Science, Technology and Innovation Indicators: Opportunities for Africa

Fred Gault[1 2]

Summary

This paper develops a presentation given at the first meeting of the Intergovernmental Committee on African Science, Technology and Innovation Indicators (ASTII) in Mozambique in September 2007 which described current work on concepts and developments related to indicators. The principal message is that indicators are going beyond measures of activities, such as research and development and innovation, to include work on indicators of linkages, of short-term outputs, and of longer term impacts of the activities and the linkages. These indicators can be used to gain understanding of the dynamic changes that are taking place in the global economy. In time, they can be used to provide comprehensive advice to ministers responsible for science and technology, comparable to that received by ministers of finance for decades. This is one of the most compelling reasons for indicator development at a time when new science and technology projects are being launched in Africa.

Key words: *Linkages, Outputs, Impacts, Policy, Dynamics, Standards.*

Résumé:

Cet article est un développement de la communication adressée aux participants de la première réunion du Comité Intergouvernemental sur les Indicateurs Africains de la Science, Technologie et Innovation (IASTI) en Mozambique, en septembre 2007, qui mettait en exergue les récents travaux sur les concepts et développements relatifs aux indicateurs. Il souligne le rôle majeur des indicateurs de la Science, Technologie et Innovation (STI) en indiquant qu'ils vont au delà des mesures d'activités telles que la Recherche, le Développement et l'In-

[1]Director of the Science, Innovation and Electronic Information Division at Statistics Canada, Chair of the Committee of National Experts on Science and Technology Indicators (NESTI) and former Chair of the Working Party on Indicators for the Information Society (WPIIS) at the OECD / Contacts: Statistics Canada, Ottawa K1A 0T6, Canada. Email: Fred.Gault@statcan.ca

[2]**Acknowledgements:** The International Development Research Centre (IDRC) made possible the attendance of the author at the Intergovernmental Committee on African Science, Technology and Innovation Indicators in Mozambique in September 2007. Discussions with participants at that meeting and with colleagues associated with the OECD Working Party of National Experts on Science and Technology Indicators are acknowledged.

novation, pour prendre en compte les travaux sur les indicateurs des liens entre les acteurs de la STI, des résultats à court terme, et des impacts à long terme des activités. Ces indicateurs peuvent être utilisés pour mieux comprendre les changements dynamiques qui font leur apparition dans l'économie mondiale. A cet égard, ils peuvent aider à la prise de décision des Ministres en charge de la Science et de la Technologie, de manière aussi comparable que ceux reçus par les Ministres des Finances pendant des décennies. C'est l'une des raisons les plus fascinantes justifiant le développement d'indicateurs à un moment où de nouveaux projets de la science et de la technologie sont mis en œuvre en Afrique.

Mots clés: *Liens, résultats, impacts, politique, dynamique, normes.*

1. Introduction

The Consolidated Plan of Action (CPA) was developed by African ministers of science and technology in 2005 to provide a roadmap for the improvement of scientific and technological infrastructure, including the development of indictors. The first meeting of the Intergovernmental Committee on African Science, Technology and Innovation Indicators (ASTII), held in Maputo in September 2007, was a step in this direction and participants discussed standards, definitions, and the use of indicators in Africa and the production of the African Innovation Outlook (AIO).

The plan was to bring the recommendations of the meeting to the expert meeting held as part of the third African Ministerial Council on Science and Technology (AMCOST) which took place in Mombasa, Kenya in November 2007. However, there was jurisdictional question involving the African Union Commission and the NEPAD Office of S&T which awaits resolution (SciDevNet 2007). Such jurisdictional issues emphasize, rather than diminish, the importance of ASTII development. At a time when agriculture, energy, environment, science and technology, and trade policy are inextricably linked, ministers responsible for these areas have never been in greater need of indicators to support evidence-based policy.

One of the decisions of the Meeting of Intergovernmental Committee on Science, Technology and Innovation Indicators was make use of the existing international definitions and to devote effort to interpreting them for use in African contexts. This fitted well with initiatives in other parts of the world to work with the Organization for Economic Co-operation and Development (OECD) on concepts and definitions and then to ensure guidelines were provided for their use outside of OECD countries.

There are different ways of doing this and one example arises from the Red Iberoamericana de Indicadores de Ciencia y Tecnologia (RICYT) which deals with Latin America, the Caribbean, Portugal and Spain.

