employment.[6] The available evidence shows that developing countries have a structure of efforts biased towards the incorporation of external knowledge, that the results of the innovative process rarely reach the level of patentable novelty and that the search for improvements focus on the realization of minor changes and incremental innovations.[7] Therefore, the measurement of the innovative dynamic based only on output indicators (innovation or patenting rate) can hide heterogeneous processes and impacts;

(c) A set of indicators able to characterize the role of public policies in supporting science, technology and innovation;

(d) A set of indicators describing the STI environment where supply and demand of STI takes place. Patent indicators and technology balance of payments are useful to characterize the STI environment where both firms and researchers operate and, from a dynamic perspective, to account processes of structural change, both towards structures with greater content of knowledge and regarding re-primarization processes. Thus, international trade relations show, in a particular but not an exclusively way, that

[6] See for instance: Kemp et al. (2003); Chudnovsky et al. (2004); Narula (2004) ; De Negri et al. (2005); Hall et al. (2006); Raymond et al. (2006); Goedhuys (2007); Lugones, Suárez and Moldován (2008); Lokshin et al. (2008); Suárez (2008).

[7] See Suárez (2006); Anlló and Suárez (2008), Blankley and Moses (2009).

technology flows and patenting processes emerge next to major technological changes.[8] In this regard, extending the analysis from TBP to the flows of goods and services in general is advisable given the relationship between productive and trade specialization patterns and growth and development performance.[9]

B. Measuring the S&T system

41. The measurement of the science and technology system in developing countries must bear in mind three common dynamics of these countries.[10] First, the collective "science and technology system" includes a range of institutions, poorly articulated, with limited strategic coordination. Secondly, developing countries are characterized by a S&T system territorially, thematically and institutionally concentrated. A small number of institutions often closely located and concentrated in a small number of science fields are responsible for the bulk of the resources and the outputs. The third feature is that, in contrast to the situation observed in developed countries, the public sector accounts for the majority of the spending on S&T activities (technological centres, universities and R&D institutes).

42. Available information about the S&T system can be compared internationally and inter-temporally, without too many adjustments and clarifications. As national statistics have followed the recommendations of the above mentioned manuals and used the same classifications, aggregated information can easily be compared. The main weakness is the limited possibility of disaggregating statistics by sectors or particular objectives. This deficiency is more relevant for the formulation of policy recommendations than for international comparisons. For example, information regarding the distribution of the efforts between public and private sources is generally available, while it is harder to find within the private sector disaggregated efforts beyond the traditional classification of primary, manufacturing and services sectors.

43. Scale problems also affect the comparison of existing indicators. Due to the need to compare in relative terms, the most disseminated indicators are presented as ratios of absolute levels of efforts (or stocks of persons) with respect to any variable capable of controlling the impact of macroeconomic dimensions (level of gross domestic product, total population, total employment, etc.). However, the danger of analyzing relative measures is loosing sight of the different scales in which each country operates. To move the knowledge frontier, a minimum scale of investment is required. In this sense, although two countries could show similar indicators, the scale, and therefore the outputs, may differ substantially.

44. Less progress has been made in measuring the linkages and concentration of S&T activities. Linkages and cooperation indicators are key to analyze the impact of S&T activities, the existence of contradictory objectives and the duplication of financial efforts. While there are advances in measuring linkages at the firm level (through the innovation surveys), internationally comparable indicators regarding linkages in the S&T system are less frequent. Indicators rarely provide information about linkages and cooperation and when they do they only serve to confirm the low level of interaction between the S&T system and the business sector. Indicators should also help understand the causes of such

[8] See for instance: Mowery and Rosenberg (1982)

[9] See Lugones and Suárez (2006); Cimoli and Correa (2005); Fagerberg and Mira Godinho (2003); Fagerberg and Srholec (2006).

[10] See for instance: Dahlman and Nelson (1991); Godinho et al. (2005); Lugones and Suárez (2006), Blankley and Moses (2009), Lundvall et al. (2009), Suárez and De Angelis (2009).

low interaction. Effort indicators (such as, the type of science that is performed, the type of training offered, the productive orientation of R&D activities or the type of activities funded) could offer some clues in this regard. Indicators related to the scientific behaviour (such as how the scientist career is evaluated, the prevailing incentive scheme for such linkages, how results are disseminated (which includes the fostered patenting system), or the timeline of science) can also help explain the causes, from the supply side, of the low levels of interaction.

45. The limited availability of indicators at the sub-national levels limits the prospects to measure the concentration of the S&T complex. There are national efforts, more or less comparable among each other and associated with special requirements or characteristics of each country to measure: the institutional distribution of researchers, the thematic concentration of specialized groups, how the national budget on science and technology is distributed, the spatial location of the centres or the geographical distribution of funds.

46. The analysis and implications of output indicators is another important aspect. In this respect, bibliometric indicators and, to some extend patent indicators, are very well disseminated measurements, with a relatively important capability to assess the scientific production. Less disseminated are, on the contrary, those indicators that account for the evaluation of the institutions and staff devoted to these activities.

47. Patent indicators are very well disseminated, but have two main constraints. First, scientific production does not necessarily ends in a patentable product o process. Minor adaptations or the resolution of location-specific problems can provide high-impact results and not be reflected in patent indicators. Secondly, to ensure comparability, international comparisons on the production of patents have been based on the assessment of patent registries in United States or Europe, narrowing the analysis to those inventions that, independently of the country of origin, were protected under these registries, leaving outside from the consideration other products and processes new to the developing country, or at least with important application for local reality.

48. Bibliometric indicators are also well standardized and disseminated (especially because they emerge from international databases). Based on these indicators is possible to measure and characterize scientific publishing dynamics. Two main issues should be kept in mind. First, these indicators will be limited just to journals and other communication media that are indexed in the mentioned databases. Second, even when these indicators take into account the different scope of the outputs (a working paper does not have the same value as a journal paper), its analysis is limited to publishable outputs leaving aside, for instance, technical assistant activities and experimental development.

49. Despite these limitations, patent and bibliometric indicators should not be neglected given their potential utility, availability and standardisation. These indicators can potentially cover aspects not addressed so far. In particular, bibliometric indicators, by measuring joint publications as some developing countries already do, can provide further insights on the linkages within S&T systems. Patent indicators are objective instruments for measuring the scope of outputs but also for measuring the impact of public expenditure, given that private appropriability of public efforts depends on the manner its results are disseminated.

50. To sum up, existent indicators cover a great part of the reality of S&T systems and developing countries have developed their usage based on the recommendation of the Frascati and Canberra Manuals. The current challenge for analysts is to be able to characterize system dynamics. A complex approach that looks at indicators as a whole will be required, including an examination of the areas where researchers vis à vis the productive structure, the relation between public and private efforts, the institutional

belonging of qualified human resources and the relation between relative and absolute levels of the research projects

C. Measuring innovation at the firm level

51. The analysis of indicators regarding innovative processes at the microeconomic level needs to bear in mind some key features of developing countries.

52. As mentioned before, developing countries tend to exhibit a productive structure scarcely diversified, defined by sub-optimal production scales and with an important proportion of informality and precarious work.

53. Within this structure there are some enclaves of modernity, with processes equivalent to international best practices, competing in the international market and in dynamic sectors. However, they tend to have few linkages and synergies with the environment in which they operate. Typically, these islands are associated with economic groups of local origin but which have grown into holdings and global companies.

54. Another feature of these economies is that they present a strong structural duality where strongly competitive sectors (generally based on natural resources in Latin America and Africa and cheap labour in Asia and the Caribbean) often coexist with less competitive ones (including knowledge intensive activities). The latter is constantly confronted with exchange rate pressures arising from the dynamics of the international markets, and the evolution of relative prices and the economic cycle, impact periodically in a negative way on the production of those activities with greater knowledge content.[11]

55. In this context, innovative processes acquire such specific characteristics that the measurement of inputs and outputs only serves to confirm the obvious: limited investments and results. The same would apply to the measurement of international flows of trade: a dynamics based on low and medium-low-tech goods, mainly commodities and goods of low content of knowledge. Even worse, traditional classifications of exports according to their technological content make it impossible to distinguish the hierarchy of activities within each of the productive sectors that are carried out inside the country. This often leads to misinterpret the actual characteristics of activities classified as high-tech (when actually they are no more than assembly activities) or low-tech (which in some cases do not allow the recognition of important efforts of product differentiation).

56. Some developing countries have measured innovative processes based on the Oslo and Bogotá manuals and they have also adapted the international recommendations to their context and incorporated, in a more or less systemic way, additional issues aimed at capturing more complex aspects. There is a considerable amount of relatively comparable information regarding innovation in the private sector. Unfortunately, the number of countries that have innovation indicators is significantly lower than those with data on S&T. Even smaller is the number of countries with information for more than one year or period. Less than a dozen countries by region have more than one innovation survey, a situation that is even worse in Africa.

57. Innovation surveys have been almost exclusively focused on the manufacturing sector, and to a lesser degree on the primary and service sectors. Paradoxically, the sectors surveyed are not those where developing countries have comparative advantages (primary products) or that have a strong potential for development and creation of added value (the knowledge intensive and the high tech services). This fact, perhaps, reflects the strong bias

[11] See Lewis (1954), Ocampo (2005) and Temple and Wossmann (2006).

of international recommendations towards the manufacturing sector, as well as the importance attached to the industry as an engine of development and source of employment. However, the surveys conducted have covered a broad spectrum of activities, collecting information on the supplying activities of primary sectors and, to a lesser extent, on the activities of technologically dynamic sectors (i.e. information and communication technologies, biotechnology, nanotechnology, the aerospace industry and the energy producer industries).

