Development of a Profile of Best Practices in the NSI

NATIONAL ADVISORY COUNCIL ON INNOVATION

SOUTH AFRICA

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Contents

Abbreviations

APEC	Asia Pacific Economic Cooperation
ARC	Australian Research Council
AU	African Union
CIS	Community Innovation Systems
CoE	Centres of Excellence
CSTP	Council for Science and Technology Policy
CSTP	Committee for Scientific & Technological Policy
DoE	Department of Education, South Africa
DST	Department of Science and Technology, South Africa
EC	European Commission
EPO	European Patent Office
EU	European Union
EUROSTAT	The European Statistics Office
FTE	Full-time equivalent
GABAORD	Government Budget Appropriations or Outlays for R&D
GDP	Gross Domestic Product
GTZ	German Technical Cooperation Agency
HEFCE	Higher Education Funding Council England
HEI	Higher Education Institution
HERD	Higher Education R&D
HMSO	Her Majesty's Stationery Office
HRST	Human Resources in Science and Technology
ICCP	Committee for Information, Computers & Communications Policy
ICT	Information & Computer Technologies
IMSI	Intelligent Manufacturing Systems Initiative
IPR	Intellectual Property Rights
ISI	Institute for Scientific Information, USA
NESTI	National Experts in Science & Technology Indicators (OECD)
NORDFORSK	Nordic Research Board
NRDC	National Research Development Corporation
NSB	National Science Board, USA
NSF	National Science Foundation, USA
NSI	National System of Innovation
OECD	Organisation for Economic Cooperation and Development

OGC	Office of Government Commerce
R&D	Research and Development
S&T	Science and Technology
SCI	Science Citation Index
SETI	Science, Engineering and Technology Institution
SIS	Science Indicator Systems
SMME	Small, Medium and Micro Enterprises
STA	Science and Technology Agency
TBP	Trade Balance of Payments
THRIP	Technological Human Resources for Industry Programme
TSP	Technology Station Programme
UN	United Nations
UNESCO	United Nations' Educational, Scientific and Cultural Organization
USA	United States of America
VIB	Inter-university Institute for Biotechnology

Executive Summary

This document reports the results of an effort to identify international best practice related to the management of National Systems of Innovation and develop relevant recommendations for South Africa.

The report is divided into three main chapters. Chapter one "Best Practice in Governance" identifies issues related to structures and organisational structures; priority setting; public funding of research and development (R&D) and management of science and technology (S&T) capacity development. Chapter two "Best Practice: Monitoring Science and Technology Systems" provides an overview of the approaches used internationally to monitor and assess the performance of the national system of innovations (NSI). In the chapter are discussed the approaches used by the National Science Foundation (NSF) in the USA; the Science and Technology Agency in Japan; the Organisation for Economic Cooperation and Development (OECD) indicators and the approach of the Trend Chart on Innovation by the European Commission. The third chapter "Best Practice: Public-Private Linkages/ Technology Transfer in Science and Technology" identifies issues related to public-private linkages in science and technology in general and of technology transfer from universities in particular. Each chapter contains a relevant to South Africa discussion and a set of recommendations. The report ends with a "Summary of Recommendations" where all recommendations are presented together.

The chapter on governance identifies that in countries with systems close to dual and decentralized archetypes governments take actions to strengthen structures which enable greater coordination across the research domains. It is identified that about half the OECD countries have a single department responsible for more than 50% of the overall research budget. Japan and Australia were moved in this category in 2001 and in France 80% of the research budget is allocated through the Ministry for Research and New Technologies.

Technology foresight is identified as the preferred mechanism for setting research priorities. It is identified that prioritization processes are fuelled by the efforts of policy makers, who are under public pressure, to respond to societal needs, maximize returns on public investment and enhance accountability. In certain countries identification of research priorities is directly linked to selecting engines of future economic growth (Korea), to redirecting their research systems towards emerging areas (USA, Denmark) and addressing budgetary constraints (Czech Republic).

In the field of public support for R&D it is identified that governments increase the volume of the allocated resources based on the recognition that R&D funding is a major determinant of the performance of the systems of innovation. Preference is given in allocating research funding according to competitive grant modes. The establishment of research chairs and the introduction of tax incentives for R&D appear to be two dominant forms of strengthening the national systems of innovation internationally. Emphasis is placed in institutionalising the support of critical areas of the science base (i.e. physical assets and cyber based infrastructure necessary for research by the country's scientists) which are not supported naturally by other funding mechanisms (e.g. research ships, equipment etc) and in setting up mechanisms monitoring "rust out" of facilities and platforms in order to inform the policy makers appropriately.

The final issue examined in the chapter is the management of S&T capacity development. Feeding the S&T pipeline to ensure an adequate supply of S&T personnel is recognised internationally as the most important challenge in the effort to support science, technology and innovation. In modern times investment in scientific human capital has been a cornerstone of the economic development policies of OECD countries as well as for emerging economies aspiring to climb the development ladder. Successful policies are based on making public sector research more attractive by increasing salaries and improving employment conditions and improving stipends for PhD students. Complementary policies are also enacted in order to retain and attract scientific staff from abroad.

In the chapter on monitoring it is identified that governments internationally improve the strategic intelligence upon which policy choices and decisions are based by developing Science Indicators Systems. Science Indicators Systems (SIS) are comprehensive collections of indicators describing the *status quo* of a country's scientific, technological and innovation activities within the local socio-economic environment and within the international arena. The National Science Foundation's approach in producing the "Science and Engineering Indicators" is identified as best practice internationally. The NSF Indicators are produced in fulfilment of the National Science Board's mandate to report to Congress on the status and health of science and technology in the USA. Factors which have been identified to have contributed in the success of the "Science and Engineering Indicators" include: firstly, it collects dispersed statistics all in only one book. Secondly, it discusses science mainly by way of charts rather than numbers. Tables appear primarily in the Appendix. Thirdly, it includes brief highlights for policy makers. Fourthly, there is small analysis. Finally, each edition always contains something new in terms of information and indicators.

A complementary approach to Indicators is the "*Trend Chart on Innovation in Europe*". The Trend Chart serves the "open policy co-ordination approach" laid down by the Lisbon Council in March 2000. It supports organisation and scheme managers in Europe with summarized and concise information and statistics on innovation policies, performances and trends in the European Union (EU). It is also a European forum for benchmarking and the exchange of good practices in the area of innovation policy.

The trend chart tracks innovation policy developments in all 25 European Union (EU) Member States, plus Bulgaria, Iceland, Israel, Liechtenstein, Norway, Romania, Switzerland and Turkey. It also provides a policy monitoring service for three other non- European zones: NAFTA/Brazil, Asia and the MEDA[a] countries.

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[a] The MEDA programme is the principal financial instrument of the European Union for the implementation of the Euro-Mediterranean Partnership. The Programme offers technical and financial support measures to accompany

The chapter on public- private partnerships/technology transfer identifies that the type of partnership best suited for a given policy objective will depend not only on the shareholders and their objectives, but also on the type of market or systemic failure being addressed and focuses more extensively on efforts by governments to bring closer universities and industry.

Following the European Commission (EC) it is argued that innovation should be fused and become part of all regulatory and institutional reform in a country. The EC argues that current innovation policy – "second generation innovation policy" - emphasizes the importance of the systems and infrastructures that support innovation**.** These, however, are influenced by many policy areas, in particular research, education, procurement, taxation, intellectual property (IP) rights and competition policy. But these policy areas are not developed having in mind innovation issues and the need to work together is not always recognised. The aim of the "third generation innovation policy" is to maximize the chances that regulatory reform will support innovation objectives, rather than impede or undermine them. While the argument is more profound in the area of technology transfer the approach is valid across the total spectrum in the management of NSI.

It is argued that mechanisms facilitating industry science interactions (technology transfer offices; incubators; science parks etc) are necessary but not sufficient conditions to bring the desirable result of technology transfer from universities to industry. There are features in the specific technological domains which should be expected to be influential. Some obvious factors would be government regulations (promoting or inhibiting collaboration); the R&D strength of the relevant industry (greater strength leads to more demand led interactions); the size structure of firms (larger firms may lead to more formal interaction); science and educational policies (e.g. the size of funding and the orientation of funding) which affect the strength of the academic research base and the quality and volume of 'output' of graduates in particular fields; the existence of a developed venture capital market; the

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the reform of economic and social structures in the Mediterranean partner countries.

functioning of various bridging institutions and the prevalent values as regards industry-academia collaboration.

Based on the above and on the local scene the report advances the following recommendations. In the heart of the recommendations lie the establishment of performance and monitoring metrics on an horizontal basis (across government and the innovation system.

Recommendations related to governance:

- The Department of Science and Technology (DST) should consider recommending the establishment of Chief Scientists Offices in Government Departments both nationally and provincially. The Chief Scientists Officers – preferably at the level of Deputy Director General - will be responsible for promoting effective use of science in policy making; for managing the Departments' research and development resources; for enhancing science capacity and quality in the fields of interest of the particular Departments and raising awareness and understanding of the effects of science and research on the Departments' activities. Chief Scientists will be ambassadors for S&T integration.

- DST within its mandate to coordinate national research and innovation should consider adopting an approach of "coordination through monitoring". DST should monitor the research funding activities of Government and publish the results annually. The "Annual Review of Government Funded R&D" will describe the extend to which the current Departmental science and technology programmes (of the individual government departments) are supporting the S&T infrastructure and are matched to the scientific and technological needs of the country. Furthermore the Review will highlight the prospects of bringing about a closer alignment between the various departmental programmes and the country's needs. The OECD recommendations for the collection of data and the development of a report on Government Budget Appropriations or Outlays for R&D

(GABOARD) and the "Forward Look" by the Office of Science and Technology (OST) in the UK can be used as prototypes.

- DST should monitor closely the implementation and fine development of the tax incentives for R&D scheme and its implications on other direct support schemes. The tax incentives scheme may have adverse consequences in the business sector innovation activities if applied inappropriately and/or if the government withdrew its support from existing direct incentives schemes. Similarly DST should monitor the progress for the establishment of research chairs at the universities with the ultimate objective of keeping the momentum and alleviating possible obstacles in the process.

- DST, within its mandate to co-ordinate the scientific and technological system, should establish an inter-departmental committee on "Critical Scientific and Technological Infrastructures". The mandate of the committee should be to investigate and make recommendations concerning policy and programmes affecting "critical scientific and technological infrastructures" such as research and training facilities, research equipment, scientific and technological telecommunications, and R&D management.

  The Committee should consider among others the viability of introducing

  - the funding of "critical S&T infrastructures" as a separate line item in the governmental budget (Expenditure defrayed from the National Revenue Account)
  - approaches promoting closer collaboration on aspects of critical S&T infrastructure among organisations reporting to different government departments (e.g. academic institutions, research councils and parastatals.)

- The National Research Foundation (NRF) should institutionalise the support of research and training equipment by establishing an appropriate directorate/division. The division should be funded by dedicated (earmarked) funds, by top-slicing the budget of the other directorates and by raising funds from local and international donors. Similarly the NRF should establish appropriate `competitive grants'/funding mechanisms promoting : the interaction between academia and industry for the development and construction of new or improved equipment; the maintenance and augmentation of the R&T equipment infrastructure; the development of the necessary infrastructures in institutions that are either lacking or are with deficient infrastructures. A programme promoting the development of remote utilisation of equipment should be considered as an urgent priority in view of its possible impact across all other programmes. Different programmes should be established for different objectives.

- The funding formula of the Department of Education (DoE) for academic institutions should make R&T equipment an explicit component of the formula. Furthermore, adequate funds should be earmarked for at least the next five years in order to facilitate the required replacement and upgrading of R&T equipment.

- DST, in collaboration with the DoE, should consider undertaking a drive to double the number of scientists and engineers graduating from the higher education sector within the next 10 years. Such a target will require an expected growth of 7% per year. Innovative approaches should be considered for funding this objective. A possible approach is to request the universities to develop proposals of the resources they require and they are prepared to commit in order to achieve the objective and choose to support those which contribute most in the achievement of the objective.

