

INNOVATION

Key Innovation and Knowledge Indicators for South Africa

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Outline

- The theory and practice of science and technology and innovation (knowledge economy) indicators
- Different categories of indicators
- Limitations of indicators
- Future indicators
- Innovation and knowledge indicators in South Africa

A THEORETICAL AND HISTORICAL FRAMEWORK FOR INDICATOR DEVELOPMENT

- Knowledge lies at the heart of a knowledge economy but is particularly hard to quantify and price (OECD, 1996)
- The nature of science, technology and innovation has changed over time and so have the indicators that are used to measure science and technology (S&T) activities
- In the 1950's and 1960's the main focus was on R&D indicators
- The list of indicators grew in the 1970's, 80's and 90's with the development of the OECD *Frascati and Oslo Manuals*

A THEORETICAL AND HISTORICAL FRAMEWORK FOR INDICATOR DEVELOPMENT

- A gradual shift in interest in developed countries from industrial R&D to innovation (Freeman and Soete, 2009)
- Led to emergence of new S&T indicators - The mid-1990's focused on the development of new indicators that could shed light on the broader system of innovation (Gault, 2006)
- Innovation indicators and the co-ordination of initiatives across countries defined and strongly influenced by the OECD and European Commission (Smith, 2000)
- Structural framework for S&T likely to remain stable, after developments in the 1990's (Gault, 2006)

Table 1: The development of science and technology indicators

1950s & 1960s	1970s	1980s	1990s to present
<ul style="list-style-type: none"> ➔ R&D 	<ul style="list-style-type: none"> ➔ R&D ➔ Patents ➔ TBoP 	<ul style="list-style-type: none"> ➔ R&D ➔ Patents ➔ TBoP ➔ High-tech products and sectors ➔ Bibliometrics ➔ Human resources ➔ Innovation surveys 	<ul style="list-style-type: none"> ➔ R&D ➔ Patents ➔ TBoP ➔ High-tech products and sectors ➔ Bibliometrics ➔ Human resources ➔ Innovation surveys ➔ Innovations mentioned in technical literature ➔ Surveys of production technologies ➔ Government support of industrial technology ➔ Intangible investment ➔ Indicators of ICTs ➔ Input-Output matrixes ➔ Productivity ➔ Venture capital ➔ Mergers and acquisitions

Source: Mani (2007)

Theoretical Framework for Indicator Development

Initiatives that have shaped the theoretical framework for indicator development include:

- The ***Frascati Manual*** - first published 1963 (OECD)
 - provides recommendations and guidelines for standard practices of R&D surveys (Gault, 2006).
 - The main distinction between S&T activities and R&D is routine and novelty (Freeman and Soete, 2009)
- The ***Oslo Manual*** - first published 1992 (OECD)
 - provides theoretical and methodological foundations and guidelines for surveys to produce new innovation data and indicators (Smith, 2000)

Theoretical Framework for Indicator Development

- **The *Community Innovation Survey***
 - started in 1992 by Eurostat, collects data from a substantial number of firms in the member states of the EU
 - has become the major data source of the *European Innovation Scoreboard*
- ***Blue Sky Indicators Project***
 - new S&T indicators project, launched OECD, concerned with the development of new indicators to better serve policy needs
- The OECD indicates that only very indirect and partial indicators for the knowledge economy exist (OECD, 1996)

TRADITIONAL OR STANDARD INDICATORS

The principal knowledge indicators, as collected and standardised by the OECD include:

- **R&D expenditure, R&D personnel, research fields** etc collected according to procedures and categories described in the *Frascati Manual*
- **Patents** - records of the United States Patent (USPTO) and European Patent Offices (EPO)
- **Technology Balance of Payments (TBoP)**
- **Other data** available for the construction of traditional indicators, include
 - Bibliometric data on patterns of scientific publication and citation
 - Various new types of data to measure innovation processes and ad hoc data sources constructed by researchers to explore scientific research issues (Smith, 2000)

Source: OECD (1996)

MEASURING KNOWLEDGE STOCKS AND FLOWS

- A general sense in the literature that existing measures for S&T indicators need to be improved
- Indicators needed for the stocks and flows of knowledge to improve the measurement of knowledge performance (OECD, 1996).
- The measurement of **knowledge stocks** - can be based on current S&T indicators if techniques are developed for dealing with obsolescence (but cycles can repeat themselves)