The RICYT example is the development of the Annex on Innovation Surveys in Developing Countries, published in the third edition of the Oslo Manual (OECD/Eurostat 2005: 135). This activity began at the 2004 meeting of OECD Working Party of National Experts on Science and Technology Indicators (NESTI), where the RICYT observer presented a proposal on behalf of RICYT that RICYT and NESTI collaborate on an annex to the third edition of the Manual which would interpret it for use in developing countries. The UNESCO Institute of Statistics (UIS) also took part in this activity and coordinated contributions from representatives of countries outside of the sphere of RICYT and the OECD. This was an important step in the science, technology and innovation (STI) indicator process as it raised the importance of taking into account the conditions that are found in developing countries which influence the gathering of the statistics which contribute to indicators while maintaining the importance of having common concepts, definitions and methodologies.

The first meeting of the Inter-Governmental Committee on African Science, Technology and Innovation Indicators (ASTII) was a step towards establishing an African equivalent of the OECD NESTI Working Party. One of the background papers for that meeting (NEPAD Office of Science and Technology 2006) argued the case for maintaining common concepts, definitions and methodologies while developing guidelines for collecting and interpreting data for indicators in African countries. This direction was emphasized by the presence at NESTI in 2007 of John Mugabe, Executive Director of the Office of Science and Technology of the New Partnership for Africa's Development (NEPAD).

More recently, the UNESCO Institute of Statistics held and expert meeting in Montreal in December 2007 to examine what had to be done to add an annex to the OECD Frascati Manual (OECD 2002) to interpret the application of the concepts and definitions for measuring and interpreting statistical data on research and development ((R&D). The discussion identified topics common to all countries collecting R&D data which could contribute to the next revision of the manual. Another class of topics was directly related to UIS data collection and which would benefit from more elaborate collection guidelines produced by the UIS. A third set of topics was on the borderline between the other two and could be considered for

inclusion in an annex to the Frascati Manual. The next step in this process is a proposal to the 2008 meeting of NESTI. The UIS initiative is indicative of interest in STI indicators and their use throughout the world.

The interconnection of all economies is a 21st century reality that has to be addressed in the development of STI indicators and this was the purpose of the second OECD Blue Sky Forum in Ottawa in September 2006. Over 250 people from 25 countries gathered for three days to examine better uses of existing STI indicators, to find STI uses for existing non-STI indicators, and to propose new STI indicators. The papers from the Forum are all available on the OECD website (OECD 2006a) and OECD has published a book, based on the contributions to the Forum (OECD 2007a), to move the discussion of STI indicators, and their applications, beyond the community of experts working with NESTI.

In addition to the book, a series of presentations were made on STI indicator development to a wide range of audiences. These include a meeting of participants in the OECD-China Project in Chongqing, China in October 2006, the 32nd CEIES Seminar in Denmark in February 2007, the VII Ibero-American Congress on Science and Technology Indicators in São Paulo, Brazil, in May 2007, the Intergovernmental Committee on African Science, Technology and Innovation Indicators (ASTII) held in Maputo, Mozambique in September 2007, and a conference on Statistics for the New Economy in Moscow, The Russian Federation, in November 2007. Within the OECD, the Committee on Scientific and Technological Policy was briefed in October 2006. NESTI, at its meeting in June 2007, considered the implications of the findings of the Blue Sky Forum for its progamme of work.

This paper presents the principal outcomes of the Blue Sky II Forum, with attention to African interests, and the reader is encouraged to consult both the OECD website (OECD 2006a) and the book that came out of the meeting (OECD 2007a). In what follows, there are three overriding themes. They are: being able to use the indicators to tell a compelling story; engaging the community involved in policy analysis, advice, and development; and, developing a new social science discipline dealing with the science of science policy.

2. Indicators and Policy

Indicators for telling the story

For indicators to be relevant, they must be used in the policy process. However, there are different uses for indicators. They are used for monitoring, for benchmarking, as part of foresight exercises, and for research into the science of science policy. The growing interest in public accountability has also resulted in a demand for indicators to support evaluation of public spending programmes and of public institutions. An example of this interest is *The State of Science and Technology in Canada* (Council of Canadian Academies 2006) which reports on the state of Canadian science, but leaves to government the responsibility for judgment and priority setting. More specific examples can be found in Bernstein et al. (2007) and Therrien (2006) and the European perspective in Veugelers (2007). Whatever the application, the indicators must be able support the telling of the story of what happens when STI activities are undertaken. Story telling, based on an informed use of indicators, as illustrated by Clark (2007) in his brief economic history of the world, is more influential that complex econometric analysis.

Moving from activity measures to impact measures

There are now many indicators of activities, such as R&D performance and funding, invention, innovation, diffusion of knowledge, technologies and practices, and the development of human resources for all of these. But, there are limited indicators of linkages among the actors (governments, institutions of education and research, hospitals, businesses, private non-profit institutions, and foreign institutions) which tell some of the story about the dynamics of the STI system. There are fewer indicators of outcomes (market share, change in profits, employment, skills, …) and fewer still on impacts of supporting and engaging in the activities and the linkages.