- Expansion of the higher education sector will be constraint in the short term by lack of appropriate number of academics. DST and Higher Education South Africa (HESA) should motivate to the Department of Home Affairs the introduction of "speedy immigration visas" for academics who may wish to come to South Africa in fields of high priority. A complementary approach is to provide incentives for the repatriation of South African academics abroad. A five year tax holiday with repatriation financial assistance and possible NRF research support may attract a number of academics who are already familiar with the South Africa system.

Recommendations related to monitoring:

- The National Advisory Council for Innovation (NACI) should develop in regular intervals (e.g. biennially) the "South African Science and Innovation Indicators". The report should present quantitative descriptions of key aspects of the scope, quality and vitality of the country's science and innovation enterprise. The report should be submitted to Cabinet and Parliament and should be publicly available for public and private policy makers. The NSF "Science and Engineering Indicators" could be used as blueprint.

- NACI should consider approaching the European Commission (Innovation Policy Directorate of DG Enterprise and Industry) with the objective of participating in the Trend Chart programme activities. Such participation not only will market the country's innovation system internationally but it will also provide the necessary discipline and benchmarking expertise required in the monitoring of the national innovation system.

- NACI should consider creating a fund supporting long term research on issues of science and innovation policy. Currently the only support for science and innovation policy research is coming from NACI's procurement activities. While NACI's approach is supporting to a certain extend the existing expertise in the field in the country, the lack of institutionalised long term support constraints the development of new expertise in the field of science and innovation monitoring and assessment.

Recommendations related to public-private linkages/technology transfer:

- DST should establish an IP Agency. The Agency will have the responsibility to promote IP within the public research institutes domain. The Agency should provide financial support for the establishment of IP, technology transfer and technology licensing offices within the public research institutes in the country and it will subsidize patent filling and maintenance costs. The Agency should further undertake to provide regulations from time to time related to the distribution of royalties of the successful inventions. A substantial percentage of royalties should accrue to individual researchers until that time that there is a culture supporting patents in the country.

- DST, (as the R&D coordinating Department) in collaboration with all relevant Departments should consider developing and expanding a Technology in Human Resources for Industry (THRIP) type programme. THRIP currently is supported by the Department of Trade and Industry (DTI) and it supports the mission and areas of priority of DTI. In a similar vein the programme should receive funds from the Department of Minerals and Energy, Department of Environment Affairs etc in order to support their respective missions and areas of priority.

- HESA, as the voice of the higher education institutions (HEIs), with the support of DST should establish the necessary structures for the monitoring and assessment of the regulatory environment in which the universities of the country operate. It should utilize the produced intelligence in order to inform policy and decision makers about appropriate actions. Similarly HESA with support from the DST should undertake the regular monitoring of the way higher education institutions fulfil their mission related to technology transfer and disseminate the information to its members. The objectives of the effort will be: to provide information regarding the continuing development of interactions; to provide information supporting the development of public funding of the third mission of the HEIs activity; to provide to HEIs benchmarking and management information.

- DST should aim to enhance the demand side for university based industrial R&D in the country. The introduction of tax incentives for R&D may be a particular useful approach as it has the potential to attract international R&D resources in the country.

- DoE and DST should place priority in enhancing basic and mission oriented research in the higher education institutions in the country.

University administrations should empower their academic staff to undertake research, development and innovation activities. Promoting decentralized approaches and supporting staff has the potential to bring the desirable effect.

The Thsumisano Trust with the support of the DST should consider enhancing its mission to support the third mission of the universities across the total spectrum of the mission (not only for the establishment of technology station) and across all universities in the country.

Preamble

The objective of this effort is to produce a profile of best practices in key spheres that account for a significant portion of the productivity, effectiveness and efficiency of the NSI.

More specifically the terms of reference specify that the expected output will be:

- Summary of national and international best practices that account for a significant portion of the productivity, efficiency and effectiveness of the NSI, and

- Informed recommendations on best practices that should be adopted in South Africa. The policy recommendations will then be converted into a Ministerial advice document.

Possible areas for the identification of best practice, mentioned in the terms of reference, include the following; monitoring infrastructure needs availability and utilisation; technology transfer; governance of the NSI; role of innovation in public-private linkages; incentives for innovation; smart ways of accessing foreign funding; incentives for regional co-operation; capacity building; role of full time equivalents (FTE) in innovation capacity provision.

Identifying best practices for benchmarking purposes (informed recommendations) is a widely used approach developed for the corporate level. At the national level benchmarking and identification of best practices are usually manifested in the form of national comparisons according to sets of relevant indicators.

It should be emphasised that identification of best practise faces a number of challenges. How do you decide that particular performance is the result of best practice? If particular policies are followed by a number of successful countries does it mean that those policies are best practices? To what depth a particular practice and its attributions should be investigated? and others. At the national level issues of best practice should also be seen in the context of other policies that may affect or be affected by best practice and the historical evolution and political dynamics of the particular recommendation.

This report is structured in three chapters which examine issues of governance; monitoring and public – private linkages / technology transfer in science and technology. Under governance are investigated issues of structures and organisational settings; issues of priority setting; public funding of science and technology (incentives) and management of S&T capacity development.

In each of the chapters we contrast international best practice with approaches in South Africa and we develop relevant recommendations.

Best Practices in Governance

Introduction

Governance of the science system as a whole is defined[1] as the decision making process that governs structural adjustments, priority setting, the allocation of funds and the management of human resources in a way that efficiently responds to the concerns of the various stakeholders involved in the system.

OECD has investigated recently the issue S&T governance under the aegis of the OECD Committee for Scientific and Technological Policy (CSTP). The project identified challenges concerning the governance of public research systems and then it addressed issues of structure, priority setting, funding and the management of human resources. As main challenges were identified the response of the innovation system to societal needs, the increasing multidisciplinarity of scientific research and the evolving interactions between institutions involved in the funding and performance of research activities funded by public funds. Information on reforms and good practice with regard to policy responses to identified challenges were collected through country surveys, case studies[2] and literature surveys.

Governance structures and organisational settings

The OECD report identifies three archetypes of structures: [b] the centralized archetype with a strong top-down management approach, high share of institutional funding and an important role for public research institutions; the decentralized archetype with relatively low top-down control, hardly any institutional funding and strong research base at universities and the dual system with mixed top-down and bottom up approaches to priority setting, a mix of institutional and competitive funding and a "balance" between

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[b] The same approach is outlined for the South African environment in A Pouris (1995) "Towards a metric of organisational structures for S&T policy: the concept of Science Policy Space" *SAJ of Science* **91:** 1-4

research performing institutions. Countries can be positioned in the triangle of the three archetypes according to their characteristics.

Each archetype has its own advantages and challenges. For example the report suggests that "Although on the whole more centralized systems seem to be more rigid, once changes have been decided they might be easier to make because top down procedures are shorter than those in the mixed approach of the dual system or the bottom up approach of the decentralized system, both of which take more time for coordination and consensus building before decisions can be made"[3]

In countries with systems close to dual and decentralized archetypes governments take actions to strengthen structures which enable greater coordination across the research domains. The greater interest in research shown by different policy domains and the scale and complexity of research are some of the reasons behind the move towards more centralized models of governance.

Two approaches stand out:

- Consolidating major research funding responsibilities within a single department
- Developing formal structures for interdepartmental co-ordination

Concerning the first approach about half the OECD countries have a single department responsible for more than 50% of the overall research budget. Japan and Australia were moved in this category in 2001. In France 80% of the research budget is allocated through the Ministry for Research and New Technologies.

As far as formal structures for interdepartmental coordination is concerned countries utilize a variety of approaches ranging from chief scientists and ministries with coordinating responsibilities to coordinating bodies drawing in external members (e.g. Science and Technology Policy Council in Finland; the Council for Science and Technology Policy in Japan; the Science and Technology Policy Council in Ireland etc).

BOX 1: Reforms in Japan

In Japan, a major administrative reform of the science system took place in the beginning of 2001, including the establishment of a central co-ordinating body for science and technology policy in the Cabinet Office of the Prime Minister (Council for Science and Technology Policy-CSTP), and the merger of the ministry responsible for education and science and the agency implementing research and development into the newly created Ministry of Education, Culture, Sports, Science and Technology-MEXT). More autonomy was given to national research institutions and national universities. The second phase of the Science and Technology Basic Plan outlining science policy objectives was approved by the government in 2001, following the first phase, implemented in 1996.

The objectives of the Council for Science and Technology Policy are basic/comprehensive science and technology policy planning and general co-ordination among the ministries comprehensive role with regard to science and technology policy by combining various types of research, academic included.

National universities are being re-organized into independent administrative institutions, with the aim of making them more autonomous and more accountable for their results. This re-organization was finalized in 2004.

With these reforms, the Japanese science system aims to priorities the allocation of resources to make R&D infrastructure, to view R&D investments in terms of a return to society and industry, and to position Japan's science and technology as a contribution to world knowledge. Great expectations are attached to the results of these reforms.

The above efforts are reflected lower down in the hierarchy of research systems. Governments attempt to improve the contributions and outputs of public research organisations and universities using a number of approaches. One approach is to centralize the administration of a number of government/public research institutions. In Spain the main research organisations were transferred to the Ministry of Science and Technology in 2000 as a first step in developing organisational reforms and changes. Another approach is the privatization of research institutions. In the UK the Department of Trade and Industry turned its research institutions into executive agencies and then it privatized a number of them such as the National Engineering Laboratory and the Laboratory of Government Chemists. Japan is using similar approaches.

BOX 2: Restructuring in the research Councils in the UK, Sweden and Norway

In the United Kingdom, research councils (RCs) have been gradually established since 1920 to manage and fund generally applicable or basic research, the priorities of which are in principle to be determined autonomously by the scientific community. They were established as independent non-departmental public bodies to support basic, strategic and applied research, postgraduate training and the public understanding of science.

In 1994 the UK RCs underwent re-organization as a result of the 1993 White Paper "Realizing our Potential". The rationale was to get them closer to potential users and structure them so that RCs could "identify areas for cross-fertilization and integration along the continuum of basic, strategic and applied research". The restructuring resulted in the creation of seven research councils. Each was provided a mission statement recognizing the importance of research undertaken to respond to user needs and support wealth creation. Each council came to have a part-time chairman from industry. They receive most of their funding (67%) via the science budget of the Office of Science and Technology (OST), but also from government departments, industry, charities and overseas source.

With effect from 1 January 2001, the Swedish parliament decided to re-organize its public research-funding agency system. This new structure was created to serve several purposes: concentrate efforts in key scientific fields, promote co-operation between different fields of research, stimulate interdisciplinary work, support outstanding research talents, improve the dissemination of information about research and research results and support work related to important societal questions (gender equality, ethical issues).

The new structure replaced a system of responsibilities which were dispersed in a variety of institutions (11 different research councils). It now comprises the *Swedish Research Council,* consisting of three separate councils (humanities and social science, natural science and technology, medicine) and a special committee for educational science. While the Council's main task is still defined as "supporting fundamental research in all scientific fields", tasks also include more general items relating to managing the science systems such as promoting renewal, profile establishment and mobility in the research community, creating a good research environment and advising the government on research policy issues.

Funding from the Council is mostly granted on the basis of competitive procedures. In its funding decisions, the Council has to take special account of support to young researchers, heavy equipment and support for "minor" subjects in the humanities.

In addition to the major Research Council, two special research councils have been established: the Swedish Research Council for Working Life and Social Sciences and the Swedish Research Council for Environment, Spatial Planning and Agricultural Sciences. The Swedish government saw a great need for new knowledge in these areas. This new funding structure for research was complemented by a new public authority for supporting applied research, technical development and innovation: the Swedish Agency for Innovation.

The transition to the new structure was facilitated not only because extensive resources were carried over from the old system, but also as a substantial proportion of the new funds made available for research were allocated to the new institutions (Swedish Ministry of Education and Science, 2000).

The Research Council of Norway (RCN) was established in 1993 by merging five primarily discipline-oriented research councils. The research council reform and the RCN were subject to a thorough international evaluation in 2000-2001. As a result of the evaluation the RCN will be reorganized. The six former divisions of the council organized by discipline will be replaced by three broad divisions, organized by function (*i.e.* advancement of subjects and disciplines, innovation and user-initiated research, strategic programmes). One of the aims of the reorganization is that the RCN will put stronger emphasis on long-term basic research as well as on R&D-based innovation. Other aims are improved user orientation and a stronger focus on interdisciplinary co-operation.