MEASURING KNOWLEDGE STOCKS AND FLOWS

- Proxy indicators often used to measure **knowledge flows** are:
 - ***Embodied diffusions***
 - the introduction into the production processes of machinery, equipment and components that incorporate new technology
 - ***Disembodied diffusions***
 - the transmission of knowledge, technical expertise or technology in the form of patents, licences and know-how)

MEASURING KNOWLEDGE STOCKS AND FLOWS

- The flows of **embodied knowledge** (i.e. embodied technology or R&D) can be measured using **input-output techniques**. Inter-industry flows of R&D embodied in intermediate and capital goods can be modelled using technology flow matrices
- Technology diffusion patterns can be measured through surveys i.e. Canadian surveys have asked firms about their use of various advanced manufacturing and ICT technologies

MEASURING KNOWLEDGE STOCKS AND FLOWS

- *Information technology indicators* developed
- Various indicators compiled by OECD the number of personal computers, fax machines etc per household
- Also number of households and businesses with internet connections
- Flows of **disembodied knowledge** measured through citation analysis i.e. publications

MEASURING KNOWLEDGE OUTPUTS

- Traditional indicators measure inputs into the knowledge economy.
- Estimation of social and private rates of return to knowledge investments must be measured
- Knowledge economy indicators should go beyond measuring knowledge inputs to measuring stock and flows, rates of return and distribution networks (OECD, 1996)

MEASURING KNOWLEDGE OUTPUTS

- Standard R&D-related inputs should be used as a starting point in measuring knowledge outputs (OECD, 1996)
- Rough indicators developed which translate certain knowledge inputs into knowledge outputs to compare economic performance (OECD, 1996)
- These measures tend to categorise industrial sectors from low to high intensity concerning R&D, knowledge or information (OECD, 1996)
 - e.g. the OECD classifies high-technology, medium-technology and low-technology manufacturing sectors

MEASURING KNOWLEDGE OUTPUTS

- “The measures are based on the assumption that certain knowledge-intensive sectors play a key role in the long-run performance of countries by producing spill-over benefits, providing high-skill and high-wage employment and generating higher returns to capital and labour” (OECD, 1996:35)
- Employment and occupational data to categorise jobs and to estimate the proportion of economic effort devoted to knowledge related activities (OECD, 1996).
- Rates of return i.e. social and private rates of return are generally estimated by computing the benefits and the costs of innovation (OECD, 1996).
- **Regression analysis** used to estimate returns of R&D in terms of total factor productivity (OECD, 1996)
- Weakness of data availability on skills levels for South Africa

MEASURING KNOWLEDGE NETWORKS

- New indicators required to capture innovation process and the distribution of knowledge (OECD, 1996)
- Involves measuring national innovation systems and distribution of knowledge among different actors and institutions (OECD, 1996)
- Innovation surveys capture: factors affecting propensity to innovate and knowledge diffusion aspects (OECD, 1996).
- Analysis in this regard includes:
 - ◆ firms propensity to innovate re traditional inputs
 - ◆ activities related to new product development
 - ◆ use of skilled labour, new domestic and imported equipment

MEASURING KNOWLEDGE NETWORKS

Innovation Surveys Measure (continued):

- Production and sales of incrementally and radically new products
- Sources of information relevant to innovation
- R&D performance and technical collaboration
- Perceptions of obstacles and stimuli to innovation
- Profitability
- Regulatory systems
- Institutional networking
- The distribution of knowledge among universities, public research institutions and industry
- The distribution of knowledge within a market between suppliers and users

INDICATORS CONCERNING THE MEASUREMENT OF THE DISTRIBUTION OF KNOWLEDGE

- Measurement of **institutional capabilities to transfer knowledge** include:
 - ◆ number, specialisation and funding of:
co-operative research projects among universities,
public research institutes and industry;
university-industry research centres;
 - ◆ number and technological specialisation of co-
patenting and co-publication among universities,
public research institutions and industry;
 - ◆ personnel mobility and patterns of recruitment among
universities, public research institutes and industry