To tell a compelling story to the policy community, indicators of impact are necessary and this requires a shift in focus of indicator programmes. This does not mean producing fewer activity indicators. It does mean producing more impact indicators and integrating them into a system of indicators of activities, linkages and outcomes.

In the African context, the launch of new science and technology initiatives is an opportunity to establish indicator programmes that will tell the story of their success and their social and economic impacts.

Co-ordinating, focusing and synthesizing

To produce a system of indicators to help tell the story requires co-ordination, focus and the capacity to synthesize. In international organizations, such as the OECD, this means working across committees and directorates to produce more integrated products. In governments, it means working across different departments and agencies to integrate human resource, financial, and other measures of STI activities, as all activities influence all others. Bringing the indicators together to tell the story requires considerable power of analysis and synthesis of information from different sources. In Africa, it means working across the AU Commission and the NEPAD OST for the common good.

Moving from macro data analysis to micro data analysis

With increasing computing power it is now possible to add micro data analysis to the existing macro data analysis. This a more powerful way of testing hypotheses and gaining insights into how the system works, especially in a world where the system changes rapidly. As most micro data are confidential, making this move requires gaining access to micro data in countries that permit it and then, if international comparisons are to be made, using the same techniques in different countries to analyse comparable micro data. This is quite different from publishing macro data in the Main Science and Technology Indicators (OECD 2007b).

Developing the science of science policy

The science advisor to the U.S. President, John Marburger, spoke at both the OECD Global Science Forum (GSF) and the Blue Sky Forum and stressed the importance of developing the subject of the science of science policy within the social sciences, a subject 'complete with journals, annual conferences, academic degrees, and chaired professorships – that focus on the quantitative needs of science policy' (Marburger 2007). In support of this, the U.S. National Science Foundation has launched a programme in the 'Science of Science and Innovation Policy (SciSIP)' which is now funding a number of proposals.

Marburger argues that, after significant changes at the end of the last century, the 21st century preoccupation is with technology-based innovation and how to sustain it. This gives rise to a need to understand how science policy can improve economic effectiveness. With global change, old correlations lack predictive value, and focus has to move from the macro to the microeconomic domain. The growth of computing power makes possible large data bases, complex models for analysis of the large data bases and the visualization of the results. However, to make use of the data bases, models, visualization techniques and skills have to be developed.

While science policy research flourishes in many countries, the emphasis on the quantitative aspects of the subject has the potential to change the way in which policy analysts think and policy makers act. The growth of this subject, with its own 'intimidating models', moves the indicator and policy community closer to being able to provide the minister of industry, research or education with advice comparable to that now received by ministers of finance and heads of central banks. It also supports public education in the areas of science and science policy.

This is particularly important as quite different policy areas are being tied together as part of the dynamic transformation of the global economy. Demand from emerging economies, such as China, has driven up the cost of oil. This has led to government subsidies in some parts of the world for the development of biofuels derived from maize. This has driven up the cost of maize. It has also driven up the cost of other grains as the land devoted to their growth has been reduced in order to grow more maize. As animals eat maize, the cost of meat has gone up and the increase in the price of oil has increased the cost of transportation of food. The resulting higher costs of food, transportation and energy have implications for all economies, but they are more serious for developing economies. From the policy perspective, agriculture, energy, trade, sustainable development and climate change are all linked to each other and to science, technology and innovation policy. These are important consideration for the development of African science, technology and innovation indicators, policies and programmes, especially in those African countries without natural resources (Crooks and Wallis 2007, Crooks and Green 2007).

3. Cross-cutting Issues in Indicator Development

Human Resource Measures

All STI activities depend upon human resources and that gives rise to the need to identify the education, training and learning facilitation that prepares people to contribute to STI, to engage in life-long learning, and to recover from learning failures. In addition, there are the immigration policies that guide the flow of skilled people across national borders and their assimilation into the society. Statistics are required to describe the characteristics of the institutions involved in education, training, learning and immigration.

In addition to the institutional statistics, some of which are quite well developed, there is a need for statistics on the characteristics of the individuals in the STI system, their age distribution, their stocks, and their flows among the actors in the system and across national borders. One of the characteristics of individuals in which more interest is being shown is that of entrepreneurship, which is the subject of an existing OECD project. There is also the information gathered in the Programme for International Student Assessment (PISA) (OECD 2006b), the work on the Career Path of Doctorate Holders (CDH) by NESTI, and the programmes of the Global Science Forum, and the Ad Hoc Group on Steering and Funding of Research Institutions.