Research Councils, as intermediate level funding agencies, are strengthened internationally as means of running competitive programmes.

Priority Setting

Priority setting is viewed as a strategic activity with the potential of increasing the return on public investments on research. A 1991 OECD[4] study concluded that:

"Priority setting is necessary for increasing the relevance of research to economic growth

Priority setting is essentially a complex political process involving may people who interact with one another

The concept of priorities should include not only "thematic" priorities but also "structural" priorities as well (e.g. training of research personnel; balancing different types of funding instruments etc).

New approaches to priorities include the development of strategic medium term plans and science and technology "watch"".

The 2003 OECD study suggests that prioritization processes are fuelled by the efforts of policy makers, who are under public pressure, to respond to societal needs, maximize returns on public investment and enhance accountability. In certain countries identification of research priorities is directly linked to selecting engines of future economic growth (Korea), to redirecting their research systems towards emerging areas (USA, Denmark) and addressing budgetary constraints (Czech Republic).

The report identifies that although prioritization is a widespread activity; countries are divided in using bottom up approaches and top-down ones. In countries with top-down approaches the central government (sometimes on the advice of a central advisory body) adopts explicit strategies, policies or plans that specify priority areas for research (Austria, Hungary, Japan, and Norway). In the bottom up, decentralized approach different government agencies use their own approaches for priority identification (Sweden, USA).

In certain countries there is an integration or mix of top-down and bottom-up approaches. For example Australia is using a sectoral and pluralistic approach to priority setting. In 2001 the government's Innovation Action Plan, *Backing Australia's Ability*[5], flagged the need for an emphasis on research in which Australia enjoys or wants to build competitive advantage. The Minister of Education, Science and Training in 2002 announced four research priority areas (supported through the Australian Research Council (ARC)); nano and biomaterials; genome/phenome research; complex/intelligent systems and photon science and technology. A total of 33% of ARC funding is targeting these priority areas.

An example of a priority setting exercise with a direct follow up in terms of investment funding is the ICES-KIS programme in Netherlands. (Box 3)

Box 3: From Natural Resources to Knowledge Society- Netherlands

ICES-KIS projects are financed from a fund constituted by natural gas revenues. Realizing that the natural gas reserves would eventually be depleted, the government chose to set aside a portion of the revenue for long-term investments in structural aspects of the economy. This portion was put into a special fund, called the Fund for Economic Structure Improvement (FES). The FES law deals with issues such as input, output and management of the fund.

In the early 1990s the knowledge infrastructure (KIS) was incorporated into the investment strategy. It was argued that an investment impulse was needed to created multidisciplinary networks of knowledge in order to address some of the complex future bottlenecks and challenges in Dutch society. To implement this strategy, a separate, inter-ministerial task force (ICES/KIS) was formed with the mission to prepare the strategy for investment in creation, development, diffusion and implementation of knowledge in the Dutch economy. Responsibility is shared by all participation ministries, particularly the Ministry of Economic Affairs and the Ministry of Education, Culture and Science.

A third ICES/KIS-round was initiated in 2000. ICES/KIS-3 is different form the previous two rounds in that the process was changed form a top-down to a bottom-up approach. More transparency and participation form all parties on the knowledge market (universities, research institutes, industry, and government) was called upon to secure wide support for the process and the final outcome. Another important suggestion for improvement was to create a three-step approach. In the first step, a long list of thematic perspectives was created. With the input form representatives of about 40 organizations involved in science and R&D, 200 ideas were generated, which were clustered into eight thematic categories. In the second step the Dutch cabinet selected six out of the eight thematic categories. In the third step, a call for tender was put out. On 20 November 2003, the Dutch cabinet will decide which tenders will be awarded with funds. The decision-making process will be supported by the reviews of scientific experts and other experts who will have considered the societal and economic merits of the proposals.

The budget available for ICES/KIS-3 is EUR 805million. With IVES/KIS, the Netherlands created a tool for initiation and management of large multidisciplinary R&D projects, economy through public-private participation. A secondary objective of ICES/KIS is to reduce the rigidity of the Dutch research system by stimulation the scientific research structure to form an integral part of the national innovation system.

An approach used from the majority of the OECD countries in order to identify needs and capacities is technology foresight. Since the publication of the book[6] "Research Foresight" by Ben Martin and John Irvine in 1989 foresight exercises have become common place internationally. Foresight has been defined as: a process by which one comes to fuller understanding of the forces shaping the long term future which should be taken into account in policy formulation, planning and decision making…Foresight includes qualitative and quantitative means for monitoring clues and indicators of evolving trends and developments and is best and most useful when directly linked to the analysis of policy implications. Foresight prepares us to meet the needs and opportunities of the future. Foresight in government cannot define policy, but it can help condition policies to be more appropriate, more flexible, and more robust in their implementation, as times and circumstances change. Foresight is therefore closely tied to planning. It is not planning-merely a step in planning" (Coates 1985).[7] Foresight exercises have been undertaken in Canada, UK, Austria, Czech Republic, Germany, Korea, Netherlands and others. In countries that do not conduct foresight governments monitor the results of foresight exercises in other countries (Denmark, Iceland).

Public Funding of R&D

R&D funding is recognised as a major determinant of the performance of the science system. OECD (2003) identifies that all countries have enhanced strategic thinking in the development of their funding policies and mechanisms. Even though its country has its own traditions in the funding of research there are some trends and approaches common to all countries.

The first such trend concerns the volume of R&D funding. This is generally increasing in OECD countries. New funding from public sources is usually attached to specific priorities, new interdisciplinary research programmes and new funding schemes such as centres of excellence, public funds and foundations.

A second trend is related to changes in the allocation of funds. The proportion of funds distributed through competitive grant schemes is increasing relative to institutional funding in the public sector. This trend, however, may have a number of undesirable consequences (e.g. limit support for research infrastructure) and remedial funding modes may be required (e.g. funding full cost of research, funding instruments supporting research infrastructure and other). Similarly the use of institutional funds by government research institutions and universities is increasingly evaluated with measurable performance indicators.

A third trend is experimentation with new (to the countries) funding schemes. Examples include support for research in interdisciplinary priority areas such as the Fonds National de la Science in France and the establishment of the Leading Technological Institutes in Netherlands; establishment of public foundations with the mission to distribute research funds such as the Knowledge Foundation in Sweden, the Bay Zoltan Foundation for Applied Research in Hungary, the Fund for Research and Innovation in Norway and others.

Box 4: The UK example

In the United Kingdom competitive funding of university research relative to institutional funding has increased rapidly in recent years. This trend is giving rise to major concerns. Funds from the Higher Education Funding Councils (HEFC) enable (HEI) to conduct research that is not supported by other sources. As the proportion of "Project" funding increases, research work funded with such funds consumes the staff time and infrastructure funded by HEFCs. The situation is aggrevated in research areas where the proportion of HEFC funds accounts for a much smaller portion of total research, notably in biomedicine in the United Kingdom. There are indications that in this area the widening distortion between "project" and "institutional" funding is resulting in "squeezing out" of some forms of long-term basic research. Although research councils do fund basic research through the "responsive" mode funding, this cannot necessarily replace HEFC funding since the RC funding through this may fail to support research at the cutting edge, as there may be time lag for RC peer review committees to be responsive to research needs at the real frontier. Also, different types of funding may induce different behaviours on the part of the researches, *i.e.* the basic research that researchers undertake with RC funding and with HEFC funding could well be different.

Another concern is that the relatively diminishing funding through the HEFC stream of the dual funding system and the increasing grant funding is resulted in inadequate funding of university research infrastructure. Research Council (RC) funding, as well as charities and industry funding of university research only covers the direct cost of research. It is assessed that remedial investments are needed in generic institutional infrastructure (buildings, plant and services, IT networks and libraries), the minimum level of research equipment and facilities to attract external funding (the "well found laboratory"), and improvements in advanced scientific equipment to maintain infrastructure for world-class science. In response, the UK government has decided to allocate a major part of the annual science budget increase to boost university infrastructure. It recently announced that it will institute a dedicated earmarked capital stream for university science research infrastructure (HM Treasury 2002*). Also, the UK research-funding bodies (government, RC's and HEFCs) agree that grant funding of university research should move towards covering the full costs of research. The HEFCs, with the encouragement of their sponsoring bodies, are working to help HEIs develop a standardized methodology for assessing the full costs of research, which is needed to move towards covering full research costs by the grant funders (see also country report on the United Kingdom).

* HM Treasury (2002) Investing in Innovation: A strategy for Science, Engineering and Technology, accessible at www.hm-treasury.gov.uk

Probably the most popular approach of funding research is the establishment of centres of excellence. Japan launched a university resource allocation prioritization scheme called the 21 Century Centres of Excellence (COE) Programme in 2002. The objective is to create research units of world class excellence in selected fields. One hundred and thirteen units will receive JPY

100 TO 500 million each for five years. Finland adopted a strategy to establish centres of excellence in 1995. During the period 2000-2007 26 centres were supported. Austria established the K-plus centres; the Czech Republic introduced "research centres" in 2000 and others.

Finally a popular approach in supporting R&D is through R&D tax concessions. R&D tax concessions are used extensively as an indirect way to encourage business R&D expenditures. During 2005[8],18 OECD countries had R&D tax incentives in place compared to only 12 in 1996.

Tax incentives and direct subsidies possess different characteristics and may be used to achieve alternative, but complementary objectives. The main differences between these two policy measures are:

Direct subsidies involve discretionary government control over decision making; funds are selectively channelled to sectors, firms or investments identified as having the greatest potential for growth or the most pressing need for assistance. With tax incentives, markets determine which investments will be undertaken; decision making remains with investors.

Tax incentives are typically structured to deliver assistance to a broad range of sectors, firms or investments. Direct subsidies are usually targeted to relatively small numbers of sectors, firms or investments.

It is generally the case that direct subsidies can be accessed by both taxpaying and non-taxpaying firms. However, tax incentives can also be designed to achieve this objective through the use of refundability or loss-transfer provisions.

The revenue cost for direct subsidies is capped at the funding level made available to the granting authority in a year while the revenue cost of tax incentives is dependent on market-determined levels of investment. Again however there are approaches[9] which can limit the fiscal costs.

The tax system can be more effective in encouraging longer-term investments -- firms can reasonably expect to receive ongoing benefits when multi-year projects are undertaken. Funding levels for direct subsidies are often established on an annual basis and may vary (sometimes significantly) from year to year.

By making use of the existing tax administration structure, tax incentives can be less costly (in terms of both administration and compliance), easier to access, more timely, more certain and less burdensome than direct subsidies.

Tax incentives make the importance of R&D an issue of discussion and understanding among communities foreign to science and technology such as accountants, financial officers and lawyers with long term benefits for science and technology.

Management of S&T Capacity Development

Feeding the S&T pipeline to ensure an adequate supply of S&T personnel is recognised internationally[10] as the most important challenge in the management of S&T capacity development. In modern times investment in scientific human capital has been a cornerstone of the economic development policies of OECD countries as well as for emerging economies aspiring to climb the development ladder[11]. OECD argues that although demographic numbers and investment in early education may be part of the set of policy instruments required to ensure an adequate scientific workforce, the structure of science and education system of a country, the funding of research and the setting of research priorities are decisive as well.

A number of countries through appropriate policies have been successful in ensuring an adequate scientific workforce during the recent years. In the year 2000, Korea, Germany, Finland, Switzerland and France led the OECD countries in the production of university level graduates in natural sciences and engineering as a share of total graduates. During the 1998-2000 period the number of S&E university degrees awarded in Iceland, Sweden, Switzerland and Ireland increased significantly with Sweden registering a 32% increase. Similarly Germany has been able to more than triple enrolments in computer science during the period 1995 to 2001. Similar successes have been achieved by a number of countries in increasing their PhD graduates. In the 1999-2000 academic years there were 4302 full time PhD students in the Hungarian doctoral schools compared to 1527 in 1993. In Australia a continuing growing trend in doctoral completions can be observed from 2905 in 1996 to 3664 in 1999.

Successful policies focus in a number of approaches. The most important of them are:

Efforts to make S&T education more attractive: In order to address this issue a number of countries such as Portugal, Finland and Belgium redesigned curricula, increased the resources dedicated to schools, established new science centres and launched science exhibitions. The UK government has committed large amounts of funds to improve deteriorating facilities and raise stipends for doctoral students[12], (Stone 2000). Updating teacher skills in various scientific fields has also be part of the set of policy instruments employed. The Finish LUMA programme is considered as an example of good practice.