58. The most widespread groups of innovation indicators are those related to the inputs and outputs of the innovation process, information and financing sources of innovation activities, obstacle indicators and those related to linkages and cooperation. In this regard, the international comparability does not seem to find deep impediments, although each group of indicators shows specificities that must be considered when cross-country comparisons are made. The main groups of indicators are analyzed in the following paragraphs.

59. Effort indicators cover, basically, expenditure on innovation activities (with different degrees of disaggregation), including expenses on R&D, capital goods and, depending on the country, other activities such as engineering, design, software and consulting. Surveys often also measure the amount of human resources devoted to innovation activities or, at least, to R&D.

60. In a similar way to the analysis of national expenditures on R&D, the innovation expenditure indicator as a proportion of sales is insufficient to explain the innovation process inside the firm, resulting in obvious and tautological conclusions. For example, the outputs and the impact of innovative processes based exclusively on the acquisition of machinery and equipment will be different from those that combine these efforts with investments in engineering and industrial design (for adaptation and improvement of the machinery, for example) or with R&D activities and staff training. Therefore, the disaggregation of the innovation expenditure is a powerful and indispensable tool to understand entrepreneur’s strategies and guide the formulation of policies. The available evidence suggests that while investment on innovation often generates positive results at the individual level (the innovative firm), some innovative behaviours also allow to provide positive impacts on employment (in terms of tenure, salaries and qualifications) and on the functioning of the national innovation system as a whole.[12]

61. This leads to some warnings regarding the analysis of innovation outputs indicators. First, as for the outputs of S&T activities at the national level, the measurement of innovation outputs at the firm level is not enough to understand what is happening inside the firm and the potential for innovation to support sustained development.

62. Given the characteristics of the productive structure of developing countries (below the technological frontier), the mere incorporation of capital goods leads almost automatically to the improvement in processes and products, increasing the rate of innovators. However, the innovation output indicators do not capture the importance or depth of innovation. This shortcoming has only been partially solved with the incorporation of traditional questions about the scope of the novelty (new to the firm, new to the local market or global innovation).

63. Measuring outputs based on patent indicators has its limitations. Some countries have made progress in the measurement of alternative ways of measuring the manner in which firms protect innovations, which has confirmed the limitation of patents indicators.

[12] See for instance: Kemp et al. (2003); Lugones, Suárez and Moldován (2008); Goedhuys (2007); Anlló and Suárez (2008); Blankley and Moses (2009).

For instance, Brazilian[13] and Malayan innovation surveys gather information on patents but also on other protection mechanisms such as trademarks and industrial secret, capturing information about formal (rights) and informal impact of innovation.

64. If innovation is the key to firm survival and growth then the innovation impacts should be captured by performance variables: such as sales and exports. Moreover, as innovation strategies often are based on the development of knowledge-based advantages (rather than price-based or cost differentiation strategies), greater demand for skilled human resources (qualifications and average wages) would indicate higher levels of innovation. Despite the logic (and the empirical evidence) that sustains these arguments, impact indicators are perhaps the less disseminated, finding this type of evidence mostly in scholar meetings and scientific publications rather than in national statistical systems or policy debates.

65. Indicators about sources of information and cooperation for innovation are widely disseminated but their levels of comparability are lower.[14] Firstly because these indicators are implemented in two ways: some surveys ask in terms of importance and others ask dichotomous questions. Secondly, different surveys include different institutions as options and there is only a small number of agents of commonly used in the surveys (basically: companies, customers, suppliers and universities). Agents related to the S&T system acquire different institutional forms (and objectives), which makes comparability difficult (e.g. a technology centre is different from a training institute in S&T or a consultant specialized in technology).

66. Another issue worth mentioning in relation to the analysis of information and cooperation indicators is the small percentage of positive answers declared. The low level of cooperation between organizations *a priori* contradicts theory but is observed both in developing and developed countries. Countries with a longer experience in the measurement of innovation have tried to enrich this information by including more questions about cooperation. While some surveys include questions related to the objectives of cooperation, others ask about the type of information that the firm was trying to access. Finally, some surveys try to understand the reasons behind the lack of interaction. In some cases the measurement of interaction has also included questions on linkages (a relation that does not imply active cooperation among stakeholders), allowing to analyze how the firm establishes relationships with its environment, independently of its formality.

67. In relation to the obstacles to innovative activity, similar comparability problems are observed. In some cases surveys ask about importance levels and others ask "yes or no" questions. Moreover, the lists of options differ among surveys so there are just a limited number of them that are common in different countries. Finally, the obstacles related to innovative practices (technological risk and easy imitation) and those related to the macroeconomic environment (instability and access to financing) are the ones that score the highest values, but there is a limited capability to convert these responses in precise policy recommendations.

68. Indicators about the sources of funding are also a very well disseminated set, but its practical application is still rare. The different response options limit international comparability and the possibility to raise conclusions that exceed the descriptive analysis about fund distributions is limited. In this respect, some countries have advanced in the measurement of the causes of lacking access to external funds (e.g.: the Argentinean innovation survey) and others have deepened the collection of information about the use of

[13] IBGE (2007) and MASTIC (2006).

[14] For a more detailed analysis of the different approaches see Lugones and Suárez (2008) and Mytelka (2004).

public funds. It is not possible yet to identify an internationally comparable set and, in fact, the adjustments and learning processes of the countries that have implemented these questions show that additional problems regarding inter-temporal comparability exist.

69. Finally, differences in the universe of the survey and in the firm size categorisations also limit the comparability of indicators emerging from innovation surveys. In relation to the universe, some surveys are administrated to all firms, independently of efforts made or results obtained (except those questions strictly related to positive answers). In other cases, different groups of questions are applied to different groups of firms: innovative firms (those that made efforts independently the results) or innovator firms (those firms that obtain results). Even within the same survey, different universes may be used. Those who seek to draw conclusions for public policy, require information about the conduct of innovative firms, including those behaviours that are not innovative. In this sense, it is relevant to known, for example, the innovative potential (firms that made efforts but could not reach results) and the obstacles that confronted those who do not exert these efforts.

70. Surveys categorize firm size differently and the unit of analysis of each survey differs: some surveys only include companies with more than 5 employees, others only those with more than 10 or even more than 50 employees. However at the same time the average size of firms in different countries varies. For instance, the average size of an Uruguayan firm is different from those in Brazil, Mexico or China. As innovation indicators reflect diverse productive structures, If the distinction between small, medium and large firms adopted by each country responds to local productive structures functioning, using a common classification may lead to compare subjects with different dynamics and the existence of different breakdowns should not be considered an insuperable obstacle to international comparability.

71. In short, less progress has been achieved in the measurement of innovative processes inside the firm than in the case of S&T. Nevertheless, there is an important critical mass of information available: several developing countries have conducted innovation surveys and a smaller group of developing countries has a strong record in the collection of innovation indicators. Those countries that have yet not conducted innovation surveys could certainly learn from other countries' successes and failures. The dissemination of methodological manuals has provided isolated national initiatives in the collection of basic information with a remarkable degree of comparability.

D. Public sector and STI indicators

72. A first approximation of the role of the public sector in the process of generation, dissemination and appropriation of knowledge can be derived from the indicators available for the S&T system and firms. The public sector is a financer of STI activities, directly through the existence of public institutions and, indirectly, through the promotion of policies. The public sector is also largely responsible for the formation of qualified human resources, both as a trainer agent (universities and public institutes) and as a regulator agent (setting the rules regarding education provision and its quality certification). Finally, the public sector may also be part of the productive structure and of the provision of public services (by companies of public or mixed capital). In this case, its relationship with innovation is identical to that faced by any other firm, with the exception that public firms normally deal with natural monopolies or spaces where social interest is the most important aspect. In this regard, the generation, diffusion and appropriation of knowledge in the provision of public goods or services (such as health, education and security) respond to a different rationale than the one guiding profit maximization. As a result, the measurement of its efficiency and effectiveness cannot be only expressed in terms of economic benefit but should also be expressed in terms of development and social welfare.

73. Progress in the measurement of STI in the public sector in those areas where it plays a key role or is, in fact, the only agent in charge (i.e. health, safety, the fight against poverty and famine) has been quite limited. The most widespread set of indicators are perhaps those addressing e-government and all the e-related concepts (e-health, e-democracy, etc.) In a broad sense, the study of e-government analyses the transition of governments towards a new manner of relating with its citizens[15], which involves doing things more efficiently (computerization of public administration, virtualization of formalities, etc.) but also improving the manner in which governments address and solve the problems of society. From this approach, indicators have been concentrated in analyzing to what extent new technologies of information and communication are used by governments and have helped improved their operations. This set of indicators permits to know to what extent governments are transiting towards the Knowledge Society and/or contributing for the closure of the digital divide. It also permits knowing to what extent public administration appropriates the benefits of technological progress to improve general welfare. This set of indicators only offers a limited contribution to understanding impact of STI in public health, the eradication of poverty or the disappearance of informal work.

74. Internationally comparable indicators to understand the impact of STI in solving social problems are remarkably absent. Apart from some national experiences quantifying the impact of the STI in solving social problems, there has been no significant progress in the development of a common set of indicators. Although it is possible to conceive some indicators capable of putting numbers to these issues, it is still worthy to wonder about how the existing information could help to address these problems. For instance, S&T effort indicators allow the disaggregation by socio-economic objective. If these indicators are read together with indicators of growth and development (indicators widely disseminated) and those related to the particular problem that wants to be studied, it would be possible to analyze to what extent increasing expenditures in a particular activity impacts on a given social area. Although such analysis would not be sufficient to obtain a complete image, it would allow, as a starting point, the analysis of input-output relations.