INDICATORS RE MEASUREMENT OF KNOWLEDGE DISTRIBUTION

- Methods by which firms access findings of university research
- Measurement of market interactions, or **private sector's capabilities** in transferring knowledge, based on:
 - Research co-operation with the enterprise sector
 - Participation of firms in industry-wide standardisation activities
 - Rates of mobility of researchers across firms and sectors;
 - Methods of access of firms to findings of other firms and sectors,
 - Degree of internationalisation
- *Source: OECD, 1996:41*

MEASURING KNOWLEDGE AND LEARNING

- Traditional proxies for measuring human capital, not reflective of quality or returns to investment (OECD, 1996)
- On-the-job training poses significant measurement problems (OECD, 1996)
- Human capital indicators = central measures for a knowledge economy (OECD, 1996)
- Measures include **private rates of return** (changes in human skills and competencies) (OECD, 1996)
- Firms' training expenditure is assessed by type of training, staff category and the type of firm

LIMITATIONS OF INDICATORS

It is well known that some of these indicators and their data sources have limitations. Freeman and Soete (2009:584) suggest that:

- “The measurement of STI investments is not an easy matter. Even simply to record the expenditures on personnel and equipment *inputs* to the R&D process is by no means as easy as it may appear at first sight, and international comparisons are beset with numerous problems, as 40 years of painstaking OECD harmonisation work bears witness to.
- The measurement of the *outputs* of the system is even more difficult and will always remain controversial”

LIMITATIONS OF INDICATORS

Limitations concerning data sources for indicator development include:

- Widely used indicators, narrow the discussion of issues
- R&D figures measure only inputs, do not necessarily relate to innovation outcomes
- R&D data may underestimate the amount of innovative activity in small firms
- Patent data is limited by the variations in firms' and industries' propensity to innovate
- Patent data may also underestimate innovation in large firms

Source: Smith (2000)

LIMITATIONS OF INDICATORS

- Bibliometric data good indicator of research's' changing shape (but not the innovation process)
- Innovation data is challenged by ability to capture aspects of novelty, learning and change involved in innovation
- Main future challenge; development of new indicators dynamics of innovation and knowledge creation
- KEIs with a focus on the social context are identified as an area for development

Source: Smith (2000)

IMPORTANT CONSIDERATIONS FOR INDICATOR DEVELOPMENT

- Indicator development requires dialogue between the producers and the users of indicators (Gault, 2007)
- Co-ordination across directorates/departments (Gault, 2007) (SA!)
- Focus on indicators that can communicate the 'big picture' (Gault, 2007)
- Micro and macro data to be used (Gault, 2007)
- Full spectrum of economic activities need to be taken into account, not just high tech, importance of manufacturing and services (Smith, 2000)
- The S&T concept needs to be broadened in order to include innovation to offer new policy insights (Freeman and Soete, 2009)

IMPORTANT CONSIDERATIONS FOR INDICATOR DEVELOPMENT

- A multi-indicator approach is required (Smith, 2000)
- Possible addition of knowledge related indicators to measurements of productivity (de Haan and van Rooijen-Horsten, 2003)
- Indicators to reflect the flow of knowledge between institutions – important policy implications (Smith, 2000)
- Weakness due to gap between conceptual and empirical aspects (Radosevic, 2007) i.e. theory and practice
- A pronounced trend in S&T indicators is the mixing of ‘hard’ and ‘soft’ data (Radosevic, 2007)
- Composite indicators useful for analysis at the appropriate level, but limited at aggregate level (Radosevic, 2007)
- Wider indicators incorporating environmental and social aspects

Future indicator developments

- Novel indicators for new areas of research and policy analysis are a future challenge (Smith, 2000)

Identified areas for future indicator development (Gault, 2006b):

- A networked approach to leverage work in statistical fields
- Improve the understanding of the mobility of human resources for S&T
- Track the circulation of disembodied knowledge and assess the economic value of innovation through the use of patent statistics

Future indicator developments

The following have been identified as areas for future indicator development (continued):

- Trace the activities and networks of the science system through use of patent statistics
- Look in depth at the innovative activity of a few select service activities
- Study the innovation process at firm-level, particularly small firms
- Measure the internationalisation of S&T activities through the use of data on the activities of multinational enterprises and patent data
- Construct indicators for specific S&T policies such as the generosity of R&D tax credits

Source: Gault, 2006b

Future indicator developments

- Cross-cutting indicators is a new direction in terms of developing new and improved KEIs.
- Human resources
 - Institutions i.e. education, training, lifelong learning, immigration and mobility, etc
 - People i.e. stock and flows classified by industry, occupation, level of education and field of study
- Firm characteristics
- Sustainability
Gault (2007)