BOX 5: Finnish LUMA program to improve teacher training**

In 1996, the Finnish National Board of Education launched a national development programme called LUMA, which aims at improving mathematical and science knowledge among teachers and raising it to an international level. Within the framework of LUMA (an acronym of the Finnish words meaning natural sciences and mathematics), mathematical and science teachers of all educational levels may participate in additional training free of fees. The LUMA project group has also developed special material teachers may use in the classroom, for instance a book to assist physic teaching in primary school or a publication dealing with scientific experiments in class.

A definite evaluation of the programme is not available yet, but the Finnish Ministry of education has already drawn a positive conclusion. The feedback from teachers was highly positive, co-operation between teachers has increased and the connections between schools and with partners outside the schools have become stronger than before. Many of the 270 educational institutions that participated in the nation-wide project have introduced classes that specialize in mathematics and science. Public appreciation of mathematics and science has risen as well with teachers placing a higher value on their profession.

** Further information on the LUMA programme is available at http://www.minedu.fi/minedu/education/luma/finn_knowhow.html

Increasing funding for PhDs: In Hungary government increased funding for doctoral schools and granted universities the right to train and award PhDs. Professors can apply for individual grants, which ensure high monthly salaries (e.g. Szechenyi and Szilard Scholarships and Szentgrorgyi Scholarships). As we mentioned, between 1993 and 2000 the number of doctorates tripled in Hungary. Portugal has one of the highest increases in new PhDs due in part to active funding. In Canada NSERC increased the number and dollar value of post-graduate scholarships. OECD suggests that "In addition to high quality research environment, salaries that can compete with those on offer in the private sector and abroad are important incentives. Better stipends at the training level and career opportunities thereafter are important at enlarging the science base at home".[13] An example is the Introduction of Integrative Graduate Education and Research Traineeship (IGERT) programmes in the USA which offer stipends in support to graduate students engaging in research in priority areas.

Attracting women and minorities to S&T is of primary importance to countries with under representation of the particular groups. The following Box provides an overview of relevant policy measures.

BOX 6: Improving the attractiveness of the public research sector

Raising salaries and funding. The UK government plans to increase the salaries of post-doctorates by 25% and increase funding for the hiring of university professors. The Czech Republic has implemented schemes to provide additional financial support to young R&D workers up to 35 years of age. The European Commission has doubled the amount of funding devoted to human resources in the Sixth Research Framework Programme to EUR 1.8 billion in order to improve the attractiveness of the European research area. The Backing Australia's Ability initiatives include establishing prestigious Federation Fellowships worth AUD 225 000 a year each. These are aimed at attracting and retaining leading researchers in key positions and up to 125 Federation Fellowships will be awarded with total funding of AUD 112.3 million over the next five years from 2002 to 2006. The Prime Minister announced the first fifteen Federation Fellowships on 25 September 2001. In addition, the number of Australian Postdoctoral Fellowships will be doubled from 55 to 110 and remuneration of these positions will be improved, with total funding of AUD 50.1 million from 2002 through 2006.

Employment reforms and post creations. Germany is launching the development of junior professorships, which are temporary posts to attract young researchers to university employment in some 30 universities. These junior professors will be tied to research departments rather than to professors, which is currently the case for new academics. In 2001, the BMBF provided EUR 6.1 million. Junior professors are granted three-year employment contracts, renewable one. In Austria, a major reform has taken place in the employment of the university system. As of January 2004, new university staff will not have civil servant status and employment contracts will be limited (four to six years) after which scientists/researchers will have to apply for new contracts, depending on the number of available posts. Tenure will only be granted to full professors. Currently 21-23% of total university staff is tenured professors. Norway aims to increase the number of doctorates by 60% by 2007 in order to secure recruitment to research in academia and industry, international recruitment and the recruitment of women. In France, the some 700 teaching-researcher posts were created between 1997 and 2001 to strengthen the public research sector and attract post-doctorates from overseas. The Dutch Ministry of Education, Culture and Science and the Ministry of Agriculture, Nature Management and Fisheries, together with the universities, have launched the Renewal Impulse scheme to retain bright young researchers in the public science system. The programme focuses on three stages of the scientific career up to professorship: young post-docs, experienced post-docs and top talent. In the first round (2000) NOW placed 43 candidates. The aim is to select over 1000 researchers between 2000 and 2010.

Source: Op cited OECD (2003)

BOX 7: What is being done to improve the role of women in academia and research?

Canada. The goal of the "Chairs for Women in Science and Engineering" programme created by the NSERC is to increase the participation of women in S&E and to provide role models for women considering careers in these fields. NSERC funding is matched by cash contributions from corporate sponsors. In addition, the University Faculty Awards (UFA) programme assists universities in hiring 25 women faculty members in the NSE each year by providing a salary supplement of CAD 40 000 per year per chair holder for up to five years.

Finland. Specific long-term measures (since the 1980s) have steadily increased the number of women in research making Finland one of the countries with the highest share of women in research at all levels: in 2000, about 32% of research personnel in general and 43% of university research personnel were women. Since 1998 all Academy of Finland calls for funding applications have encouraged women in particular to apply. In 2000, the Academy adopted an equality plan to promote gender equality in the science community: where applicants are equally qualified for the post, preference is given to women.

Germany. The BMBF has set up a "women in education and research" division. The division's responsibilities include establishing gender mainstreaming in the BMBF itself with the aid of a separate budget item entitled "strategies for achieving equal opportunities for women in education and research". Non-university research organizations have created career track posts to attract more female researchers to science and technical areas.

Iceland. In recent years there has been a move towards improving the conditions for women to participate in the labour market. The Icelandic Parliament (Althing) has passed laws enabling longer parental leaves for both parents; companies have introduced flexible working times and methods such as remote work stations for women at home. Day care centers have been a limiting factor in some communities.

Attracting talent from abroad is a strategy followed by a number of countries in order to complement their S&T pipelines at different points. Canada, the UK and the USA have traditionally met part of their demand through the immigration of foreign nationals. In 1999 the number of individuals with masters or doctoral degrees immigrating to Canada was equal to the national production. During the same year 33% in the UK, of all PhD doctorates in science and engineering were awarded to students from outside the UK. Apart of the attraction of the research system and salaries the interplay of administrative and fiscal incentives influences the decision of foreign researchers to work in certain countries

Netherlands. The Aspasia programme run by the Research Council NWO with financial participation of NWO, the Ministry of Education, Culture and Science and the universities aims to promote women assistant professors (UD) to associate professors (UHD).

Sweden. Positive discrimination is expected in the recruitment process for posts in the higher education sector.

United Kingdom. The ATHENA project, funded by OST and the UK higher education funding councils, is working to tackle the issue of women's under-presentation in higher education employment. It has been in existence for two years and a further two years are planned before a full review. The government has also set up a Web site on women in S&T to provide statistical data on women in S&T with a view to informing policy: www.set4women.gov.uk. **United States.** The NSF's Advance Program focuses on advancing the early academic careers of women in postdoctoral or equivalent positions.

Source: Op cited OECD (2003)

BOX 8: Science and Technology policies to retain and attract scientific talent

Attracting foreign and expatriate talent: The UK government, jointly with the Wolfson Foundation, is funding a Research Merit Award scheme run by the Royal Society and worth GBP 20 million over five years. This offers institutions additional funds to increase the salaries of researchers whom they wish to retain or recruit from industry or overseas. In Germany, the Humboldt Foundation and the German Federal Ministry for Education sponsor a EUR 22 million Research Award the "Sofja Kovalevskaja-Preis" to help young scientists from overseas as well as expatriate German scientists carry out research in Germany for a period of three years. A single award can be as much as EUR 1.2 million. France has long supported the temporary stay of foreign researchers each year, in particular from emerging economies such as Brazil, China, Mexico and South Africa.

Providing tax incentives to encourage recruitment of foreign personnel: Denmark, the Netherlands and Belgium have passed laws to alleviate the tax burden on foreign experts and highly skilled workers. In Quebec, the government is offering five-year income tax holidays (credits) to attract foreign academics in IT, engineering, health science and finance to take employment in the provinces universities. In 2001, Sweden adopted similar policies for highly skilled workers who live in Sweden for less than five years.

Repatriation schemes for post-docs and scientists: The Academy of Finland has a programme to ease the return to Finland of Finnish researchers who have been abroad for a length of time. In Austria, the Schroedinger scholarships help returning Austrians integrate into scientific institutions. Germany's Ministry for Research and

Education (BMBF) has also launched a new programme in 2001 to attract the return migration of German researchers overseas. In support of the repatriation of Canadian postdoctoral researchers, the Institutes of Health Research offers a supplementary year of funding to Canadians and permanent residents who are recipients of either the Japan Society for the Promotion of Science (JSPS) Postdoctoral Fellowships for Foreign Researchers or Welcome Trust/CIHR Postdoctoral Fellowships. In order to be eligible for the "Canada Year" funding, training must take place in a Canadian laboratory. Italy has recently introduced the "Reverse Brain Drain Project", which is aimed both at attracting foreign professors and scientists and at facilitating the repatriation of Italian scholars abroad. In 2002, the Italian government provided EUR 20 million in additional funding for new positions. Over 100 foreign scholars have been employed in Italian universities, most of them in the fields of mathematics and physics (51%) and engineering. Also, 63 Italian scholars benefited from the project.

Leveraging immigrant and Diaspora networks: Such networks do not only exist among emigrants from developing countries; Swiss scientists in the US have created an Internet network and directory (Swiss-list.com) to link Swiss scientists and post-doctorates working in the US to colleagues in Switzerland. The French foreign ministry sponsors meetings between French post-doctorates working in US research institutions and French companies.

Source: OECD, AD Hoc Group on Steering and Funding of Research Institution questionnaire results; International Mobility of the Highly Skilled, 2002

It should be emphasised that the above efforts are undertaken after employment of R&D staff in the higher education sector increased sharply between the mid 1980s and mid 1990s in a number of countries i.e. Australia, Austria, Denmark, Germany, Ireland, Norway and Portugal. For example Finland and Ireland have doubled the numbers of their research staff in the higher education sector.

In general OECD countries and particularly the USA spend substantial percentages of their GDP for the development of their higher education sectors. Figure 1 shows the expenditure on tertiary education as a percentage of GDP in 1999. The data cover all expenditure (direct and indirect, public and private) on universities and other public and private institutions involved in delivering or supporting tertiary educational services.

This figure shows clearly how the US puts more emphasis than the EU on investing in tertiary education. In fact, the EU figure stands at only 1.3% of GDP spent on tertiary education, while the US percentage is 2.3%. Much can be said about regional disparities in these data, but it remains true that no single country in the EU spends as large a share of its GDP on tertiary education as the US. The EU countries with the highest public expenditure per GDP on tertiary education are the Nordic countries Finland, Sweden and Denmark, all above 1.5% of GDP, followed by Austria with 1.5%.

In the EU and throughout the developed world, primary and lower secondary education is characterised by largely universal enrolment. Together with upper secondary education, which is also characterised by very high enrolment rates, these levels represent the bulk of educational expenditure. At the same time, higher spending per student at the tertiary level of education compensates for lower enrolment rates and causes the overall investment at that level to be higher than at the secondary level.