75. Finally, another central issue when it comes to STI indicators related to the public sector has to do with the different organizations that national administrations assume and the different units of sub-national governments. For example, indicators on the amount of public budget devoted to STI do not provide much information on how such financing is distributed among the different levels of government.

76. In short, there is no suitable dissemination of indicators related to the public sector and its relation with the process of production, dissemination and appropriation of knowledge. The public appropriation of STI in those more urgent social aspects of developing countries has a less developed empirical basis.

E. The STI environment and the STI process

77. STI indicators are a necessary tool but not a sufficient one for analyzing the dynamics of growth and development. They are certainly inputs, together with the rest of the indicators that make up the statistical systems, for policy development. The contribution that STI indicators can make will depend on their ability to be articulated with other sets of specific information. This section will address the issue of patents indicators and TBP.

[15] For a full analysis of e-government and how to measure it, see Lisbon Manual (Lugones, Suárez and de Almeida Alves, 2008).

78. In relation to patenting, the most widespread indicators are those analysing the dynamics of application and granting of such intellectual property rights, distinguishing between residents and non-residents. These indicators are used to build, for example, the rates of dependency and self-sufficiency (relation between the patents applied by residents and by non-residents and the relation between the patents applied by the latter in respect to total, respectively) and the coefficient of invention (applications of residents each 100 thousand inhabitants).[16] These indicators should be used as proxies for technical progress only under certain precautions. Not every innovation is patentable and not every patented product becomes an innovation. Patent indicators will not account for the innovation activities of companies developing marginal improvements (incremental innovations).

79. Another issue to consider is the distinction between residents and non-residents. Although a patent application made by a resident person or company is most likely to be the result of the activities performed within the country, in the case of patents from non-residents the association is not that direct.

80. National legislations and, thus, the process of patenting, the entity of proof and the time between application and granting vary significantly among countries. Patent indicators will be affected by these specificities and the amount of information necessary to clarify the differences will take much of the explanatory power away. To overcome this problem, indicators based on integrated patent systems (as the European one) or on patents registered in key countries (United States or Japan, for example) have been used. Again, these types of approaches reflect only a particular type of innovative behaviour or technological development of firms with a specific patenting strategy.

81. Despite these disadvantages, patent indicators are widely disseminated and incorporated as a key variable analysis in most complex studies. The reason lies, probably, in its easy collection (because arise from administrative records) and the simplicity of the comparability (because they are property rights that grant temporary monopolies on an invention). Denying its existence does not seem to be the most adequate solution. Patent indicators can be a powerful tool for monitoring the progress of the technological frontier and how central technologies breakdown towards connected developments. The analysis of the distinction between patents applied in a given country or abroad allows the observation of national and regional dynamics as well as the extent to which globalization forces technological convergence —even if only regarding the acquisition of external technology.

82. The analysis of technology flows is important to understand the transfer embodied and disembodied knowledge and, thus, the dissemination of technological advances. From a developing country's point of view, it is important to study the dynamics of the incorporation of this knowledge and the progress made from negative trade balances towards more virtuous patterns of export/import of technologies. The aggregate analysis of these transfers provides an idea of a country's competitiveness based on their potential as creators and disseminators of new knowledge.

83. In developing countries, and in contrast to the other indicators presented, TBP indicators arise more as a construction of traditional trade indicators than as a clear set of information related to technology transfer. Trade indicators are, in contrast, the most disseminated indicators because they are easy to generate (they are also based on administrative registers), simple to interpret (given the almost universal acceptance of the ISIC, it is possible to build an important number of categories of exports internationally and inter-temporally comparable) and can contribute to explain the productive dynamics.

[16] In some cases, also, innovation surveys can be used to analyze the patenting (applications and granted patents) dynamics.

84. Again, the methodological recommendations of the OECD have led to the existence of comparable indicators based on the classification of goods and sectors by their technological intensity. This classification groups the productive sectors into four categories (low, medium-low, medium-high and high technological intensity) according to the technological-intensity of their final product. However, in a context of international relocation of value chains and the dominance of intra-firm trade, this classification limits the analysis that can be made based on the fact that within the same productive sector different activities (with different requirements of knowledge) can take place.[17]

85. For example, in the case of Mexico, the assembly *maquila* scheme in the ICT sector leads to a high rate of exports of high-tech goods although the activities performed in Mexico tend to be activities with a low content of knowledge. In other words, as well as different sectors generate different added-value and demand different skills in human resources, the same applies for several activities included in each sector. Unfortunately, although some progresses in the measurement of the industrial production distinguishing some activities that involve different levels of technological-intensity have been made, there are not homogeneous indicators yet to deepen the analysis, distinguishing activities (not final goods) with high or low technological content.

86. In short, the availability of comparable information regarding trade patterns constitutes a key input for the measurement and characterization of national systems of innovation, both differentiating countries with heterogeneous degrees of development and also analyzing countries' evolution over time. Certain precautions must be taken when interpreting the data, in particular in respect of the distinction between activities and sectors.

F. Towards a core set of STI indicators

87. The previous sections have discussed the progress made in the field of STI measurement as well as the areas not yet covered. This section presents a proposal for a core set of STI indicators that accounts for the reality of developing countries *vis à vis* that of developed ones. In order to account for the special requirements of information for developing countries, this set of indicators could be extended towards the other levels presented in Figure 1, complementing the available information and in contributing to more precise policy recommendations. Given the four types of actors presented the analysis (the S&T system, the firms, the government and the STI environment), Table 1 synthesizes the variables that would be required to build a set capable of characterizing a NIS. The indicators have been selected based on the availability of information and on the possibility of generating such information upon the basis of existing indicators and variables. In other words, this set is the result of a triple balance of comparability, utility and availability.

88. The suggested indicators constitute a minimum set. This set, for example, does not include the indicators on sources of financing of innovation activities or the staff devoted exclusively to the R&D ones. This does not mean neglecting the importance of such information but accepting that there is an inverse relationship between comparability and availability. Also, despite its limited extension, the joint analysis of these indicators can provide a general approximation of the reality of each country and their relative position on STI key issues.

[17] For a more detailed analysis of this classification see: Bianco and Porta (2006) and Lugones and Suárez (2006).

89. The third column of the table includes the reference variables that are necessary to build the relative indicators. As noted, this information has been gathered over decades and its presentation in the framework of the STI indicators would be based on information available in other sites. As discussed in previous sections, the analysis of the dynamics of knowledge generation, diffusion and appropriation requires relative indicators (expenditure/GDP) and absolute variables, in order to quantify the differences in scale.

90. The classifications used in this proposal are ones that have proved to be the most illustrative of the reality of developing countries as well as the most widely used and standardized. Future methodological developments may overcome the limitations identified and the dissemination of indicators (and the surveys and registers that give them origin) will optimize the expected comparability.

91. Taking into account the need to generate information capable of contributing to the design, implementation and evaluation of public policies, these indicators can be disaggregated and complemented to allow deeper analysis of particular systems at the national and regional level. For example, indicators of the S&T system could be classified according to sources of financing (public or private) and the field of knowledge (from basic sciences to engineering). In the case of enterprises, we could differentiate by location, sector, size and origin of capital. For the case of exports, traditional classifications could be deepening by the consideration of the items where high tech activities prevail and those based on of low content of knowledge.

92. In short, this proposal is a starting point and not the intended point of arrival. This set of indicators represents a set of information that analyzed as a whole would permit to obtain relative positions, identify strengths and weaknesses and generate questions regarding the need for more information.

93. On the other hand, for those countries with less experience in the production of STI indicators, progress in the collection of this core set of indicators would allow them to make the first measuring exercises, taking advantage from the successes and failures of other countries. Moreover, the set of indicators have a solid methodological basis and procedural guidelines for its creation, simplifying its technical implementation. From the perspective of the public decision-making process, building this set could enable the rapid identification of relative positions, even in the case of gaps in information for inter-temporal comparability, and could receive a strong support from the international community.

Table 1
Core set of STI indicators

	INDICATORS	DEFINITION AND NOTES	POTENTIAL DATA SOURCES
1.S&T System	1. 1. S&T expenditure (% of GDP)	Total S&T efforts (breakdowns by financing sources, economic sector and field of Science) / Gross domestic product	UNESCO* / WB* LAC: ECLAC* / RICyT* Asia: ANSTIP* / ESCWA */ ITTIN-ASEAN-KISTI* / APEC* Africa: ECA / NEPAD-ASTII
	1.2. R&D expenditure (% of GDP)	Total R&D efforts (breakdown by financing sources, economic sector and field of Science) / Gross domestic product	
	1.3. Researchers in S&T (%o Labour force)	Total S&T human resources (breakdown by financing sources, economic sector and field of Science) / per 1000 labour force	
	1.4. Researchers in R&D (%o Labour force)	Total S&T human resources (breakdown by financing sources, economic sector and field of Science) / per 1000 labour force	
	1.5. Labour force with tertiary education (% of total labour force)	Total graduates (breakdown by field of Science) / Total labour force	
	1.6. Scientific articles (% of total labour force)	Number of scientific and engineering articles (breakdown by field of Science) / 1000 labour force	
2. Firms	2.1. Innovation expenditure (% of sales)	Total expenditures on innovation activities (breakdown by innovative activities) / Total sales	LAC: ECLAC* / RICyT* Asia: ANSTIP* / ESCWA */ ITTIN-ASEAN-KISTI* / APEC* Africa: ECA / NEPAD-ASTII
	2.2. Qualified Human Resources	Total personnel with tertiary education (breakdown by field of Science) / Total personnel	
	2.3. Human Resources on innovation activities	Total personnel on Innovation Activities / Total personnel	
	2.4. Human Resources on R&D	Total personnel on Research and Development / Total personnel	
	2.5. Innovation outputs	Total innovator firms (breakdown by scope and type of innovations) / Total firms	
	2.6. Linkages with S&T system	Total firms with linkages with the S&T system (breakdown by objectives of the linkages) / Total firms	
	2.7.Linkages with other firms	Total firms with linkages with other firms (breakdown by objectives of the linkages) / Total firms	
3. Government	3.1. Public budget on S&T	Public budget on S&T (breakdown socio-economic objective) / Total public budget	LAC: ECLAC / RICyT Asia: ANSTIP / ESCWA / ITTIN-ASEAN-KISTI / APEC Africa: ECA / NEPAD-ASTII
	3.2. Share of public funds in innovation activities expenditures	Acceded public funds on innovation activities (breakdown by productive sector) / Total expenditure on innovation activities	
4. Environment	4.1. Exports structure	High, medium-high, medium-low and low exports / Total exports	United Nations COMTRADE* / WB* LAC: ECLAC* / RICyT Asia: ANSTIP / ESCWA* / ITTIN-ASEAN-KISTI / APEC* Africa: ECA / NEPAD-ASTII
	4.2 Granted Patents	Granted Patent (breakdown by residents and non-residents) / Million population	WIPO / WB LAC: ECLAC* / RICyT* Asia: ANSTIP* / ESCWA* / ITTIN-ASEAN-KISTI* / APEC* Africa: ECA / NEPAD-ASTII