Future indicator developments: Environmental Innovation

ENVIRONMENTAL INNOVATION

- An emerging theme and research area in the knowledge economy. CIS contains questions on environmental innovations
- A new or significantly improved product (good or service), process, organisational method or marketing method that creates environmental benefits compared to alternatives

Future indicator developments: Environmental Innovation

- Certain indexes include indicators concerning environmental issues eg the Oregon Innovation Index (OII) :
 - Renewable energy usage
 - Greenhouse Gas Emissions
 - Energy intensity

What are innovation and knowledge indicators in South Africa?

- Same as in the rest of the world (have both OECD/EU compatible R&D and Innovation Surveys as a start)
- Need surveys and metrics (e.g. patent counts) to provide indicators
- South Africa lacks detailed educational attainment and skills levels data for knowledge economy indicators

Innovation & R&D Surveys

- CeSTII undertaking second innovation survey
- First survey (CIS4) 2002-2004
- Second survey (CIS5) 2005-2007

- New R&D Survey series since 2001/02 now rolling out 2008/09 (sixth survey)

Is the Innovation Chasm in SA a myth?

- South Africa apparently falls short in transforming research into commercially-viable products and services and the creation of new industries

The facts

- 2006/07 R&D expenditure at 0.95% GDP (R16.5 billion)
- 55.9% of R&D performed by business
- 19% of Bus R&D funded by government

Is the Innovation Chasm in SA a myth?

The facts (cont.)

- 51.7% of SA firms are innovative vs an EU average of 40%
- 21.9 % of turnover generated by innovations new to the market or new to the firm = R145 billion (versus R27.8 billion expenditure on innovation) 2004
- 6.5% of all innovative enterprises received public funding for innovation (vs an average of about 25% in EU)

Is the Innovation Chasm in SA a myth?

Conclusion

- There is probably an innovation chasm in terms of converting R&D projects to new technology products
- Innovative activity rate is high (easier in less mature economies)
- Lots of incremental innovations and improvements and improved services
- Firms are getting a good return on their innovation expenditure (5.2 x return)

Examples of innovations in SA (2005-2007)

- Introduced robotic handling of bricks rather than manual or mechanical handling
- Beneficiation of rubber waste
- Twine and rope used alternative low cost raw materials and reduced costs by 32%
- Introduced ready to eat omelettes, new flavour sandwiches
- Development of new eucalyptus hybrids for saw-log production

Main References

- DE HAAN, M. & VAN ROOIJEN-HORSTEN, M. 2003. *Knowledge Indicators based on Satellite Accounts*. Final report for NESIS – Work package 5.1. Statistics Netherlands, Division of Macro-economic Statistics and Dissemination.
- FREEMAN, C. & SOETE, L. 2009. *Developing science, technology and innovation indicators: What we can learn from the past*. *Research Policy*, 38:583-589.
- GAULT, F. 2006b. *What indicators for science, technology and innovation policies in the 21st century?* Paper presented at the OECD Blue Sky II Forum. Ottawa, Canada, 25-27 September 2006.
- GAULT, F. 2007. *Science, Technology and Innovation Indicators in the OECD: Next Steps*. Presentation at the VII Ibero-American Congress of Science and Technology Indicators, Sao Paulo, 23-25 May 2007.

Main References

- (OECD) ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT. 1996. *The Knowledge-based Economy*. Paris: OECD.
- RADOSEVIC, S. 2007. *Knowledge based economy indicators. Presentation at the Science, technology and innovation indicators: Trends and challenges in South Eastern Europe workshop*. Skopje, 27-31 March 2007. Accessed: 23 June 2009. Available: http://www.uis.unesco.org/TEMPLATE/pdf/S&T/Workshops/Skopje/032007_7.pdf
- SMITH, K. 2000. *Innovation Indicators and the Knowledge Economy: Concepts, Results and Policy Changes*. Paper presented at the Quinta Conferenza Nazionale di Statistica: innovazione tecnologica e informazione statistica. Rome, 15-17 November 2000. Accessed: 16 March 2009. Available: <http://www.istat.it/istat/eventi/conferenze/quintaconf/smith.pdf>