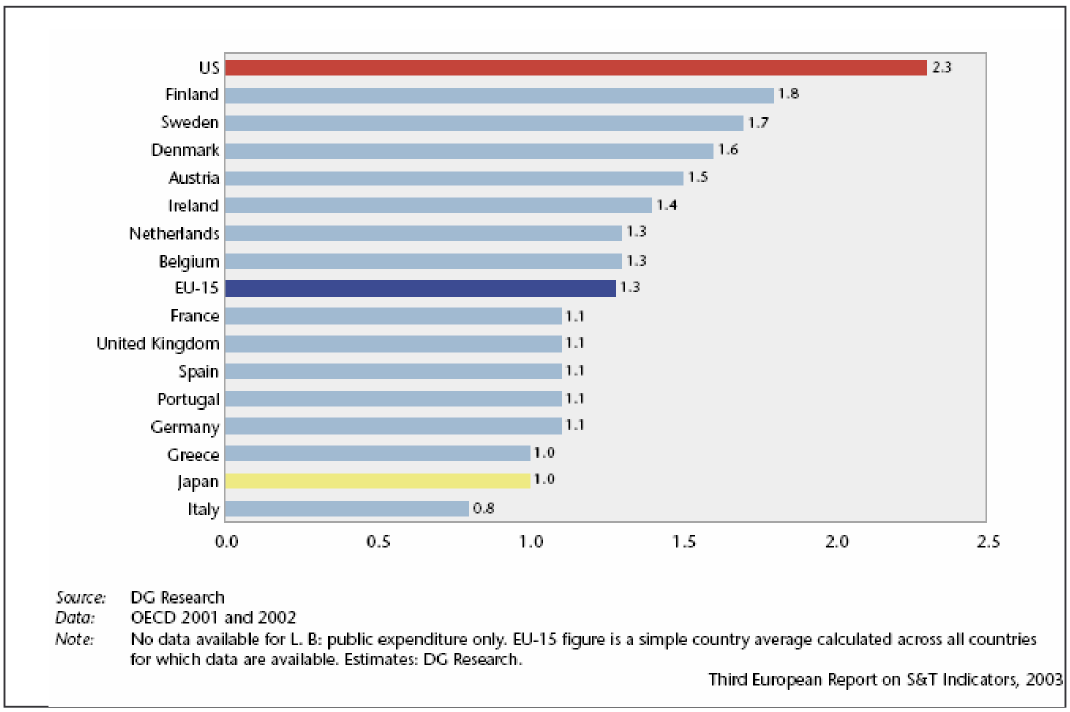
In the EU, educational expenditure at pre-primary, primary, secondary and post-secondary non-tertiary levels in 1999 accounted for 76% of the total educational expenditure. Expenditure at tertiary level, on average in the EU, represented nearly one-quarter of the total expenditure on education. When examining these data one should take into account that students at tertiary education level in Europe represent about 15% of the total student population enrolled in the entire education system (EC, 2000, p. 103).

The percentage of educational expenditure going to tertiary education varies significantly from one Member State to another. Countries such as Finland or Ireland invest 30% or more of their educational expenditure in tertiary education. Italy, France and Portugal, on the other hand, allocate a smaller share (less than 20%) of their educational expenditure to the tertiary level. Compared to the US, where tertiary education represented 35% of total expenditure on education, Europe allocates a much smaller proportion.

It should be emphasised that these figures depend on enrolment rates and on demographic constellations. However, they also express differences in the approach to education and in educational structures and systems in different countries. Higher investment in tertiary education leads to the generation of highly qualified experts that can develop new technologies.

Expenditure on tertiary education during the 1990s grew slightly faster than overall GDP. In 1995 1.1% of European GDP was devoted to the financing of tertiary education; in 1999 it was increased up to 1.3% of GDP. In Finland and the UK, there was a slight decrease of the share of national wealth allocated to tertiary education (from 1.9% of GDP in 1995 to 1.8% in 1999 in Finland, from 1.2% of GDP in 1995 to 1.1% in 1998 in the UK). Conversely, at the end of the 1990s, Greece, Ireland, Portugal and Spain devoted a higher share of their GDP to tertiary education funding: from 0.70% in 1995 to 1.0% in 1999 in Greece, 1.3% to 1.4% in Ireland, 0.9% to 1.1% in Portugal, and 1.0% to 1.1% in Spain).

Figure 1: Expenditure on tertiary education as percentage of GDP (1999)



Governance of S&T in South Africa

The South Africa system of innovation can be characterized as a decentralized (pluralistic) one. Government departments (at National level) oversee their own research councils/ contract research organisations with minimal if any coordination. For example the Department of Water Affairs oversees the Water Research Commission; the Department of Health the Medical Research Council; the Department of Minerals and Energy oversee MINTEK etc. The Department of Education is responsible for the Higher

Education Institutions and the Department of Science and Technology is responsible for NRF, CSIR and HSRC. An effort by the Department of Science and Technology to coordinate the efforts of the research councils/ contract research organisations was abandoned during 2005.

The pluralistic character of the system is extended to Higher Education Institutions as well. The Department of Education is officially responsible for the management and financial support of the country's universities. However NRF the agency promoting research in the university sector reports to the Department of Science and Technology and the THRIP programme – the major mechanism promoting University-Industry collaboration in the country- is an initiative of the Department of Trade and Industry.

The weaknesses of the pluralistic system are manifested in a number of ways: a number of departments abdicate their responsibility to support science and technology for their sectors; policy decisions are taken without scientific/ research support and conflicting initiatives affect adversely the NSI.

Following international best practice we recommend the following:

- DST should consider recommending the establishment of Chief Scientists Offices in Government Departments both nationally and provincially. The Chief Scientists Offices will be responsible for promoting effective use of science in policy making; for enhancing science capacity and quality in the fields of interest of the particular Departments and raising awareness and understanding of the effects of science and research on the Department' activities. Chief Scientists will be ambassadors for S&T integration

- DST within its mandate to coordinate national research and innovation should consider adopting an approach of "coordination through monitoring". DST should monitor the research funding activities of Government and publish the results annually. The OECD recommendations for the collection of data and the development of a report on Government Budget Appropriations or Outlays for R&D (GABOARD)[14] and the "Annual Review of Government funded

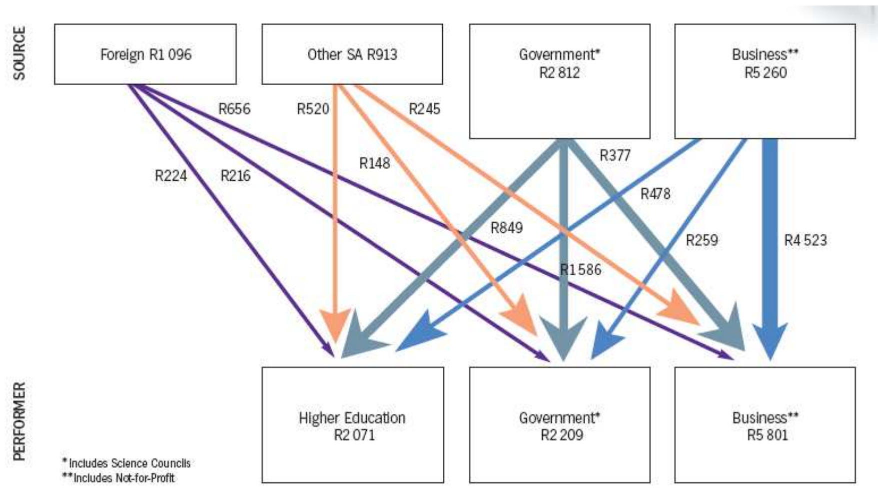
Research and Development" by the Cabinet Office[15] in the UK can be used as prototypes

Government in South Africa plays a modest role in the funding of R&D, spending below R3 billion per year mainly for the support of research in Government organisations (fig 2). The percentage of Business Enterprise Expenditure in R&D (BERD) financed by Government is just below 6.5% (11.9% in UK and 10.9% in USA, Korea 8.1%, France 9.9%). Government's support for BERD in South Africa is exclusively through direct incentive schemes (e.g. Innovation Fund, Support Programme for Industrial Innovation etc). In the 2006 Budget Speech it was announced that a tax incentive scheme for R&D will be introduced. This approach can be argued to be one of the most important ones for the attraction of R&D funding from abroad.

Similarly Government's financial support for higher education is small in comparison to international standards. Government spending on higher education is 0.72% of GDP in South Africa (2003). The relevant figures for other countries are substantially higher – USA 2.3% of GDP; Finland 1.8% of GDP; etc. Recently the DST in collaboration with the National Research Foundation announced the intent to establish more than 200 research chairs in the universities of the country infusing approximately R500 million per year in the sector.

The issue of equipment is of importance in the context of university support by Government. A recent article[16] comments that Government appears to ignore infrastructural needs and requirements in the sector. It states "The *White Paper on Higher Education* mentions equipment only circumstantially and in aggregation with other needs and the *National Research Foundation Bill* does not give the "responsibility" to the Foundation to protect and develop this infrastructural need. It should be mentioned that the NRF is enabled by the Bill to support equipment needs, but this does not become an entrenched responsibility in the same way as the disciplinary interests have become". The article identifies that there is a substantial backlog in equipment which hamper research and training in the country.

Figure 2: Flows of Funding for R&D[17] (2003/4 R millions)



Based on the above findings we propose the following:

- DST should monitor closely the implementation and fine development of the tax incentives for R&D scheme and its implications on other direct support schemes. The tax incentives scheme may have adverse consequences in the business sector innovation activities if applied inappropriately and/or if the government withdrew its support from existing direct incentives schemes.

- DST should monitor the progress for the establishment of research chairs at the universities with the ultimate objective of keeping the momentum and alleviating possible obstacles in the process.

- DST, within its mandate to co-ordinate the scientific and technological system, should establish an inter-departmental committee on "Critical Scientific and Technological Infrastructures". The mandate of the committee should be to investigate and make recommendations concerning policy and programmes affecting "critical scientific and technological infrastructures" such as research and training equipment, scientific and technological telecommunications, and R&D management.

  The Committee should consider among others the viability of introducing

➳ the funding of "critical S&T infrastructures" as a separate line item in the governmental budget (Expenditure defrayed from the National Revenue Account)

➳ approaches promoting closer collaboration on aspects of critical S&T infrastructure among organisations reporting to different government departments (e.g. academic institutions, research councils and parastatals).

- The NRF should institutionalise the support of research and training equipment by establishing an appropriate directorate/division. The division should be funded by dedicated (earmarked) funds, by top-slicing the budget of the other directorates and by raising funds from local and international donors.

- The NRF should establish appropriate `competitive grants'/funding mechanisms promoting :

    - the interaction between academia and industry for the development and

    - construction of new or improved equipment;

    - the maintenance and augmentation of the R&T equipment infrastructure;

    - the development of the necessary infrastructures in institutions that are either lacking or are with deficient infrastructures.

- A programme promoting the development of remote utilisation of equipment should be considered as an urgent priority in view of its possible impact across all other programmes. Different programmes should be established for different objectives.

- The funding formula of the Department of Education for academic institutions should make R&T equipment an explicit component of the formula. Furthermore, adequate funds should be earmarked for at least the next five years in order to facilitate the required replacement and upgrading of R&T equipment.

We have argued that education is undoubtedly the most important factor contributing to employment of individuals, international competitiveness, development and economic growth.

In South Africa only a small percentage of the appropriate age population attends tertiary education. In comparison with countries in Asia, Europe and America, South Africa has a very small number of students at tertiary education level.

South Africa should increase this number by a factor of 4 to 5 in order to become competitive with the rest of the world. The ratio of first degrees in Natural Sciences and Engineering to 24-year old population is also highly distorted in comparison with the rest of the world. The relevant population should increase by a factor of 10 if South Africa wants to be comparable with the rest of the world.

Table 1: Ratio of Natural Science & Engineering Degrees and first university degrees per 100 24 year olds

	Natural Science & Engineering degrees	First university degrees	Ratio of Nat Science & Engineering Graduates over all first university deg. graduates
	to 24 year old population		
UK	10.0	36.0	0.28
S Korea	9.0	24.7	0.36
Australia	8.0	35.9	0.22
Japan	7.7	30.1	0.26
Canada	6.9	31.2	0.22
European Union	6.5	22.4	0.29
Israel	4.3	22.3	0.19
Cuba	3.2	13.6	0.24
Chile	2.5	9.5	0.26
Thailand	1.7	9.8	0.17
Brazil	1.7	8.2	0.21
Mexico	1.6	9.4	0.17
South Africa	0.6	4.8	0.13

Source: Unesco Databases and Science and Engineering Indicators-2002

The CHE[18] reports that the number of university and technikon graduates increased from 81764 in 1995 to 101680 in 2002. This is an increase of 24% over the 7 year period or an annual growth rate of approximately 3% per year. Even if we assume a zero population growth, it will take 50 years for South Africa to reach the levels of S Korea and Israel.