* Data already available (see section 3).

III. Current efforts on the collection of STI indicators

94. This section reviews international and regional efforts to collect STI indicators and provides an overview of current capabilities to collect STI indicators in developing countries.

A. Overview of international initiatives collecting STI indicators

95. Existing international statistical databases offer plenty of information. The challenge is rather how to combine it to produce a complete and useful view of the situation. Of course, there is some information that is, unfortunately, still missing.

96. Table 2 summarizes the main international databases regarding STI indicators. It is evident that efforts have focused on the generation of data about the S&T system (expenditures and human resources) and the STI environment characteristics (exports and patents). Information about innovation in enterprises and the public sector has received less attention, international statistical databases only offer an analysis of the type of S&T efforts (government and business).

Table 2
Available indicators per institution (main international databases)

Institutions	S&T system		Firms	Government	STI environment	
	S&T	R&D	Innovation	Public funds	Patents	Trade
United Nations COMTRADE						X
UNESCO		X		X		
WIPO					X	
World Bank		X		X	X	

97. In terms of the characterization of the S&T system, R&D indicators are the most widely spread and the ones that most countries report. In that sense, the United Nations indicators about R&D come at first, basically due to the Human Development Report Statistics (HDR), the UNESCO Institute for Statistics (UIS) and the World Bank Statistics (WB). These institutions collect and disseminate information about financial efforts on R&D which can be considered a legacy of the OECD's indicators plus some indicators that the National Science Foundation collects for the United States of America. This information is also available by common breakdowns (i.e. sector of performance and source of the funds).

98. Regarding human resources, indicators are very different among institutions: the information provided refers to the R&D human resource base (R&D researchers, R&D workers, R&D technicians or other categories) or to S&T human resources (researchers, students and graduates of science and others). By combining the United Nations databases is possible to obtain indicators related to the stock and flow of human resources: researchers, professional and technical workers, tertiary students, masters and PhDs, already formed or in formation and by gender.

99. In terms of outputs of the S&T system, the most widespread indicators are those about publications. The World Bank through its World Development Indicators (WDI) database provides information about scientific and technical journal articles.

100. Also in the orbit of the United Nations, there are some indicators with global scope regarding patents and high technology exports. Both sets of indicators are present in the United Nations Human Development Report Statistics and the World Development

Indicators, which also considers other protection mechanisms. The most complete database about patents is -of course- the one maintained by WIPO.

101. The suggested indicators on public funds are not standard international indicators but can be partially found in international databases. The first indicator suggested (Public funding on S&T) should be available and published although its availability depends on national accounts and efforts to construct it. The calculation of the second indicators (Share of public funds in total innovation expenditure) will depend on the existence of innovation surveys.

102. Public expenditure to total public budget indicator is determined by the level of each state accountability and its construction by the specific efforts aimed at collecting it. On the contrary, while the participation of S&T expenditures to total budget should be available (and published), the calculation of public innovation efforts to total innovation expenditure will depend on the existence of information about the innovative process which referred to the existence of innovation surveys.

103. In developing countries there are no institutions that implement common innovation indicators (like, for example, EUROSTAT for European countries) or that provide a forum for dialogue and consensus in terms of common innovation questionnaires or indicators. On the contrary, national efforts which apply to different extents the Oslo or Bogotá Manuals are the common scenario in the three regions here. Consequently, the existence of comparable innovation indicators is the result of specific analyses more related to the academic research than to statistical diffusion.

104. The following subsections present the indicators on the S&T system, innovation activities and the STI environment that are available in international and regional databases. While S&T and the STI environment indicators can be analysed at the international and regional level, innovation surveys have to be approached at the national level because efforts on collecting innovation indicators at the regional level are, at best, scarce.

105. Besides those institutions that have published STI indicators, there are several regional initiatives that are developing efforts to increment national capabilities for the design and perform of surveys aimed at gathering primary information and constructing indicators. Some examples of these initiatives are Medibkitar, the INNOVAlatino Project, which is led by the OECD and INSEAD and Asialics, a spin-off of Globelics. However, it is rather premature to derive conclusions regarding their impact.

B. Latin America and the Caribbean

1. Regional initiatives

(a) S&T system

106. Latin American organizations cover similar indicators than those collected by the international ones. As observed in Table 3, the Economic Commission for Latin America and the Caribbean (ECLAC) and the Ibero-American Network on Science and Technology Indicators (RICyT) provide data about R&D expenditures (with the same breakdowns included by UNESCO) and data about R&D personnel for a wide range of countries.

107. RICyT also provides a large amount of information about human resources in S&T and in R&D (researchers, technicians, etc.) facilitating the complete analysis of high-qualified personnel (university graduates, masters and PhDs). It is important to mention that RICyT indicators include different classifications of expenditures and human resources on S&T and R&D activities such as per inhabitant, by funding source, by performance sector, by socioeconomic objective and by field of science. This institution also presents a full list

of bibliometric indicators related to several groupings of indexed journals. The information available covers the period 1990-2008 and although long-time series are not available for all countries there are at least two-year comparisons for almost all member countries.

(b) Firms

108. There are no regional databases about innovation at the firm level but RICyT has recently announced the launch of an "Innovation Section" which will include innovation indicators extracted from national innovation surveys. It will be the first regional effort on disseminating comparable data about the innovative activities of firms. However, the information is not available yet.

(c) Government

109. Although there are neither international nor regional databases with standardized indicators about the public participation in the NIS dynamics, some indicators can be derived from the information regarding public participation on total R&D or S&T expenditure and researchers and S&T personnel working in the public sector. As regional databases (RICyT´s and ECLAC´s) follow the Frascati and Canberra manual recommendations, this information is gathered on regular basis. If countries report the participation of public expenditure to total R&D expenditure and the percentage of personnel working for public organizations, these indicators should also be available.

(d) STI environment

110. Both ECLAC and RICyT include in their databases patent indicators. RICyT presents a relative more extended set of indicators including not only granted and applied patents but also the disaggregation between residents and non-residents and the rates of dependency and self-sufficiency.

111. Based on information from United Nations COMTRADE, ECLAC has a regional database with international trade data, where import and exports are presented for several years and many regional and extra-regional countries. The classification of goods is based on international standards: primary products, manufactures based on natural resources and low, medium and high technology goods.

Table 3
Synthesis of available databases for LAC countries

Institutions	S&T system		Firms	Government	STI Environment	
	S&T	**R&D**	**Innovation**	**Public funds**	**Patents**	**Trade**
ECLAC		X		X	X	X
RICyT	X	X	X	X	X	

2. National initiatives

112. In the case of Latin America, the activities conducted by RICyT and the Bogotá Manual particularly, have contributed substantially to the generation of indicators and the implementation of innovation surveys. Since the early 90s, more than a dozen of countries have performed at least one exercise of measuring innovation at the firm level. However, there are clear differences within this region in the frequency and comparability of the available information. In this sense, two groups of countries can be distinguished: 1) Southern cone countries plus Mexico (an OECD member country) and Colombia, and 2) Central American and the Caribbean countries.

113. As table 4 shows, within the first group of countries, innovation surveys are regularly implemented and the production of S&T indicators responds to the international

standards. There are institutional capabilities to generate and disseminate information, especially that arising from administrative records, and access to is simply and quick (in most of the cases, data can be accessed through the official websites).

114. In the rest of the region, isolated efforts are the common situation. In these countries only one innovation survey has been carried out –at best- and the available indicators are the result of the international organizations activities – RICyT especially. Institutional publishing capabilities are lower and there is scarce interaction between the published data and the user (many websites do not even allow the download of methodological notes, standard tables or time series).

115. This disparity in the quantity of available information and the inexistence of a supra-national organization with the capacity of articulating methodologies and procedures, leads to a strong heterogeneity in the statistical information, particularly evident in the case of innovation surveys and indicators.