There were five papers at the Forum that addressed the human resource issues in STI (Auriol, 2007, Hansen 2006, Kim 2006, Moguerou, Da Costa, Paoli de Pietrogiacomo and Laget 2006, and Sandgren and Perez (2006)) and it was clear that there is a need to co-ordinate the work in order to provide the common concepts and definitions leading to comparable indicators that had once been the objective of the OECD / Eurostat Canberra Manual (OECD 1995). This is a role for the OECD and Eurostat in consultation with other international organisations.

In the African context, the UIS has been collecting statistics on education for years, but more is needed understand the stocks and flows of human resources for science, technology and innovation.

Classification and Guidelines

Standard classifications of industry, occupation, education were not only necessary to the development of new indicators of economic activity, but

they had to be revised in a way that reflected the needs of analysts who where trying to present STI indicators to the policy community in an accessible manner. This revision required on-going liaison between the OECD and the international bodies, such as the UN Statistical Commission, that are responsible for the international standard classifications.

Firm characteristics

While firm characteristics have always been important to STI analysis, globalization, interest in the urban and rural economies, the importance of small and medium-sized enterprises (SMEs), as well as large firms and multi-nationals, highlighted the importance of common measures of firm size, geographical location, and the location and characteristics of the (foreign) affiliates of firms.

Sustainability

In a global economy, with competition for people, water, food, and fossil fuels, and concern for the impact of the results of STI activities, there is the question of whether the STI activity is sustainable, or even feasible in the short term. Indicators of sustainability are needed as part of the development of indicators for the next decade. (Bordt et al, 2007, Gault 2007).

4. Indicators of Activities, Linkages, Outcomes and Impacts

4.1 Activities

Actors (governments, businesses, education and research institutions, foreign institutions …) engage in STI activities. This section looks at R&D, invention, innovation and the diffusion of knowledge, technologies and practices, and highlights some findings. As noted in the introduction, these findings are not radical but suggest the need for oversight, co-ordination and communication. A key actor in the development context is donor organization.

R&D and Globalization

The formal creation of knowledge is an important input to the activity of innovation and it is being affected by globalization. The requirement is to go beyond the collection of data on the performance of R&D in countries to the adding of a global dimension (OECD 2005a). This would include the classification of domestic industrial R&D by the country of control of

the firm performing the R&D as well as the collection of information on the affiliates of that firm, especially those abroad, and the R&D performed by those affiliates. This then leads to questions on foreign direct investment (FDI) both incoming and outgoing.

Going beyond the firm and its affiliates, there are questions about the payments and receipts for technological services, including R&D services. This is covered in the OECD manual on the Technological Balance of Payments (OECD 1990) and it bears of the current issue of outsourcing of R&D, as well as other activities, and the information is needed for a complete picture of the R&D enterprise. There is also a need to distinguish between the purchase or the sale of a service, and a transfer payment, or company tax, to pay for a central R&D facility.

There is some work on globalization of R&D going on in NESTI (Åkerblom 2006, Perani and Cozza, 2006), which is of immediate policy relevance. There is also work on the capitalization of R&D for national accounting purposes. The decision to treat R&D as a capital investment in the next revision of the 1993 System of National Accounts (SNA) was taken by the UN Statistical Commission at its meeting in February 2007.

Invention

Invention leads to intellectual property which may be protected by an intellectual property instrument such as a patent, copyright or a trademark, or by trade secrecy. Once an instrument of protection is chosen, indicators can be developed. The current OECD manual (OECD 1994) is being revised to take account of indicator development since the first Blue Sky Forum on 1996[3].

Innovation

Experience of surveying the activity of innovation has grown through the surveys in many countries, including the Community Innovation Survey (Eurostat 2004). The issue now is the making of this information more policy relevant and a number of proposals were raised (Arundel 2007). These included the qualifying of existing variables to make the resulting measures more comparable and an example was moving from just presenting the revenue from new products, to revenue from new products

[3]A selection of papers relating to the first Blue Sky Forum can be found in the OECD STI Review, OECD (2001).

sold abroad to get an indicator that was more internationally comparable. Another example was the qualifying of new products by their degree of novelty, which is already suggested by the 3rd edition of the Oslo Manual (OECD/Eurostat 2005). The use of panel data and longitudinal data bases are discussed by Fabling (2007).

New ways of doing innovation, and the related indicators, were considered which included open innovation (Chesbrough 2003) and the democratization of innovation resulting from user initiated innovation (von Hippel 2007). Both could be examined in case studies or pilot surveys, leading to new indicators.