Based on the above we propose the following:

- DST in collaboration with the Department of Education should consider undertaking a drive to double the number of scientists and engineers graduating from the higher education sector within the next 10 years. Such a target will require an expected growth of 7% per year. Innovative approaches should be considered for funding this objective. A possible approach is to request the universities to develop proposals of the resources they require and they are prepared to commit in order to achieve the objective and choose to support those which contribute most in the achievement of the objective.

- Expansion of the higher education sector will be constraint in the short term by lack of appropriate number of academics. DST and HESA should motivate to the Department of Home Affairs the introduction of "speedy immigration visas" for academics who may wish to come to South Africa in fields of high priority. A complementary approach is to provide incentives for the repatriation of South African academics abroad. A five year tax holiday with repatriation financial assistance and possible NRF research support may attract a number of academics who are already familiar with the South Africa system.

Summary of Recommendations

Governance is a multifaceted activity including governance structures and organisational settings; priority setting; public support and funding of research and innovation and management of S&T capacity development. In this chapter we have discussed international trends and the comparative situation in South Africa. Next we provide the list of the relevant recommendation made in the chapter.

Recommendations related to governance:

- DST should consider recommending the establishment of Chief Scientists Offices in Government Departments both nationally and provincially. The Chief Scientists Offices will be responsible for promoting effective use of science in policy making; for enhancing science capacity and quality in the fields of interest of the particular Departments and raising awareness and understanding of the effects of science and research on the Department' activities. Chief Scientists will be ambassadors for S&T integration

- DST within its mandate to coordinate national research and innovation should consider adopting an approach of "coordination through monitoring". DST should monitor the research funding activities of Government and publish the results annually. The OECD recommendations for the collection of data and the development of a report on Government Budget Appropriations or Outlays for R&D (GABOARD)[19] and the "Annual Review of Government funded Research and Development" by the Cabinet Office[20] in the UK can be used as prototypes

- DST should monitor closely the implementation and fine development of the tax incentives for R&D scheme and its implications on other direct support schemes. The tax incentives scheme may have adverse consequences in the business sector innovation activities if applied inappropriately and/or if the government withdrew its support from existing direct incentives schemes.

- DST should monitor the progress for the establishment of research chairs at the universities with the ultimate objective of keeping the momentum and alleviating possible obstacles in the process.

- DST, within its mandate to co-ordinate the scientific and technological system, should establish an inter-departmental committee on "Critical Scientific and Technological Infrastructures". The mandate of the committee should be to investigate and make recommendations concerning policy and programmes affecting "critical scientific and technological infrastructures" such as research and training equipment, scientific and technological telecommunications, and R&D management.

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- the funding of "critical S&T infrastructures" as a separate line item in the governmental budget (Expenditure defrayed from the National Revenue Account)
- approaches promoting closer collaboration on aspects of critical S&T infrastructure among organisations reporting to different government departments (e.g. academic institutions, research councils and parastatals).

- The NRF should institutionalise the support of research and training equipment by establishing an appropriate directorate/division. The division should be funded by dedicated (earmarked) funds, by top-slicing the budget of the other directorates and by raising funds from local and international donors.

- The NRF should establish appropriate 'competitive grants'/funding mechanisms promoting : the interaction between academia and industry for the development and construction of new or improved equipment; the maintenance and augmentation of the R&T equipment infrastructure; the development of the necessary infrastructures in institutions that are either lacking or are with deficient infrastructures. A programme promoting the development of remote utilisation of equipment should be considered as an urgent priority in view of its possible impact across all other programmes. Different programmes should be established for different objectives.

- The funding formula of the Department of Education for academic institutions should make R&T equipment an explicit component of the formula. Furthermore, adequate funds should be earmarked for at least the next five years in order to facilitate the required replacement and upgrading of R&T equipment.

- DST in collaboration with the Department of Education should consider undertaking a drive to double the number of scientists and engineers graduating from the higher education sector within the next 10 years. Such a target will require an expected growth of 7% per year. Innovative approaches should be considered for funding this objective. A possible approach is to request the universities to develop proposals of the resources they require and they are prepared to commit in order to achieve the objective and choose to support those which contribute most in the achievement of the objective.

- Expansion of the higher education sector will be constraint in the short term by lack of appropriate number of academics. DST and HESA should motivate to the Department of Home Affairs the introduction of "speedy immigration visas" for academics who may wish to come to South Africa in fields of high priority. A complementary approach is to provide incentives for the repatriation of South African academics abroad. A five year tax holiday with repatriation financial assistance and possible NRF research support may attract a number of academics who are already familiar with the South Africa system.

Best Practices in monitoring S&T Systems – Science Indicator Systems

When you can measure what you are speaking about, and express it in numbers, you know something about it;

but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind"

(Lord Kelvin)

Introduction

An important way of enhancing policymaking is to improve the strategic intelligence upon which policy choices and decisions are based. During the past 50 years governments and their agencies have developed a number of approaches monitoring their systems of innovation.

While this type of intelligence is generated via a variety of tools such as evaluations, technology foresight, technology assessment and others the prime feedback to Governments' mechanism of policy-making is an extensive set (system) of S&T Indicators. S&T Indicators help the policy making bodies in government or non-governmental institutions in their advisory capacity, to evaluate past and present policies, and design and implement new ones.

Science Indicators Systems (SIS) are comprehensive collections of indicators describing the status quo of a country's scientific, technological and innovation activities within the local socio-economic environment and within the international arena.

In the last 40-50 years the S&T indicators have developed considerably, thanks to the efforts of the academic community, national agencies such as NSF in the USA and international organisations like OECD and EUROSTAT for the European Community. International harmonisation of concepts and common methodologies for data collection have been developed on the international level, especially for the OECD countries, by the preparation of the "Frascati", "Oslo" and "Canberra" manuals that contributed to a considerable improvement in the quality and quantity of indicators, as well as their compatibility. So, creation of a useful source of information for policy planning, decision-making and evaluation processes is methodologically sound.

Indicators are used by a variety of clients. Five types of potential users of S&T indicators can be identified: *the policy makers*, *the business*, *the scientific community*, *the general public and the international organisations*. Two of these groups are usually investors in production processes: policy makers (government, its departments and Parliament) and business.

Each group have different demands: *policy makers* want to have a complete overview of development in the S&T for use in policy deliberations. They need up-to-date, key indicators by policy relevant categories. The *Business sectors* also need general overview and detailed information on their own and relating sectors. The *Scientific community* is looking for long time series, detailed statistics and comparable institutional indicators. Interest groups of researchers also would like to get detailed information on their own field. The *International organisations* (e.g. G7, UN, OECD, EU, European Parliament, APEC, AU etc.) are interested in the ranking of nations according to scientific capabilities, competitiveness and so on. Detailed S&T information can help searching co-operation partners and obtain knowledge of global trends.

National Science Foundation Indicators

Probably the most well known SIS is the one produced regularly by NSF. The law creating the NSF also gave it a role in policy advice and in the evaluation of research. The NSF was asked to "provide a central clearinghouse for the collection, interpretation and analysis of data on scientific and technical resources in the United States" In 1968, Congress explicitly mandated the NSF to report on the status and health of science and technology.[21]

The National Science Board (NSB) followed a conservative approach initially and published a set of statistics without any policy analyses and assessments. The argument at the time was that it would be "unrealistic to expect one federal agency to render judgement on the overall performance of another agency or department."[22]

President Nixon in 1970 and Congress in 1976 asked for an annual report on the status and health of science and technology (reminding the NSB that they were not fully meeting their obligation). These requests shaped NSB's decision to produce an annual report that would provide baseline data for each year with a series of chapters providing an assessment of the health of science.

The "Science and Engineering Indicators" has been a great success for a number of reasons: "firstly, it collected dispersed statistics all in only one book. Secondly, it discussed science mainly by way of charts rather than numbers. Tables appeared primarily in the appendix. Thirdly, it included brief highlights for policy makers. Fourthly, there was small analysis. Finally, each edition always contained something new in terms of information and indicators."[23]

Science and Technology Agency Indicators

The Science and Technology Agency (STA)[24] in Japan have investigated the issue of SIS in the process of the development of their system. The main findings of that analysis underpin the current theoretical and empirical understanding of SIS and we report them below.

First, a SIS should be used to grasp the *status quo* of the country's scientific and technological activities. Second, it should be used to set goals which will be attained within a certain time period. Third, it should be used to formulate and evaluate alternative policies which have been or will be implemented.

Based on the purpose of the indicators STA derived the following typology:

1. Reporting indicators

The purpose of this type of indicators is to measure the various aspects of the present scientific and technological (S&T) activities as accurately as possible. Emphasis should be placed on investigating the right indicators which truly reflect the S&T activities to be measured.

From the policy maker's viewpoint, this type of SIS can be utilised as an early warning system for S&T activities.

2. Judgement indicators

The purpose of this type is to formulate national goals of S&T. Some goals must be decided concerning a country's timetable of S&T activities during a specified time period.

In order to transform the reporting type into the judgement type, the selectively chosen individual indicators must be organised. Indicators which are more or less randomly chose without assuming causality should be integrated into several comprehensive indicators. These indicators, which are selected to measure the current status of a specific country's S&T activities, should be consistently compared with the time series data of the country and with the corresponding data of other countries.

Through such transformation, policy makers can utilise SIS as the basis for formulating national goals of S&T activities.

3. Evaluation indicators

The purpose of this type of indicators is to examine the causal relationships among indicators. The system must be further organised so that some statistical analysis could be made on the relationships among the indicators.

STA concluded that almost all existing "science indicators" are the reporting type, although occasionally some attempts to construct a judgement type of "science indicators" are being made in various countries. However, such attempts have not yet been on a systemic and regular basis.

Nevertheless, this typology shows that reporting type indicators are the basis for the two other types. In other words, the various types and purposes of SIS can be constructed based on the reporting type. Thus, efforts should be centred initially on the development of a reporting type SIS.

STA has further argued that R&D activities are performed within a more general scientific and technological infrastructure and that the S&T infrastructure is formed on the basis of a more general "societal infrastructure" which supports a country's activities. Consequently SIS should contain indicators reflecting the various infrastructures.

On the principles mentioned above, STA developed the Japanese SIS which contains the following type of indicators shown in table 2.

In a similar to STA fashion the Office of Technology Assessment (OTA)[25] in the USA has investigated the adequacy of the US SIS.

Table 2: Distribution of selected indicators

Major Category		Sub-category		Sub-sub-category	
SOCIETAL INFRASTRUCTURE	3				
S&T INFRASTRUCTURE	14	Education	6		
		Economy	4		
		Culture	4		
R&D INFRASTRUCTURE	35	R&D elements	14	Input elements	8
				Support elements	6
		Institution	12	R&D evaluation	8
				R&D support	4
		Evaluation	9	R. evaluation	5
				T. assessment	4
R&D RESULTS	35	Knowledge	9	Accumulation	6
				Creativity	3
		Private goods	15	Direct effects	7
				Indirect effects	8
		Public goods	6	Standard	3
				Service	3
S&T CONTRIBUTION		Industrial	6		
		International	6		
		Societal	6		
SOCIETAL ACCEPTANCE	3				
TOTAL	**103**				

The conclusion of the report was that better data on the federal research system are instrumental for the creation and refinement of research policies; that Congress needs agency and budget specific data, while the agencies need data related to the performance of their programmes and their constituent research projects and that depending on data collected by NSF and NIH risks generalising results and trends that might not apply to the system as a whole.

Table 3 shows the data and indicators identified as desirable and their primary users.

Table 3: Desired data and indicators on the federal research system

Category	Description	Method	Primary Users			
			Congre ss	Agencie s	OMB	OSTP
Agency funding allocation method	Funding within and across fields and agencies Cross-agency information on proposal submissions and awards, research costs, and the size and distribution of the research work force supported	Agency data collection (and FCCSET)	✔		✔	✔
Research expenditures	Research expenditures in academia, federal and industrial laboratories, centres, and university/ industry collaborations Agency allocations of costs within research projects, by field Mega-project expenditures: their components, evolution over time, and construction and operating costs	Agency data collection	✔	✔	✔	
Research work force	Size and how much is federally funded Size and composition of research groups	Lead agency survey	✔	✔		✔
Research process	Time commitments of researchers Patterns of communication among researchers Equipment needs across fields (including the fate of old equipment) Requirements for new hires in research positions	Lead agency survey; onsite studies		✔		
Outcome measures	Citation impacts for institutions and sets of institutions International collaborations in research areas Research-technology interface, e.g. university/ industry	Bibliometrics; surveys of industry and academia	✔	✔		✔

	collaboration					
	New production functions and quantitative project selection measures					
	Comparison between ear-marked and peer-reviewed project outcomes					
	Evaluation of research projects/programmes					
Indicators	Proposed success rate, PI success rate, proposal pressure rates, flexibility and continuity of support rates, project award and duration rate, active research community and production unit indices	Agency analysis	✔	✔		✔

Source: Office of Technology Assessment, 1991

Box 9: The establishment of National S&T statistics indicator system in China

The S&T census in 1985 for the first time collected data reflecting national S&T activities (except for Taiwan province), which laid a foundation for further setting up China's S&T statistical indicator system and implementing S&T statistics.