Table 4
Available indicators for LAC economies*

	S&T system		Firms	Government	STI environment	
	S&T	R&D	Innovation	Public funds	Patents	Trade
Anguilla						X
Antigua and Barbuda						X
Argentina	X	X	X**	X	X	X
Aruba					X	X
Bahamas					X	X
Barbados					X	X
Belize					X	X
Bermuda		X				X
Bolivia	X	X		X		X
Brazil	X	X	X**	X	X	X
British Virgin Islands						X
Cayman Islands						X
Chile	X	X	X**	X	X	X
Colombia	X	X	X**	X	X	X
Costa Rica	X	X	X	X	X	X
Cuba	X	X	X		X	X
Dominica					X	X
Dominican Republic					X	X
Ecuador	X	X	X	X	X	X
El Salvador	X	X		X	X	X
Grenada						X
Guatemala	X	X		X	X	X
Guyana					X	X
Haiti					X	X
Honduras	X	X			X	X
Jamaica	X	X			X	X
Mexico	X	X	X**	X	X	X
Montserrat						X
Netherlands Antilles						X
Nicaragua	X	X			X	X
Panama	X	X	X	X	X	X
Paraguay	X	X	X	X	X	X
Peru	X	X	X	X	X	X

	S&T system		Firms	Government	STI environment	
	S&T	R&D	Innovation	Public funds	Patents	Trade
Saint Kitts and Nevis						X
Saint Lucia		X		X	X	X
Saint Vincent and the Grenadines		X		X	X	X
Suriname						X
Trinidad and Tobago	X	X	X	X	X	X
Turks and Caicos Is.						X
Uruguay	X	X	X**	X	X	X
Venezuela, Bolivarian Rep. of	X		X	X	X	X

* S&T system and STI environment: availability based on the above summarized international and regional databases. Firms: based on national exercises.

** More than one exercise of measuring.

C. Asia

1. Regional initiatives

(a) S&T system

116. The Asian case is synthesized in Table 5. The United Nations Economic and Social Commission for Western Asia (ESCWA) collects information about R&D activities in the same terms that UNESCO and other United Nations institutions do. In addition to traditional data on R&D researchers and personnel, ESCWA also gathers data on the number of students in higher levels of formal training and other human resources (bachelor graduates, master graduates, Ph.D. graduates, universities graduates, graduates from technical institutes, among others) but S&T institutions variables (universities, technical institutes, S&T colleges in universities, humanities and social science colleges in universities). ESCWA does not include additional bibliometric indicators than those published by the United Nations. It only provides data on the number of publications.

117. Another main space for S&T indicators is the cooperation agreement between the ASEAN members[18] and the Republic of Korea: the Project on Investment and Technology Transfer Information (ITTIN). This project is an initiative of the Korea Institute of Science and Technology Information (KISTI) and it was implemented by the Sub-Committee on S&T Infrastructure and Resources Development (SCIRD). The ITTIN project provides the classical indicators related to the amount of researchers, R&D personnel, including distinctions by performance sector, with no significant differences in relation to indicators collected by Latin American or other international organizations. ITTIN also provides some innovative indicators on skilled labour, brain drain, availability of IT skills and qualified engineers as well as an indicator that accounts for technological development funding, which could be assimilated to the indicator about governmental participation in innovation expenditures.

118. The Asian Network for Science, Technology and Innovation Policy project (ANSTIP) and the Asia-Pacific Economic Cooperation (APEC) host the Industry Science and Technology Internationalization Database, exclusively devoted to compile information

[18] The Association of South-east Asian Nations (ASEAN) is an integration agreement signed by Indonesia, Malaysia, Phillipines, Singapore, Thailand, Brunei, Viet Nam, the Lao Democratic People's Republic, Myanmar and Cambodia.

on STI for Asian Countries. The former provides the links to national, regional or international organizations that include data on STI indicators for Asian countries, being R&D efforts the most frequent reported indicator. The latter, on the contrary, presents a large database, including the proposed indicators about R&D plus the traditional breakdowns as well a huge disaggregation for publications distinguishing among those catalogued by different indexes (Science Citation Index, Index to Scientific and Technical Proceedings and Engineering Index) and S&E citations and articles.

(b) Firms

119. Once again, there are no regional databases with indicators about innovation at the firm level. Analyses about STI behaviours of firms can only be done with information about efforts and human resources on R&D from the business sector.

120. However, the ANSTIP project provides links to most of the existent innovation surveys in the member countries, which although is not a database, constitutes a remarkable effort in collection information at the regional level and, of course, could significantly contribute to create a common database.

(c) Government

121. As presented in table 6, the number of countries with information about R&D is slightly higher than the number of countries which also provide the sectoral R&D information necessary to extract data regarding the governmental involvement in STI.

(d) STI environment

122. The ASTNET/KISTI project gathers data about patents granted to residents and patent and copyright protection. In addition to that, UNESCWA provides some indicators that account for the quality of the exports (including high technology exports). The project under APEC provides rich information about patents since it distinguishes among patents in force, granted, applied and the share of residents. It also provides data about other mechanisms of protection as well as indicators regarding high technology exports.

Table 5

Synthesis of available databases for Asian countries

Institutions	S&T system		Firms	Government	STI environment	
	S&T	R&D	Innovation	Public funds	Patents	Trade
ESCWA		X		X	X	X
ITTIN/ASEAN- KISTI		X		X	X	
ANSTIP	X	X		X	X	
APEC		X		X	X	X

2. National initiatives

123. In the case of Asia, distinctions must be done in terms of Southeast Asia plus China, India, Israel and Turkey, and the rest of the continent. Within the first group, a notable trajectory in measuring STI activities and a large scope of information available (in terms of the breakdowns proposed by the manuals) is observed. Most of these countries have also performed innovation surveys (see Table 6). Five of South-east Asian economies (The Republic of Korea – OECD member country – Taiwan Province of China, Singapore, Malaysia and Thailand) have carried out at least one innovation survey and all the innovation surveys have been carried out under the methodological recommendations of the Oslo Manual. In India and China, although they count with an important amount of information about human resources in S&T (in all cases according the Frascatti and Canberra Manual recommendations), official innovation indicators are scarce, probably due

to the lack of innovation surveys. In the case of Turkey, its UE-associated condition has triggered the generation of STI indicators under EUROSTAT standards, which of course explains the existence of three consecutive innovation surveys in both industry and services. The available information about STI as well as the way they are published leads to rank these countries in a relatively high level in terms of capabilities to collect indicators, in respect to the rest of the continent.

124. In the rest of the region, STI information is significantly limited and in this case the available information can be attributed to the UNESCO initiatives, which through its statistical arm (UNESCO Institute of Statistics (UIS)) has contributed significantly to the S&T indicators, the creation of awareness and training spaces. Unfortunately, besides a minimum set of S&T indicators (with strong disparities in terms of the period of reference and the countries that regularly inform it), the information available is extremely scarce, more associated with the national accounts and administrative records than with the creation of STI indicators as a tool for private and public decision making processes.

Table 6
Available indicators for Asian economies*

	S&T system		Firms	Government	STI environment	
	S&T	R&D	Innovation	Public funds	Patents	Trade
Afghanistan						X
Armenia		X		X	X	X
Azerbaijan		X		X	X	X
Bahrain					X	X
Bangladesh					X	X
Bhutan						X
Brunei Darussalam		X		X	X	X
Cambodia		X		X		X
China	X	X	Taiwan	X	X	X
Cook Islands						X
Dem. People's Rep. of Korea					X	X
Fiji						X
Georgia		X		X	X	X
Hong Kong (China), SAR		X		X	X	X
India		X		X	X	X
Indonesia	X	X		X	X	X
Iran, Islamic Republic of		X		X	X	X
Iraq					X	X
Israel	X	X	X	X	X	X
Japan	X	X	X**	X	X	X
Jordan		X				X
Kazakhstan		X		X	X	X
Kiribati					X	X
Kuwait		X		X		X
Kyrgyzstan		X		X	X	X
Lao People's Dem. Rep.		X		X		X
Lebanon						X
Macao, China		X			X	X
Malaysia		X	X**	X	X	X
Maldives						X
Marshall Islands						X

	S&T system		Firms	Government	STI environment	
	S&T	R&D	Innovation	Public funds	Patents	Trade
Micronesia (Federated States of)						X
Mongolia		X		X	X	X
Myanmar		X				X
Nauru						X
Nepal					X	X
Niue						X
Occupied Palestinian Territory						X
Oman						X
Pakistan		X		X	X	X
Palau						X
Papua New Guinea						X
Philippines		X		X	X	X
Qatar						X
Republic of Korea		X	X**	X	X	X
Samoa					X	X
Saudi Arabia		X			X	X
Singapore		X	X	X	X	X
Solomon Islands						X
Sri Lanka		X		X	X	X
Syrian Arab Republic					X	X
Tajikistan		X		X	X	X
Thailand		X	X**	X	X	X
Timor-Leste						X
Tokelau						X
Tonga						X
Turkey	X	X	X**	X	X	X
Turkmenistan					X	X
Tuvalu						X
United Arab Emirates						X
Uzbekistan					X	X
Vanuatu						X
Viet Nam		X		X	X	X
Yemen					X	X

* S&T system and STI environment: availability based on the above summarized international and regional databases. Firms: based on national exercises.

** More than one exercise of measuring.

D. Africa

1. Regional initiatives

(a) S&T system

125. As Table 7 shows, obtaining information for African countries is a difficult task. Information on S&T is still absent in most of the countries.

126. The new project aimed at gathering STI statistics for Africa, the African Science, Technology & Innovation Indicators (ASTII) Initiative (under The New Partnership for

Africa's Development (NEPAD) is still in an early phase. And the United Nations Economic Commission for Africa (ECA), has not been able to provide statistics because there is a generalized lack of national capabilities in this type of statistics.