Other aspects of innovation where discussed, such as the role of design (Gertler and Vinodrai 2006, Lambert 2006, and Vinodrai et al. 2007). Design, as part of innovation, also linked to sustainability, (Douglas 2007) and is an area of growing interest for indicator development. With the expansion of the definition of innovation in the 3rd edition of the Oslo Manual to include industrial organization and practices, and market development, there was discussion of indicator development linked to organizational forms and innovative practice (Arundel and Lorenz 2006).

Diffusion of Knowledge, Technologies, and Practices

Knowledge is diffused in codified form through books and journals and through the more difficult transfer of tacit knowledge from person to person. Both cases presuppose an absorptive capacity so that the knowledge can be received and used.

The use and planned use of technologies was treated separately from innovation in the first and 2nd edition of the Oslo Manual. With the 3rd edition, they were incorporated into innovation that was in the lowest novelty class, new to the firm. However, if the technology was adopted earlier than the reference period, it did not qualify as an innovation, even at the lowest novelty level. While some technology use is captured in innovation surveys, there is still a place for the study of the diffusion of technologies.

The OECD pilot surveys of knowledge management practices in 2001 looked very like the 1980s surveys of technology use and demonstrated that there is no reason why 'practices' cannot be treated in the same way as technologies (Foray 2007). The expectation of the Forum was that business practices, including knowledge management, would continue to be measured and that attention should be given to practices in public organisations.

There was also an expectation that the diffusion of technologies would continue to be measured and the list of technologies expanded. Those mentioned where Information and Communication Technologies (ICTs) (OECD 2005b), Biotechnologies (OECD 2006c), Nanotechnologies (including ICT miniaturization, biotechnology applications, development of large (nano-scale) molecules, and new materials), Materials, Biofuels, Hydrogen Power, Grid Computing, and Health Technologies.

4.2 Linkages

The measuring of linkages is fundamental to the understanding of the dynamics of the STI system. However to monitor the linkages requires co-ordination across measurement programmes.

Linkages have been measured through the bibliometric analysis of publications with more than one author, representing different institutions. This kind of work shows the connections between the institutions in the system and their spatial distribution. Work has also been done on contracts for R&D performance. A contract is a linkage measure as it is a formal agreement between two organisations which can be classified by industry, geography, and field of science. Collaborations are more difficult to measure unless they are part of a contract and, there is commercialisation of intellectual property.

Linkages do not have to be just between two people or institutions; they can include networks. This raises questions of and how networks are measured or visualized. Networks also raise the question of network capital, the knowledge stored in the social network that goes beyond the human capital stored in the individual participants. Social networks and network capital are significant areas for indicator development.

Commercialization is an important linkage measure as it is the creation of market value from knowledge. It can result from the sale of intellectual property, or its licensing to the private sector, or the spinning off of a new firm to bring the new knowledge to market, or a combination of these.

Innovation surveys collect information on the sources of ideas for the activity of innovation but they do not focus on the money made by the source of the ideas, if it is a commercial transaction. There is a place for capturing more information on commercialization and the value chains in which the activity is embedded. This is especially true as value chains become more global.

Linkages also involve people and machinery and equipment. Institutions hire people and they come from other institutions and carry knowledge with them, or, at the very least, the capacity to absorb knowledge. Machinery and equipment embodies knowledge which is transferred to the firm by the supplier. There is a link between the client and the supplier, especially if there is discussion about modifying the machinery and equipment to serve better the client needs.

Linkage measures are topics for consideration by NESTI, and member countries are being encouraged to share information from case studies and surveys. The 3rd edition of the Oslo Manual provides a starting point for this work which should include the development of a conceptual framework for the understanding of commercialisation.

4.3 Outcomes

The outcomes of an activity, such as R&D, innovation, or the diffusion of knowledge, technologies and practices provide direct evidence of the consequence of engaging in the activity, such as increased revenue, market share, or employment as a result of innovation.

The need is to share country experience of the measuring of outcomes through surveys and through common methods of analysis.

For Africa, this is a role for Intergovernmental Committee on ASTII.

4.4 Impacts

The impact of an activity is difficult to determine as the STI system is non linear. It is evident that wireless telephony, computing and broadband have had an impact on quality of life and business practices and organisation. However, it would be difficult to tie this impact to the early research on wireless communication and surveys are not the ideal instrument as they cover a limited time period. Case studies and historical analysis are required to bring the components together to tell the story.