Since 1986, annual reporting system has been constructed in R&D institutions affiliated to government departments, large and medium sized enterprises, and higher learning institutions, which has formed a network from the central to the local operated and co-ordinated by the State Science and Technology Commission, the State Education Commission and the State Statistics Bureau. R&D performing units are surveyed according to their geographic location through the network. Since that time, statistical scopes and contents have been expanded gradually. Currently, the implemented statistics surveys are as follows:

- survey for basic information on S&T activities of R&D institutions in social and humanity and natural sciences fields;
- survey on performance of national S&T programmes
- patent statistics
- survey on S&T achievements and awards
- survey on technological market
- survey on non-governmental S&T institutes
- national scientific publication and citation statistics:
  retrieved China's publications catalogued by four international index systems, SCI, ISR, ISTP, EI, and make statistical analysis of 1200 domestic scientific journals, research papers published, and citation
- statistics of import and export of high-tech products:
  based on the Standard International Trade Classification and OECD's High-Tech Product Classification, to make statistical analysis for exports and imports of China's high-tech products by using China's Customs Annual Report.

The focus of the efforts is on:

- international compatibility, and
- support local policy demands

OECD Indicators

OECD has made a crucial contribution in the international acceptability of S&T indicators by creating "standards" for the development of internationally compatible relevant indicators.

OECD has been one of the first multilateral organisations to investigate indicators relevant issues (other important organisations in the field are also UNESCO, EUROSTAT and NORDFORSK). In 1963 it produced guidelines for the collection of input data to R&D (Frascati Manual).

R&D input data has been the predominant policy variables for almost 20 years when the move away from the linear model of innovation brought to the surface the limitationsc of the R&D input statistics and made profound the need for additional indicators.

The following are indicators whose development is recommended by OECD and indicators on which OECD is working currently.

R&D statistics

The collection of R&D statistics started in the 1960s supported by the rapid growth of the amount of national resources devoted to research and experimental development. The amount of money spent on R&D has been the primary input indicator for decades and has been used as a measure of

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c The use of spending data is limited in its relevance to the impacts of R&D. There is some correlation between the level of R&D spending and innovative success. For example, if fewer research projects are performed, then companies and countries forgo the potential benefits of the research. However, spending alone does not guarantee innovative success because many additional factors figure into the innovation process and have important effects on the resulting outputs. The reality of the process of innovation is much more complex than expenditure data alone can reveal.

Furthermore, the usefulness of R&D spending indicators is limited because the way in which innovative activities are structured and managed can be as significant as the amounts of resources devoted to them in determining their outcomes and effects on performance. Those nations or firms with extremely efficient innovation systems can outperform those that use greater R&D resources inefficiently.

how much research is being performed. The human resources involved in R&D is the second indicator in the inputs of R&D. The major advantages of using expenditure data as an indicator are that they are easily understandable, readily available, have been consistently gathered over time and they can measure efforts in different project, disciplines, sector, etc. according to same unit.

The straightforward rationale — the more R&D spending, the more innovative activity — is the primary advantage to using expenditure data in policy discussions. Its simplicity and close ties to the linear model of innovation allow it to be readily understood by those with little specialised knowledge, making it appealing in policy discussions. These same simplifying characteristics may have led to its use in other areas. In some contexts, countries and companies are categorised according to their technological sophistication on the basis of their R&D spending levels; little attention is given to other factors.

Guidelines for the collection of R&D statistics are provided in the *Proposed Standard Practice for Surveys of Research and Experimental Development* (Frascati Manual 1993) and *R&D Statistics and Output Measurement in the Higher Education Sector* (Frascati Manual Supplement 1989). OECD, Paris, France

Technology balance of payments statistics

The TBP registers the international flow of industrial property and know-how. This type of statistics measure the international diffusion of disembodied technology by reporting all intangible transactions relating to trade in technical knowledge and in services with a technology content between partners in different countries.

Transactions which are covered by these statistics are purchase and sales of patents, licenses for patents, know-how, trademarks, franchising, technical services, models and designs and finance of industrial R&D outside the national territory.

OECD reports currently TBP data according to industry, type of operation and geographical area.

Guidelines for the collection of R&D statistics are provided in the *Proposed Standard Method of Compiling and Interpreting Technology Balance of Payments Data* (1990), OECD, Paris, France

Bibliometrics

Bibliometrics is the generic term covering information extracted from publications. Bibliometric analysis uses data on numbers and authors of scientific publications and on articles (and in patents) and the citations therein to measure the "output" of individuals/research teams, institutions, and countries, to identify national and international networks, and to map the development of new fields of science and technology.

Most bibliometric data come from commercial companies or professional societies with main general source the Science Citation Index (SCI) set of databases created by the Institute for Scientific Information (ISI) in the US

Patent data

Statistics on patent constitute an important output indicator of the innovation systems. The global data concern the number of patents applied for (as opposed to the number finally granted) via national, European and other international procedures broken down by country of application and country of residence of the applicant.

The main information that can be drawn from patent documents relates to the type of technology covered by the claim, the name and nationality of the inventor (individual, government agency, private corporation), links between a new patent and knowledge in earlier ones and scientific publications, the economic sector where the invention originated, and the fields and markets covered by the patents.

Patent indicators are used in order to identify technological strengths and weaknesses of corporations, countries etc. and to analyse the rate and direction of technical change.

Guidelines for the collection statistics are provided in *Using Patent Data as Science and Technology Indicators* (1994), OECD, Paris, France

Trade based indicators

There is an international recognition of the symbiotic relationship between investment in science and technology and success in the market place. Science and technology support competitiveness in international trade and commercial success in the international marketplace provides the resources required to support new S&T. Consequently trade in products embodying new knowledge is a performance measure for the national investment in R&D and in science and engineering.

Trade in high-tech products reflects a country's ability to carry out research and development, and to exploit the results in global markets (i.e. a well functioning NSI). Moreover the industries producing these goods are generally a source of high value added and well-paid employment. Exports of such products therefore represent an important indicator of competitiveness and globalisation in the knowledge-based economy.

Guidelines are provided in the *OECD Handbook on Economic Globalisation Indicators,* (2005), OECD, Paris, France

Human resources

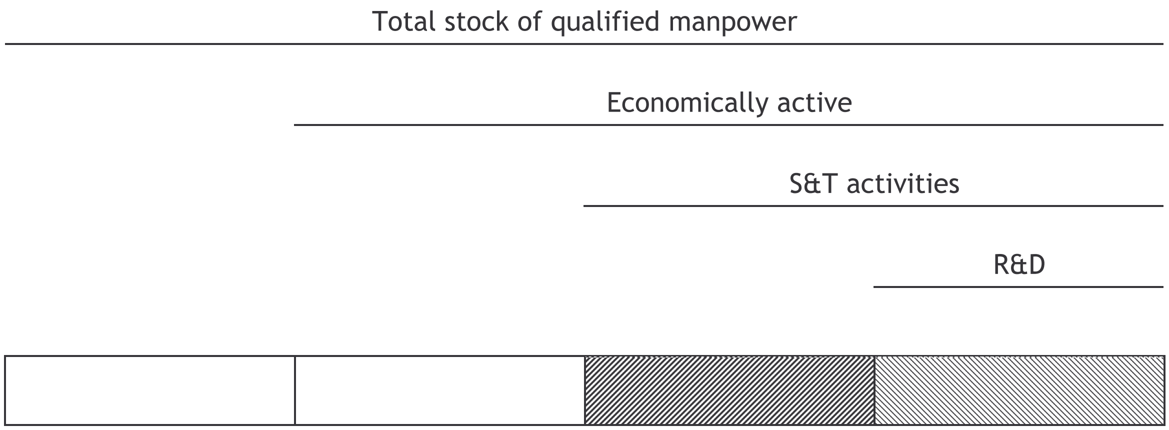
The term human resources in S&T extends to cover everyone who has successfully completed post-secondary education or is working in an associated S&T occupation. It refers to the human resources actually or potentially devoted to the systematic generation, advancement, diffusion and application of scientific and technological knowledge.

Users of HRST data include policy-makers and analysts in government related agencies, the private sector and academics. Issues of brain-drain or gain, skills, availability and planning for the higher education sector are addressed with the use of HRST data.

HRST data is wider and more detailed then the R&D personnel statistics defined in the Frascati Manual.

Figure 3 illustrates the relationship among the various categories of human resources.

Figure 3: Relationships of various categories of human resources



Guidelines for the collection of R&D statistics are provided in the *Measurement of Human Resources Devoted to S&T* (Canberra Manual, 1995). OECD, Paris, France

Innovation data

Innovation data aim to enlarge the picture of the process of innovation provided by the R&D and patent statistics. The innovation data focus on the innovation process other than R&D and in particular on these aspects affecting diffusion rates.

The data collected in different countries differ widely in terms of objectives, methods, definitions and so on. However, they conclusively slow that a wide range of data can be produced in the innovation process and assist policy making.

The OECD *Oslo Manual* provides the basis for international compatible:

1. definitions of innovation and innovative activities;
2. measuring aspects of the innovation process;
3. measuring the cost of innovation;
4. classifications and areas of difficulty for innovation surveys.

Guidelines for the collection of R&D statistics are provided in the *OECD Proposed Guidelines for Collecting and Interpreting Technological Innovation Data* (Oslo Manual 1997). OECD, Paris, France

New indicators for knowledge based economies

OECD has developed and is currently working in the development of a number of indicators which will complement and extend those advocated in the Frascati family of manuals. The most important of these are:

Mobility of resources: between firms, between industries, between the public and private sector. Human resources are the main vehicle for the circulation of knowledge. Led by Sweden (NUTEK and Statistics Sweden) this project has two main components. (i) an inquiry into the mobility of skilled workers as revealed by the exhaustive tax records in Sweden focusing initially, on the "knowledge intensive business sectors" (e.g. financial services) in order to explore the methodological issues (e.g. the effect of the birth and death of firms). (ii) a review of the sources available in OECD countries and how the Swedish methodological findings could be applied to countries with less detailed data. A comparison of the results from tax records and from more broadly available sources will be undertaken for Sweden, in order to assess the loss of information resulting from use of the latter. The United States is also joining this project.

Patents based indicators: The aim is to go beyond simple patent counts. This project differs from the others in that it makes use of international data, which can be directly processed in a harmonised way. Discussions with the European Patents Office (EPO) have been undertaken with the aim of setting up a quite large data base of European patents (with their world-wide extensions) to include information on patent renewal and on patents citations, which are currently largely omitted from patent studies. Data on patents granted by the USPTO are also being used. Experts are being retained to design and calculate indicators using these data, to measure the economic value of inventions, their social or technological value, and the diffusion of knowledge within and across national boundaries. Tests will be made to compare various indicators of technological performance at the firm level and at aggregate level: productivity, innovation and patents. A revision of the OECD "Patents Manual" is envisaged. Since patents data are essentially international, there was no need of lead countries and the OECD Secretariat is directly in charge of this project.

Innovative and absorptive capacity of firms: This project makes use of data collected through the first round of innovation surveys in European countries Community Innovation systems (CIS). The aim is to design and calculate aggregate indicators of innovative intensity at national and sectoral levels, indicators of the circulation of knowledge and the sources of technological information used by firms, and of the factors which favour or hamper innovation. EUROSTAT, which co-ordinated the first CIS and which holds the micro-aggregated data, is a partner in this project and Italy is a lead country. Italian studies have already shown the high potential of such data, in terms of description of national innovation systems and innovation policy design. One available, the new methods could be applied in the forthcoming CIS2 surveys and in innovation surveys outside Europe.