(b) Firms

127. African countries lack information about innovation the most. However, the specific objective of the ASTII initiative is to move forward in the measuring of innovative process in 19 African countries (Algeria, Angola, Burkina Faso, Cameroon, Egypt, Ethiopia, Gabon, Ghana, Kenya, Lesotho, Malawi Mali, Mozambique, Nigeria, Senegal, South Africa, Uganda, the United Republic of Tanzania, and Zambia) with the manifest purpose of generating useful information for public policies. Further details on this initiative are provided in Box 1. Its ultimate goal is to create an African Science, Technology and Innovation indicators observatory. Several workshops and meetings have already been held to join efforts and establish common methodological frameworks for national innovation surveys. Up to date, however, their activities have not yet translated into indicators.

(c) Government

128. Since no regional organization has an STI indicator database, the existent information about public expenditure is that from international initiatives. In this case, and differently from the rest of the regions, while many African countries report R&D expenses, the numbers drop significantly when it comes about the origin of the funds. As a result, countries with information about government funds to total R&D expenditure are limited.

(d) STI environment

129. In 2006, the African Union set up a special commission to create the Pan-African Intellectual Property Organization, which will be in charge of "provide(ing) a broad-based platform for African Member States to benefit from a coordinated stock of specialized intellectual property knowledge and services with a view to promote innovation, techno-industrial competitiveness, and economic growth in Africa".[19] Although not included in the fundamental act, this initiative could set the bases for a regional database on intellectual property rights.

130. Despite the generalized absence of statistics in regional initiatives in Africa, international databases and administrative records provide a relative up-to-date information about patents (from WIPO) and trade (from United Nations COMTRADE).

Table 7
Synthesis of available databases for African countries

	S&T system		Firms	Government	STI environment	
	S&T	**R&D**	**Innovation**	**Public funds**	**Patents**	**Trade**
ECA						
NEPAD/ASTII			X		X	

[19] Extraordinary conference of the African Ministers of Council on Science and Technology (AMCOST) 20 – 24 November 2006, Cairo, Egypt.

Box 1. The African Science, Technology and Innovation Indicators (ASTII) Initiative

The African Science, Technology and Innovation Indicators Initiative* is a program ran by the African Ministerial Council of Science and Technology, the organization in charge of the science and technology programmes of the African Union (AU) Commission and the New Partnership for Africa's Development (NEPAD).

The ASTII initiative was established in 2005 under the Africa's Science and Technology Consolidated Plan of Action as a result of the awareness and concerns about the lack of information about S&T among African countries. More than a dozen of African countries committed themselves to create a regional STI indicators database (the original member countries where Algeria, Angola, Burkina Faso, Cameroon, Egypt, Ethiopia, Gabon, Ghana, Kenya, Lesotho, Malawi Mali, Mozambique, Nigeria, Senegal, South Africa, Uganda, the United Republic of Tanzania, and Zambia). In the same meeting, the representatives decided to apply the recommendations and follow the manuals produced by the OECD and that the ASTII initiative and the African Observatory for Science, Technology and Innovation (to be created by ASTII and approved in 2008) would monitor and coordinate efforts in order to reach the consensus needed to develop a common set of indicators.

Consequently, the ASTII objectives are:

- To develop and support the adoption of internationally compatible STI indicators;
- To build human and institutional capacities for STI indicators and related surveys;
- To enable African countries to participate in international programmes for STI indicators;
- To inform African countries on the state of STI in Africa.

The ASTII initiative is oriented to foster and support the creation of African STI indicators to monitor, foresee and evaluate public policies and regional realities. In that sense, after a background document published in 2004 (Mytelka, 2004), a set of recommendations on the local application of international standards (OECD manuals) for the construction of STI indicators where presented to the members in 2005 (ASTII, 2005). Its foundational mandate includes an explicit reference to the interaction with the main international organizations having special interest in STI indicators (among other, UNESCO/UIS, OECD, EUROSTAT). The mentioned ASTII proposal states that there are common agreements about the necessity of a system approach, which means an approach based on:

(a) Agents involved: people, governments, businesses, institutions of education, non-government organizations, and other organized groups;

(b) Process: innovative activities, human resource development;

(c) Interactions: linkages and cooperation among agents, policy incentives;

(d) Results: outcomes and impacts.

However, since there is a significant lack of information about methodologies and indicators capable of characterizing African reality, some issues where suggested to be addressed with a more qualitative approach in order to feed further methodological discussions. These issues are: the informal economy, indigenous knowledge and rare events. Other issues are also supposed to be monitored closely: how human qualified personnel could contribute to the fight against AIDS/HIV, and how biotechnology could be combined with African biodiversity in order to solve regional problems.

Although the first African Innovation Outlook was set for the end of 2009 and training workshops and harmonizing meetings were still being held in 2009, the ASTII initiative constitutes a cornerstone of African STI indicators and an example of how the lack of information has been converted into an opportunity to set the basis for a regional database. One of the most difficult barriers to overcome in the matter of comparable indicators is, paradoxically, the existent of previous national surveys, since any change in the basic information could attempt against inter-temporal comparability, creating a generalized national reluctance to change or modify questionnaires.

* www.nepadst.org/astii/index.shtml

2. National initiatives

131. Trade indicators are the only indicators available for all African countries (see Table 8). In all the other sets of indicators appear several blank spaces. In the case of S&T, even when some countries do produce S&T information, this is not compiled in regional databases. Hence, their collection requires efforts to homogenize and even construct international comparable indicators.

132. Only two countries have at least one innovation survey (South Africa and Tunisia). While for the two previous regions the work of international organizations resulted in the existence of relatively comparable indicators, in the African continent these are still ongoing projects. These projects aim at achieving a minimum set of STI indicators but they have not collected them so far.

Table 8
Available indicators for African countries*

	S&T system		Firms	Government	STI environment	
	S&T	R&D	Innovation	Public funds	Patents	Trade
Algeria		X			X	X
Angola					X	X
Benin						X
Botswana		X		X		X
Burkina Faso		X		X		X
Burundi					X	X
Cameroon						X
Cape Verde						X
Central African Republic						X
Chad						X
Comoros						X
Congo					X	X
Côte d'Ivoire						X
Dem. Rep. of the Congo		X		X		X
Djibouti						X
Egypt		X			X	X
Equatorial Guinea						X
Eritrea						X
Ethiopia		X		X	X	X
Gabon						X
Gambia						X
Ghana					X	X
Guinea						X
Guinea-Bissau						X
Kenya					X	X
Lesotho		X			X	X
Liberia					X	X
Libyan Arab Jamahiriya					X	X
Madagascar		X		X	X	X
Malawi					X	X
Mali						X
Mauritania						X
Mauritius		X			X	X
Morocco		X		X	X	X
Mozambique		X				X
Namibia					X	X
Niger						X
Nigeria					X	X
Rwanda					X	X
Sao Tome and Principe						X
Senegal		X		X		X
Seychelles		X		X	X	X
Saint Helena		X				X
Sierra Leone					X	X

	S&T system		Firms	Government	STI environment	
	S&T	R&D	Innovation	Public funds	Patents	Trade
Somalia						X
South Africa		X	X**	X	X	X
Sudan		X		X	X	X
Swaziland		X			X	X
Togo						X
Tunisia		X	X	X	X	X
Uganda		X		X	X	X
United Republic of Tanzania						X
Zambia		X		X	X	X
Zimbabwe					X	X

* S&T system and STI environment: availability based on the above summarized international and regional databases. Firms: based on national exercises. ** More than one exercise of measuring.

E. Synthesis of national capabilities on the collection of STI indicators

133. Table 9 summarizes the country level information presented in the previous tables, based on international and regional databases and on the existence of national innovation surveys. One main conclusion can be extracted: data availability varies significantly not only among regions but also within them. Under the hypothesis that the level of statistical information available is correlated with national capabilities to generate indicators, one can conclude that there is also a strong heterogeneity in terms of STI statistical skills.

134. The existent heterogeneity of capabilities among regions and within them has been noticed and tackled by many international and regional organizations. In terms of indicators, the ultimate goal of international efforts was to built competences and skills in national agencies in order to create useful and comparable databases. In so doing, during the past years several regional and worldwide organizations have moved forward in the collection of STI indicators. These organizations have concentrated their efforts in the compilation of information produced by national agencies plus a reduced number of surveys administered by themselves. The fact that the availability of information depends on national efforts leads to reproducing the heterogeneity of statistical capabilities.

Table 9

Synthesis of available information published in international and regional databases (number of countries per region)

Region	Number of countries	S&T system		Firms	Government	STI environment	
		S&T	R&D	Innovation	Public funds	Patents	Trade
LAC	41	20	22	14	18	29	41
Asia	65	5	32	7	27	37	64
Africa	54	0	19	2	13	27	54

135. For those countries with higher competencies in the collection of STI indicators, the international databases have been an optimum space to increase the international comparability of their indicators, disseminate the results and improve the quantity of information available (although in some cases, with strong duplication of indicators). For

those countries that collected limited STI data, the statistical catch up has been small. Nevertheless, international efforts have been a step forward in the collection of information, at least in terms of the traditional input and output R&D indicators.

136. Any action plan aimed at generating a comparable set of STI indicators will have to contemplate the different levels of existent capabilities. On the one hand, there is a group of countries (South America plus Mexico and Colombia; South-east Asia plus India, China and Turkey; and South Africa and Tunisia) where efforts should be concentrated on improving existing information. On the other, in the rest of the developing world (or most of it); the challenge is to be able to generate indicators from a weaker and less experienced institutional structure.

137. Regardless of the challenge, the existence of developing countries with a long record in the collection of STI indicators constitutes an asset and their experiences should be incorporated to the learning process of those with a shorter history or even a non-existent statistical base. This should help avoid reproducing mistakes and set the bases for a complex set of indicators with different levels of comparability.