Analysis of productivity and economic growth provide a means of getting at some of the causes, as do case studies. However, if the subject of the science of science policy is to develop, and if the policy community is to have a story to tell about government interventions in the economy and the society, more work has to be done on impacts (Ertl et al. 2007).

5. Analysis

Analysis of STI data needed to populate statistics and to construct indicators requires concepts and definitions acceptable to the international community that govern both the measurement and the interpretation of the data. This is part of the on-going work of NESTI and its collaborators such as Eurostat, the UNESCO Institute of Statistics (UIS), and other international organisations such as RICYT and representatives from Africa.

At present, depending upon the area being studied, there are not only data bases at the OECD but also at other international organizations such as the International Monetary Fund (IMF), the World Bank (WB) and the International Telecommunications Union (ITU). There is a need for co-ordination to facilitate the standardisation and use of these data bases.

A recurring theme of the Forum was the importance of analyzing micro data in addition to doing more macro analysis using OECD data bases such as the Structural Analysis Statistics (STAN) data bases and the need to facilitate access to micro data holdings for institutions that hold such data.

There was also a question of analytical techniques. While much has been learned from the use of econometric modeling, there is also much that could be learned from micro analytic simulation models capable of supporting scenario analysis and engaging the policy community in a dynamic learning activity. This is one of the subjects of interest in the science of science policy.

There is also an analytical role for case studies in illuminating those relationships that are outside the capability of the models and which raise new research questions.

In summary, analysis is needed to create information from data and knowledge from information. The analytic activity requires international standards, co-ordination, micro and well as macro analysis, and a variety of techniques to tell the story about what is going on in the STI system. This is especially important in a rapidly changing world.

6. Moving Forward

The speed of introduction of new indicators and systems of indicators depends upon institutional factors and the willingness to adopt a common language and common tools. Bill Gates (2007) makes the point that for

robotics to advance, in same way that personal computers took off thirty years ago, there have to be common standards and language. The same is true for the development and application of STI indicators.

A second issue governing the rate of progress is managing the transition from the indicators needed for policy development in the 20th century to those needed in the 21st century. Freeman and Soete (2007) make the point that indicators that served well in the past may be no longer as important as they were and they may even be misleading. This makes the choice of the trajectories along which indicators will develop both critical and urgent. Again, institutions, and their collaboration, will play a key role.

Institutions Producing Statistics

STI statistics are produced by many different institutions including statistical offices, government departments, research institutes, central banks and industry associations. The model for the collection and dissemination of statistical data ranges from the centralized to the widely disbursed. In the European Union (EU), there is also the European statistical office, Eurostat, that works with EU member countries. In the UN context, the UIS deals with STI statistics.

The economy is changing as a result of globalization, service industries are becoming even more dominant, and products and occupations are appearing, and disappearing, and making existing classification systems less relevant. This has led to suggestions that statistical data on firms be held in data bases that support analysis and different aggregations, with analysis driven by policy questions rather than being constrained by standard classifications.

In the shorter term is the need for micro data linkage of files that allow STI surveys, or administrative data bases to be linked to data from other surveys or administrative data bases to produce files for analysis without additional burden on respondents and more relevant variables for analytical work.

The OECD has a key role to play in the revision of international classifications and in working with statistical offices through the Statistics Committee of the Statistics Directorate. Additional co-ordination is required for the work of the many other organizations that produce STI statistics.

Institutions and Framework Conditions

Activities do not take place in isolation. They occur in a country which has a government that may or may not intervene in the economy and society, a culture, or cultures, a history, an education and research system that creates new knowledge and produces highly qualified people, a banking system, and an established legal system which ensures that consumers are protected, contracts are supported, and intellectual property is managed. These characteristics of the country are influenced by public and private institutions – governments, education and research organizations, and business.

Assuming a stable environment, surveys of STI activity can be conducted and compared over time. However, for there to be meaningful inter country comparisons, account has to be taken of the framework conditions. This is a point raised by Christopher Freeman and Luc Soete (2007) who divide the world into developed economies, emerging economies of which the BRICs, Brazil, Russia, India and China are leading examples, and developing economies. They then identify different policy challenges for the three categories. For developed countries, it is about getting the balance right between large firms operating in a Schumpeter Mark II environment of dominance, collection of innovation monopoly rents, and the creative accumulation of knowledge compared with smaller firms in a Schumpeter Mark I environment of entrepreneurial dynamism and creative destruction. For emerging countries the issue is moving quickly to a Schumpeter Mark II environment. For the developing countries, the challenge to provide the framework conditions necessary for the creation of a Schumpeter Mark I environment in the hope that it will in due course create dominant firms that can function in a Schumpeter Mark II environment. This means that STI policy in developing countries is necessarily quite different from that of the emerging or developed countries and it is important to take this into consideration when developing STI indicators.