IV. Policymaking based on STI indicators

A. The use of STI indicators in public policy

138. The consolidation of the National Innovation System framework as a basis for STI analysis has led to an increasing demand of STI indicators in the policy decision arena. The demand for STI indicators has focused on establishing relative positions and developing short and medium term goals and benchmarking indicators, without paying much attention to the collection of information capable of providing insights into the strengths and weaknesses of national innovation systems.

139. Current available information for developing countries is the result of the adoption (and sometimes limited adaptation) of methodologies and approaches put in practice in developed regions. This, in turn, have led to the establishing of goals and objectives aimed at diminishing the distance between the developed world levels and developing countries reality.

140. Of course, even with the limitations of the STI measuring record of developing countries, the collection of statistical information has contributed in a positive way to the public decision process. The increase in STI indicators has allowed the identification and measurement of STI related issues, and has revealed the importance of public interventions. The possibility of observing the evolution of these indicators through more than a decade, through periods of higher and lower liberalization and deregulation has confirmed that market incentives are not enough (and not always the best way) to trigger a sustained growth process and, even less, equitable development and has led several countries to incorporate into their long and medium term agendas the development of STI incentives.

141. The question is how much STI indicators have contributed to the development of national development strategies. Although it is not possible to neglect some cases of successful application of statistics in high impact public decisions (this is, for instance, the case of Brazil case – see Box 2), the use of STI indicators has been scarce. The low level of use responds to several reasons: 1) the dynamics of the design-monitoring-redesign public policy process, 2) the place STI statistics have in national information systems and 3) the lack of appropriation of analyses beyond the information that comes from macro-indicators.

142. The implementation of public policies in developing countries (and not only STI policies) often lacks monitoring and redesign mechanisms, narrowing the use of STI

indicators to the establishment of initial relative positions and, at best, to pseudo evaluations of output or impact. The use of indicators is limited to benchmarking and the absence of monitoring indicators in the conception of policies reinforces the idea that the only necessary (or useful) indicators are those that already exist.

143. The fact that STI indicators have been conceived as islands in the national information systems, with scarce linkages with other economic and social indicators, also limits their use in policy making. This matter, which also goes beyond STI aspects, is the result of a lack of policy articulation. Probably, the most outstanding expression of this is that "National Plans" are only STI agendas and not "Development Strategies" generally speaking. The lack of dialogue among educational, industrial and scientific statistics is reproduced among indicators, which reduces their impact and utility. Consequently, STI indicators are limited –at the end- to STI policies.

Box 2. Brazilian policymaking based on STI indicators

The Brazilian information system is probably the most developed in Latin America and is generally used as benchmark for the region.

Two institutions are the pillars of the interaction between the creation and collection of national STI indicators and their translation into public policies: the Brazilian Institute of Geography and Statistics (IBGE*) and the Institute of Economic Applied Research (IPEA**); the former depending on the Ministry of Planning, Budget and Management and the latter on the Secretariat of Strategic Affairs of the Presidence of the Republic.

IBGE is in charge of national statistics and gathers information about the economy and society. In both aspects, STI indicators have been included. In the matter of innovation surveys, the IBGE has implemented and published three exercises with information for the periods 1998-2000, 2001-2003 and 2003-2005, all of them based on the Oslo Manual and the European Community Innovation Survey. IPEA is a research institution that provides technical assistance to the Federal Government for the design, implementation and evaluation of public policies for development. In addition, it has the mission of disseminating economic analysis and information, through publications and workshops.

One of the main projects these institutions performed together was the matching of the several entrepreneurial surveys and administrative registers in order to create a wide dataset. By doing this, a database with more than 70 thousand cases containing firm level information about economic performance, labour, trade and innovation was created. Using this database, several research and analysis where performed allowing the analysts to link innovation with other aspects of the entrepreneurial behaviour and, more importantly, to extend innovation impact from sales to quality of labour, level of salaries and tenure of employees. For instance, De Negri et al. (2005) found that Brazilian firms can be classified into three different groups: the ones that export and differentiate products, the commodity exports and the rest of the productive structure. The first group was the most dynamic in terms of sales and exports (larger scales and higher prices, respectively) and in terms of salaries, years of formal education and tenure of their personnel.

This project served as an example for the region. Following it, Argentina created the Entrepreneurial Development Database (BDDE) with information about innovation, trade, economic performance and labour for 1.200 firms. Although there is no institution similar to IPEA in Argentina, several researchers from public and private organizations followed De Negri et al. analysis and also found specific characteristics in the Argentine manufacturing sector. Lugones, Suárez and Moldovan (2005) and Suárez (2009) found that firms' innovative behaviour can be classified according to the intensity, continuity and composition of their innovative behaviour. Firms with high and continuous innovative efforts that invest in endogenous and exogenous knowledge creation (combining R&D investment with capital goods acquisitions, training activities, industrial design and engineering, etc.) achieve private benefits in terms of productivity as well as higher salaries, more qualified personnel and intense interactions with the rest of the National Innovation System.

The Brazilian and the Argentine analysis also found that these different strategies where present in all sectors. Hence, there were high technology firms following a "low-technology innovative" strategy (with lower productivity and salary levels) and traditional or low technology firms adopting an offensive technological strategy based on the search for genuine competitive advantages and higher salaries.

This type of exercises allowed for two specific recommendations. First, the importance of collecting information about the innovative process. Second, the need for a closer assessment of the industrial policy: if a dynamic innovative behaviour can be found in low-tech sectors, then policies should foster strategies and not sectors; if not every innovation is equally good in terms of social spillovers, then public policy should go beyond incentives to increase R&D expenditure and foster firms that carry out a balanced and continue innovative strategy.

* www.ibge.gov.br /
** www.ipea.gov.br

144. Thirdly, the limited use of STI indicators in policy making has also been connected to the failure in articulating S&T institutions with the governmental sphere. The number of innovators or the proportion of GDP allocated to R&D can only serve as starting points for policy design or policy evaluation. In this sense, existing STI indicators are macro-indicators, measuring concrete situations in a static way, which say little improving areas or

weaknesses of the national innovation system. The analysis of the linkages between the STI complex and the Government has been relegated to a few isolated pieces of research and documents, or even worst, to the existence of personal linkages between scholars and policy makers. In that sense, the lack of dialogue between both groups of agents has reduced the usefulness of available information and has increased the belief that STI indicators are a useful starting point but they are not as useful as claimed when it comes to policy design and implementation.

145. As a result, strategic plans or policy statements repeat the same issues that occupy the centre of the developed countries debate: increasing R&D expenditure, training human resources, raising high-tech exports, developing strategic sectors (most of the cases, biotechnology, nanotechnology, ICTs and energy) and, depending on the region, agro-foods, mining or tourism. While these objectives are strategic, the exploitation of existing capabilities, the increase in the value added of the predominant productive structure and the design of a strategy where these goals are means to national development should be the cornerstones of strategic plans.

B. Main limitations of STI indicators

146. The previous section discussed the scarce use of STI indicators in relation of public policy, regardless the problems and limitations indicators. This section discusses the intrinsic limitations of indicators to help formulate public policies in an attempt to identify the key aspects that future statistical work should overcome.

147. The first aspect that constraints the application of STI indicators in the design, implementation and evaluation of public policies is the timing of information. This issue is far more evident in the case of innovation surveys, where information is gathered once every three years, at best. This contrasts with policy management, where decisions are taken almost on a daily basis. At the same time, the problem of timing gets worse when it is combined with the way results are disseminated. On the one hand, many countries disseminate information by means of official publications, with pre-established tables and charts which hamper the range of possible analysis. When a significant amount of information is presented, often is not possible to access to specific cross-section analysis or particular cuts of reality, even within the same government. In some countries, it is almost impossible to access the microdata, narrowing the analysis to traditional variables and breakdowns.

148. A second problem, also more acute in the case of innovation surveys, is the segmentation of available information. There are some trade-offs between the need to access sub-national information and the importance of measuring innovation at the firm level (and not at the facility one) and between the need for information and the size of the exercise and the possibility of generating specific dissagregations.

149. The third limitation is the need for temporal monitoring. In some countries (the largest ones, specially), the gathering of information responds to sample-based exercises that are later extrapolated to the total population. The possibility of monitoring behaviours and records depends on the possibility of including the same agents survey after survey.

150. A fourth issue is that the generation of STI information is not always included in the regular budgets of the agencies in charge of it. Of course, this is a limitation that also affects other statistics in developing country. In these circumstances, information is generated when financial surpluses are available or political wills of the funding agency (or urgency) converge. The information is shaped by the funding agent interests and is not necessarily comparable with information produced previously or expected to be designed

later on. In the same way, indicators that might be useful for a particular policy design will not necessary be re-created or help to monitor and evaluate of the policy derived from them.

151. Finally, STI indicators have emerged as distinct statistics from the general statistical plan. Only in a few countries, efforts have been made towards an integrated statistical database, making STI indicators a fundamental input for policy recommendations. In most countries, there are still significant conceptual and methodological difficulties for linking STI indicators with the official information. As a result, although some indicators are perfectly comparable with the ones from developed world, in many cases is almost impossible to combine them with other sources of national information in order to perform more complex analysis. For instance, while there is no doubt about the need to increase the stock of qualify human resources related to engineering and sciences, little is known about the determinants of the degree choices of students based on middle education (secondary) statistics. In the same sense, while there have been important progresses in the analysis of policies that foster innovation, we know little about the impact that tax structures, or labour regulation, have on the innovative strategy of the firm.

152. In this context, as indicators follow the suggestions put forward by manuals, the drawing of international comparisons is the logical outcome. Problems appear when we try to disaggregate them in an attempt to fulfil different policy requirements. As a consequence, those indicators that facilitate policy making are less abundant than those indicators that respond to international comparability. It is important for national statistics systems to strike a balance between these two objectives (international comparability and national usefulness). Given that many features or problems are similarly present in countries in the same region, regional initiatives could help in the definition and collection of STI indicators that respond to national needs this area.

153. Regarding the availability of information, it must be acknowledged that there is a good quantity of databases with STI indicators that have relatively long series, for an important number of countries, especially regarding S&T indicators. As the internationally comparable data is available for several countries, building the top level of the previously defined STI indicator system is not an impossible task.

154. Regional data should add more region-specific indicators. There are rich regional databases for Asia and Latin America in relation to some STI indicators. Nevertheless, important blank spaces related to the innovation data exist and, more precisely, the dissagregation of innovation activities is poor and limited to R&D activities. In the case of Africa, extended work is needed given that databases are not frequent and the statistical information, if there is any, is aggregated by blocks of countries.

V. Conclusions

155. The first section of this chapter summarizes key issues that have to be taken into account to improve the measuring processes and to strength the capability of STI indicators to fulfil their function as tools for the design of public policies.

156. Section two presents some priorities for future work aimed at creating and collecting STI indicators, which does not mean other lines should not be included. The development of a full research agenda will depend on the integration of different approaches and academic contributions, as well as the interaction with those in charge of gathering primary information and collecting international databases.

157. The recommendations presented here are not meant to compete with other regional or international initiatives or to propose methodologies. On the contrary, they are intended as a contribution to the integration of ongoing efforts. These recommendations can be a

useful tool for future work by countries with fewer resources. The creation of common indicators could contribute to improve cooperation among the ongoing initiatives on measuring and collecting STI indicators.

A. Key issues to be considered

1. Building a systemic approach

158. STI indicators have emerged as distinct from the general statistical set. In a few countries, efforts have been made towards building an integrated statistical database, revealing STI indicators to be a fundamental input for policy recommendations. In most countries, there are still significant conceptual and methodological difficulties for linking STI indicators with the rest of the official information. As a result, in many cases, it is almost impossible to combine STI indicators with other sources of national information in order to perform more complex analysis. STI indicators should also be capable of accounting for special features, complementarities and development potential. Only with a set of indicators based on a systemic approach, where processes (and not only input-output rates) are measured, can useful policy recommendations be reached.

2. Developing a four-level set of STI indicators

159. Developing countries require a set of indicators that combines features prevalent in developed countries with those related to the distinct characteristics of their own realities. They require a set of statistical information based on the combination of different comparability levels: the international, the regional, the national and the sub-national. International comparability should consist of a minimum set of indicators; otherwise, its extension would undermine its chances of implementation. The regional and national comparability should rest on more specific principles of relevance. The result of such an approach would lead to a set of STI indicators that combines the needs of local and regional policies with the importance of monitoring and assessing world rankings.

3. A better understanding of the NIS

160. STI indicators should capture the processes of generation, diffusion and appropriation of knowledge in the national innovation system. Although some improvements have been made using output indicators (bibliometric, patent and innovation indicators), still very little is known about the dynamics of the system as a whole. Therefore, future efforts should be directed towards the identification and characterization of the agents of the NIS, how their knowledge and capabilities are being improved, how they interact and whether STI is generating the expected externalities and spillovers.

4. Linking the S&T system

161. Existing indicators account for a great part of the reality of the S&T system. Many developing countries, in particular, have based their indicators in common recommendations (Frascati and Canberra Manuals). In contrast, less progress has been made in the measurement and characterization of the articulation of S&T activities. Articulation and cooperation indicators are key inputs to analyze the national impact of S&T activities, the potential existence of contradictory objectives and the duplication of financial undertakings. Further efforts should be made in developing indicators capable of linking S&T dynamics and social needs.

5. Moving beyond innovation output indicators

162. The ratio of R&D to total sales of a firm is insufficient to explain innovation processes at the level of the firm. Relying on it results in obvious and tautological conclusions. Innovation dynamics at the firm level is often informal, based on the incorporation of capital goods and aimed at reaching incremental innovations. Available evidence also confirms that while all investment on innovation often generates positive results at the individual level (the innovative firm), only some innovative behaviours combine private and social benefits (productivity and incomes). Therefore, the disaggregation of innovation expenditures, the analysis of the endowment of qualified personnel, the continuity in time of innovation activities, the search for product differentiation and the dynamics of the firm's external insertion represent powerful and indispensable tools for the analysis of the entrepreneur's strategies and the innovation processes.

6. Enhancing the understanding of the relationship between trade and STI

163. Trade indicators and technology-based classifications are widely disseminated and internationally comparable, and are central information to analyze the role that developing countries play in international trade. An analysis of the indicators related to the technological content of exports helps understand the extent to which STI dynamics is enabling a country to produce high-tech goods to world standards. However, in a context of international relocation of the value chain and the dominance of intra-firm trade, traditional technological classifications based on technological sectors are not sufficient to understand which high-technology activities are taking place in a country. Consequently, in order to identify the knowledge content of goods and how STI is contributing to a positive technological balance of payments, a more descriptive and methodological analysis is required.

7. Assessing regional specificities

164. Although developing countries are heterogenous, a number of regional aspects can be addressed with a common set of indicators. However, available indicators about economic and social impact of STI efforts are not sufficient. Systemic analyses could contribute to generating comparable and relevant policy and indicators proposals. Existing information could facilitate the first steps in measuring the relationship between public efforts and social problems but they must be complemented with more qualitative analyses capable of identifying national and regional specificities. Progress should also be made in identifying more specific issues (and their indicators), associated with regional (Latin America, Asia and Africa) and sub-regional (for instance, Central America, Africa Sub-Saharan and East Asia) problems.

8. Linking STI indicators with development goals

165. The STI plans of developing have included in their "strategic goals", those of developed countries: to increase R&D expenditure, to increase human resource endowments and high-tech exports and foster a few key sectors (in most of the cases, biotechnology, nanotechnology, ICTs, energy and, depending on the region, agro-foods, mining or tourism). These objectives are strategic indeed. However, strategic plans should also emphasise the exploitation of existing capabilities, the increase in the value added of the predominant productive structure, the quest for growth with equity, the eradication of poverty and improvement of health conditions. Efforts should therefore be aligned towards the creation of national and regional indicators capable of identifying and measuring not only the mechanism but also the extent to which STI is contributing towards these goals.

9. Supporting statistical catch-up

166. Data availability varies significantly not only between regions but also within them: on the one hand, there is a group of countries (Southern Cone plus Mexico and Colombia; Southeast Asia plus India, China and Turkey; and South Africa and Tunisia) where efforts should be concentrated on the improvement of existing information. For the rest of developing countries the challenge is to generate indicators from a weaker institutional structure. In those countries with less experience, awareness and technical support should be strengthened, supporting them to start collecting the set of indicators. In those countries where statistical capabilities are relatively higher, the challenge is advancing towards a national well-performing information STI system.

10. Fostering dialogue between developing regions

167. Although innovation is central to the impact of STI on development, there is a still a significant lack of innovation indicators. Different regional initiatives are taking place in an isolated fashion. At the regional level, the European Community Innovation Survey (CIS) is being used as a reference. Although using the CIS as a reference may lead to internationally comparable indicators, the particular form that questions adopt together with the specific adjustments each region or nation incorporate, can reduce the likelihood of that outcome. The ability to use innovation indicators to identify common features in developing countries will also be undermined. Therefore, efforts should be allocated to creating a space where developing countries could start sharing experiences, solve common problems and learn from others. International diffusion of innovation indicators based on national surveys will serve as a trigger to start looking for regional specificities and common needs.

B. Areas that require further efforts

168. Taking into account the key issues that STI indicators face to support policy making in developing countries, this section elaborates two key areas for action.

Broadening the scope of STI Indicators being collected

(a) Moving from R&D to S&T indicators

169. S&T indicators are the most widespread ones but they mostly cover R&D efforts. While many countries have improved their statistical systems, expanding the S&T information and increasing the number of sectors covered by R&D surveys, the dissemination of best practices and newer indicators capable of linking the S&T system with the rest of the national information is still limited. Future work and research is needed in order to identify:

- Leader and lagging countries in the implementation of S&T indicators in all of the three regions;
- The characteristics of the best practices in the collection of STI indicators (frequency, level of dissagregation, institution in charge, diffusion);
- Countries and topics in these regions not currently covered by the existing initiatives.

(b) Assessing the impact of public sector activities on the National Innovation System

170. More work is required to develop and use indicators able to explain how governments are contributing to the development of the NIS. In this case, key areas to develop would include:

- The identification of the sources of information for the proposed indicators;
- The assessment of the possibilities of international comparisons given the different governmental administrative organization;
- The creation of an international database.

(c) Exploiting existent trade and patent databases

171. International trade and patents are the indicators with the most inclusive and extended databases. The potential and limitations of these indicators have been briefly analyzed before. Further research is required to identify the linkages between all the different datasets and the international commerce and patenting trends. Future work should include:

- The identification of cause and effect relationships;
- Matching trade and patents information with S&T and innovation indicators;
- Examining the possibilities of identifying activities with different levels of knowledge content.

(d) Developing a strategy to create common innovation indicators

172. The major weakness in current efforts is the lack of indicators covering innovation as distinct activities from science and technology. Further work is required to analyse to what extent current efforts and national surveys lead to comparable sets of indicators. This will mainly involve the identification of:

- National characteristics of the exercises (frequency, samples, population targeted, etc.);
- Possibilities of creating common indicators;
- Aspects not covered by current innovation surveys and indicators and best practices.

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