Development and Developing Countries

STI activities are part of economic development, but they need the support of public institutions to succeed. The knowledge developed by the OECD on how the STI system works can be shared with international organisations, such as those of the UN that deal with development and with those that represent developing countries such as the African Union and the Office of Science and Technology of the New Partnership for Africa's Development (NEPAD). Fostering a link between the NEPAD

Office of Science and Technology and the OECD committees engaged in STI policy and indicator development and use would promote knowledge exchange and capacity building as NEPAD develops its own set of STI indicators and guidelines for their use (NEPAD Office of Science and Technology 2006).

In China, the China Society for Science and Technology Indicators (CSSTI) organizes forums for the discussion of international STI indicators and it works closely with the Ministry of Science and Technology (MOST) in Beijing. Chinese experts have also contributed to NESTI meetings. In China and Africa, and in the OECD and UN organizations, the indicator development and use is done by government officials or is closely tied to government. This helps provide coherence and a direction. In the case of Latin America and the Caribbean, RICYT is an organization with some similarities to the Chinese case, as it has mainly academic participants engaged in methodological developments. However, RICYT also has the participation of the national institutions responsible for science and technology and related indicators. This ensures a link between official data and RICYT activities.

7. Conclusion

This paper has stressed the development of new STI indicators, especially indicators of impacts, in a well ordered way as part of an international process. To justify the resources needed for such an undertaking, STI indicators must be used. For them to be easily used by the policy community, they must support the telling of a compelling story. The goal for indicator development is to provide the minister of industry, research or education with advice comparable to that now received by ministers of finance and by central banks.

These conclusions apply to all countries, but they are particularly relevant to Africa at time when there is support for indicator development and new STI initiatives that need indicators to show their success and their economic and social impacts.

References

Auriol, Laudeline (2007), *International Mobility of Doctorate Holders: First Results and Methodology Advances*, in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.193-212.

Åkerblom, Mikael (2006), *Ideas for New Indicators on Globalization of R&D,* in OECD (2006a).

Arundel, Anthony (2007), *Innovation Surveys: What Impact on Innovation Policy,* in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.49-64.

Arundel, Anthony and Lorenz, Edward (2006), *Organizational Forms and Innovative Performance*, in OECD (2006a).

Bordt, Michael, Boivin, Johanne and Rosa, Julio Miguel, *Science, Technology and Innovation for Sustainable Development*, in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.251-268.

Bernstein, Alan, Hicks, Vern, Borbey, Peggy, Campbell, Terry, McAuley, Laura and Graham, Ian (2007), *A Framework to Measure the Impact of Investments in Health Research*, in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.231-250.

Chesbrough, Henry (2003), *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Boston: Harvard Business School Press.

Clarke, Gregory (2007), *A Farewell to Alms: A Brief Economic History of the World*, Princeton: Princeton University Press.

Council of Canadian Academies (2006), *The State of Science and Technology in Canada*, Ottawa: Council of Canadian Academies. www.scienceadvice.ca/study.html, Accessed December 28, 2007.

Crooks, Ed and Wallis, William (2007), *African Aid Wiped Out by Rising Cost of Oil*, London: Financial Times, December 29-30.

Crooks, Ed and Green, Matthew (2007), *Soaring Fuel Bills Put Pressure on Africa's Fragile Economies*, London: Financial Times, December 29-30.

Douglas, Ed (2007), *Better by Design*, New Scientist, January 6-12, 2007, pp. 31-35.

Ertl, Heidi, Bordt, Michael, Earl, Louise, Lacroix, Anik, Lonmo, Charlene, McNiven, Chuck, Susan Schaan, Uhrback, Mark, van Tol, Bryan and Veenhof, Ben (2007), *Towards Understanding the Impacts of Science, Technology and Innovation Activities*, in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.101-122.

Eurostat (2004), *Innovation in Europe: Results for the EU, Iceland and Norway*, Luxembourg: European Communities.

Foray, Dominique (2006), *Enriching the Indicator Base for the Economics of Knowledge*, in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.87-100.

Freeman, Christopher and Soete, Luc (2007), *Developing Science, Technology and Innovation Indicators: What we can Learn from the Past*, in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.193-212.

Gates, Bill (2007), *A Robot in Every Home*, Scientific American, January 2007, pp. 58-65.

Gault, Fred (2007), *Assessing International S&T Co-operation for Sustainable Development: Towards Evidence-Based Policy*, in International Science and Technology Co-operation for Sustainable Development, OECD: Paris, pp. 107-114.

Gertler, Meric, S. and Vinodrai (2006), Tara, *Better by Design? Capturing the Role of Design in Innovation*, in OECD (2006a).

Hansen, Wendy (2006), *Linking Human Resources in Science and Technology and Scientific Performance: The Use of Existing Data to Develop New Indicators to Analyze the Scientific Base of High and Medium High Technology Manufacturing Industries*, in OECD (2006a).

Kim, Ki-Wan (2006), *Developing indicators for the effective utilisation of HRST: The case of South Korea*, in OECD (2006a).

Lambert, Ray (2006), *Design as a Source and Enabler of Innovation – New and Improved Indicators*, in OECD (2006a).

Marburger, John (2007), *The Science of Science and Innovation Policy*, in OECD (2007a), Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.27-32.
Moguérou, Philippe, Da Costa, Olivier, di Pietrogiacomo, Maria Paola and Patrice Laget Patrice (2006), *Indicators on Researchers' Career and mobility in Europe: A Modelling Approach*, in OECD (2006a).

NEPAD Office of Science and Technology (2006), *African Science, Technology and Innovation Indicators (ASTII) – A Discussion Document: Towards African Indicator Manuals*, Pretoria: NEPAD. www.nepadst.org/doclibrary/pdfs/iastii_jun2006.pdf Accessed December 28, 2007.

NSF(2006), *Investing in America's Future, Strategic Plan FY 2006-2011*, NSF 06-48, Virginia: National Science Foundation.

OECD (1990), *Manual for the Measurement and Interpretation of Technological Balance of Payments Data – TBP Manual*, The Measurement of Scientific and Technological Activities Series, Paris: OECD.

OECD (1994), *Using Patent Data as Science and Technology Indicators – Patent Manual* 1994, OECD/GD(94)114.

OECD (2001), *STI Review, Special Issue on New Science and Technology Indicators*, No. 27, Paris: OECD.

OECD (2002), *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development*, Paris: OECD.

OECD (2005a), *Measuring Globalization: OECD Economic Globalization Indicators*, Paris: OECD.

OECD (2005b), *Guide to Measuring the Information Society*, Paris: OECD.

OECD (2006a), *Proceedings of the OECD Blue Sky II Forum*, www.oecd.org/document/27/0,2340,en_2649_34451_37083163_1_1_1_1,00.html, Accessed December 28, 2007.

OECD (2006b), *Messages from PISA 2000*, Paris: OECD.

OECD (2006c), *OECD Biotechnology Statistics 2006*, Paris: OECD.
OECD (2007a), *Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs*, Paris: OECD.

OECD (2007b), *Main Science and Technology Indicators*, Volume 2007/2, Paris: OECD.

OECD/Eurostat (1995) *The Measurement of Human Resources Devoted to Science and Technology – Canberra Manual*, The Measurement of Scientific and Technological Activities, Paris and Luxembourg: OECD and Eurostat.

OECD/Eurostat (2005), *Guidelines for Collecting and Interpreting Innovation Data: Oslo Manual*, Paris and Luxembourg: OECD/Eurostat.

Perani, Giulio and Cozza, Claudio (2006), *A Proposal for Developing New Indicators on the Internationalization of R&D by Matching Micro-Data from National R&D Surveys*, in OECD (2006a).

Sandgren, Patrick and Perez, Eugenia (2006), *Mobility of the Higher Skilled in the Swedish Innovation System — An Indicator for Knowledge Flows*, in OECD (2006a).

SciDevNet (2007), Editorials, *Now its up to Africa*, November 29, 2007, Science and Development Network, www.scidev.net/editorials, Accessed December 28, 2007.

Statistics Canada (2006), *Innovation Analysis Bulletin*, Blue Sky II Forum 2006, Catalogue 88-203, Vol. 8, no. 3, December 2006, Ottawa: Statistics Canada
Available at www.statcan.ca, click on Publications, Free Internet Publications, Science and Technology, and Innovation Analysis Bulleting. Accessed December 28, 2007.

Therrien, Pierre (2006), *Benefits from R&D Investment in the Canadian Federal Government*, in OECD (2006a).

Veugelers, Reinhilde (2007), *Developments in EU Statistics on Science, Technology and Innovation: Taking Stock and Moving Forward Towards Evidence Based Policy Analysis*, in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.33-46.

Vinodrai, Tara, Gertler, Meric, S., and Lambert, Ray (2007), *Capturing Design: Lessons from the United Kingdom and Canada*, in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.65-86.

Von Hippel, Eric (2007), *Democratizing Innovation: The Evolving Phenomenon of User Innovation*, in Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs, Paris: OECD, pp.125-138.