Internationalisation of industrial R&D: The aim is to measure the extent, the factors and consequences of business R&D internationalisation, especially via multinational firms and via international alliances of firms. Data of foreign affiliates, collected by the Secretariat, and patents data will be used. New indicators of the technological content of international flows of goods are being tested. The lead countries are Germany and France.

Government support to industrial R&D and innovation: The aim is to develop accurate indicators of "indirect" government support for industrial R&D notably via fiscal incentives which following the current recommendations of the Frascati Manual, is not credited to government as a source of funds in the regular OECD R&D survey. This builds on an initiative launched at the 1995 meeting of NESTI and is being pursued as part of Module 2 of Phase II of the Jobs Study. It draws on data and methods established by the Working Party on Support to Industry of the Industry Committee and also on the experience of the Working Group on Innovation and Technology Policy. Australia and Canada are the lead countries.

Information and communication technology: this project was added to meet a request from the Committee for Scientific and Technological Policy (CSTP). It will be carried out in co-operation with the new statistical panel of the Committee for Information, Computers and Communications Policy (ICCP), which first met in June 1997. It will address the following topics: measuring technical change in Information and Computer Technologies (ICT) products, the actual, total cost of using ICT (including complementary investment, foregone production, etc.) and training in firms in connection with the use of ICT and ICT and innovation in the financial services.

Currently SIS are produced and published by almost all countries with developed science and technology systems. Examples include "*The European Report on S&T Indicators*" by the European Commission; the "*Science and Technology Indicators in the Commonwealth of Independent States*" by the Ministry of Science and Technology Policy of the Russian Federation; The "*Netherlands Science and Technology Indicators Report*" by the Netherlands Observatory of Science and Technology; the "*Indicadores de Actividades Cientificas y Technologicas- Mexico*" by Consejo Nacional de Ciencia y Technologia and others.

Trend Chart on Innovation in Europe

The "trend chart of innovation in Europe" is a complementary to indicators approach to monitoring science, technology and innovation used by the European Commission.

The 'First Action Plan for Innovation in Europe', launched by the European Commission in 1996, provided for the first time a common analytical and political framework for innovation policy in Europe. Building upon the Action Plan, the *Trend Chart on Innovation in Europe* is a practical tool for innovation organisation and scheme managers in Europe. Run by the Innovation Policy Directorate of DG Enterprise and Industry, it pursues the collection, regular updating and analysis of information on innovation policies at national and European level.

The Trend Chart serves the "open policy co-ordination approach" laid down by the Lisbon Council in March 2000. It supports organisation and scheme managers in Europe with summarized and concise information and statistics on innovation policies, performances and trends in the European Union (EU). It is also a European forum for benchmarking and the exchange of good practices in the area of innovation policy.

The trend chart now tracks innovation policy developments in all 25 EU Member States, plus Bulgaria, Iceland, Israel, Liechtenstein, Norway, Romania, Switzerland and Turkey. It also provides a policy monitoring service for three other non- European zones: NAFTA/Brazil, Asia and the MEDA countries.

The Trend Chart website (www.cordis.lu/trendchart) provides access to the following services and publications, as they become available:

- a database of innovation policy measures across 33 European countries;
- a news service and related innovation policy information database;
- a "who is who" of agencies and government departments involved in innovation;
- annual policy monitoring reports for all countries and zones covered;
- all background material for four annual policy benchmarking workshops;
- the European Innovation Scoreboard and other statistical reports;
- an annual synthesis report bringing together key of the Trend Chart.

Discussion and Recommendations

This chapter identifies monitoring as an integral part of policy making internationally. The chapter focuses on the indicators constituting the National Systems of Indicators and describes the Trend Chart approach utilised in Europe to monitor innovation.

We suggest that the majority of countries with scientific systems collect a number of indicators (as suggested by the OECD) and disseminate them in comprehensive documents regularly. The National Science Foundation in the USA and the OECD provide leadership in the field with their publications "Science and Engineering Indicators" and "Main Science and Technology Indicators" respectively.

In South Africa, NACI has recognised the importance of indicators and has established the "Indicators Programme". The Programme consists currently of the following three components:

- The National R&D Survey
- The National Innovation Survey
- Representation and participation in international indicators bodies such as the OECD's National Experts on S&T Indicators (NESTI).

However, South Africa does not produce a comprehensive document with indicators (like the NSF one) in order to disseminate existing information and neither supports relevant research in the field.

Based on the above we advance the following recommendations:

- NACI should develop in regular intervals (e.g. biennially) the "South African Science and Innovation Indicators". The report should present quantitative descriptions of key aspects of the scope, quality and vitality of the country's science and innovation enterprise. The report should be submitted to Cabinet and Parliament and should be publicly available for public and private policy makers. The NSF "Science and Engineering Indicators" (see Appendix) could be used as blueprint.
- NACI should consider approaching the European Commission (Innovation Policy Directorate of DG Enterprise and Industry) with the objective of participating in the Trend Chart programme activities. Such participation not only will market the country's innovation system internationally but it will also provide the necessary discipline and benchmarking expertise required in the monitoring of the national innovation system.

- NACI should consider creating a fund supporting long term research on issues of science and innovation policy. Currently the only support for science and innovation policy research is coming from NACI's procurement activities. While NACI's approach is supporting to a certain extend the existing expertise in the field in the country, the lack of institutionalised long term support constraints the development of new expertise in the field of science and innovation monitoring and assessment.

Best practices in public-private linkages/ technology transfer in science and technology

Introduction

The term "public/private partnership", in the area of technology policy, is defined as any innovation-based relationship whereby public and private actors jointly contribute financial, research, human and infrastructure resources, either directly or in kind.[26] Partnerships can be formal or informal arrangements governing general or specific objectives in research or commercialisation and involve two or multiple actors (e.g. consortia). As such, partnerships are more than simply a contract research mechanism for subsidising industrial R&D.

Private firms may enter into R&D partnerships by themselves. They may do so to overcome market failures that result from uncertainty and resource constraints and the inability to internalise significant spillovers. OECD (1998) suggests that "private R&D partnerships can be seen as a market response to market failures that prevent firms from conducting the socially optimum level of R&D. In the same vein, public sponsorship of R&D partnerships is a policy response to similar types of market failures that are not resolved by market mechanisms alone. This occurs, for example, when the transaction costs associated with R&D partnering are too high to induce collaboration or when the incentives for partnering (e.g. cost-sharing of inputs, appropriation of outputs) are insufficient and thereby result in the rejection by firms of socially beneficial joint R&D projects. Systemic failures that arise from mismatches in the incentives for co-operation among the various actors in the innovation system (e.g. universities, firms, laboratories) can also impede collaboration in R&D and technology, thus leading to lower social returns from public research".

Probably the main appeal of public/private partnerships is that they reduce the risk of failure that results when governments try to "pick winners" through traditional R&D subsidisation schemes. Public/private partnerships entail the competitive selection of participants and greater influence from the private sector in project selection and management, helping ensure that the best participants and projects are targeted.

OECD[27] suggests that there are no silver-bullet approaches (one fit all) in the field. It is suggested that the type of partnership best suited for a given policy objective will depend not only on the shareholders and their objectives, but more importantly on the type of market or systemic failure being addressed. Partnership programmes must thus be targeted and adapted to the market and institutional environments in which firms and public research partners operate. The size of firms, their sectors and their position on the innovation ladder (e.g. internal R&D capability) also have a bearing on their ability to collaborate with public research.

In this chapter we discuss mainly efforts by governments to bring closer universities and industry, as this type of partnership constitutes one of the most important policy issues internationally and we briefly discuss international collaborations.[d]

Universities are an important public sector partner in the domain of public-private partnerships. Universities have an important contribution to make in this process and the traditional perception of universities as merely institutions of higher learning is gradually giving way to the view that they could be important engines of economic growth and development – the emergence of universities' third mission.

For some the emergence of third mission runs counter to "social contract" for science and universities established by Vannevar Bush[28] in 1945 and to the von Humboldt model of the university. However it is generally accepted that major political and economic changes have affected science and universities during the last decade. Those changes gave rise to a number of interpretations and analyses. Gibbons et al[29] have argued that there is a shift

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d This chapter draws on Pouris, A. (2006) "*Technology Transfer and Diffusion: Capacity and Potential in South Africa's Public Higher Education Sector*" HESA, Pretoria in production of knowledge from Mode 1 (conducted within disciplines, largely by universities and government research institutes and with little consideration of eventual use) to Mode 2 (conducted on a multidisciplinary basis by a variety of institutions and in the context of application). Etzkowitz et al.[30] view changes in terms of the emergence of a "Triple Helix" i.e. closer interaction between universities, government and industry and their "co-evolution" in a changing environment. In another approach Guston and others[31] have couched changes in terms of a shift in the "social contract" between science and the universities on the one hand and government and society on the other. Under the traditional social contract, based on a linear approach to innovation, universities had to focus on basic research and teaching and governments had to support them benefiting from the flow of benefits in terms of wealth, health and security coming from the end part of the innovation chain.

Despite the proliferation of explanations and theories the "third mission" is not new (the land grant universities in the USA were set up with a social mission in 1860s) neither has been applied successfully across the board.[32] In the UK innovation surveys show that, while almost half of manufacturing firms consider universities to be an important source of innovation only 10% have developed formal relationships with them.

Governments and universities internationally attempt to introduce the new mission hopping for the additional benefits to the institutions and the regions. These initiatives include the establishment of technology transfer offices, science and technology parks, incubators and other property based institutions that could potentially generate revenue for the university, knowledge spill-overs to the local firms and the creation of new jobs and industries. In many countries, governments have provided support for these initiatives through legislation to facilitate technological diffusion from universities to firms (e.g. Bayh-Dole Act of 1980); indirect incentives to engage in collaborative research (e.g. National Cooperative Research Act of 1984); direct subsidies for research joint ventures (e.g. US Department of Commerce's Advanced Technology Programme) and shared use of expertise and laboratory facilities (e.g. NSF's Engineering Research Centres).

However, mechanisms facilitating industry science interactions are necessary but not sufficient conditions to bring the desirable result. There are features in the specific technological domains which should be expected to be influential.[33][34] Some obvious factors would be government regulations (promoting or inhibiting collaboration); the R&D strength of the relevant industry (greater strength leads to more demand led interactions); the size structure of firms (larger firms may lead to more formal interaction); science and educational policies (e.g. the size of funding and the orientation of funding) which affect the strength of the academic research base and the quality and volume of `output' of graduates in particular fields; the existence of a developed venture capital market; the functioning of various bridging institutions and the prevalent values as regards industry-academia collaboration. Consequently, analysis of the academia -industry interactions needs to include a range of analyses of features in the surrounding innovation system as well.

Following this line of thinking the European Commission[35] argues that innovation should be fused and become part of all regulatory and institutional reform in a country. The report argues that current innovation policy – "second generation innovation policy" - emphasizes the importance of the systems and infrastructures that support innovation**.** These, however, are influenced by many policy areas, in particular research, education, procurement, taxation, IPR and competition policy. But these policy areas are not developed having in mind innovation issues and the need to work together is not always recognised. The aim of the "third generation innovation policy" is to maximize the chances that regulatory reform will support innovation objectives, rather than impede or undermine them. While we refer to the third generation policy in the context of technology transfer, the approach is valid across the total spectrum of managing the NSI[e].

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[e] An example where comprehensive support achieved the desirable policy objective is the establishment of "Software Technology Parks" in India. The companies in STP not only receive financial support by the government but also they don't have to obey in labour law regulations and in foreign exchange controls; they receive preferential treatment in energy outages;

International Experience

A recent study (Dylan Jones-Evans 1998)[36] investigated university – industry interactions in different regions (namely Ireland, Sweden, Portugal, Northern Ireland, Wales, Spain and Finland) in Europe. The study shows that in all of the universities studied, the general mission of the Industrial Liaison Office (ILO) function within the university is broadly similar, namely to devise and increase the links between the university and external organisations. However, the study indicates that there are a number of different models of organising the industrial liaison function within different regions of Europe. Within countries such as Spain, Portugal and Finland, only the most basic tasks are undertaken by the ILO function, whilst in countries such as Wales and Ireland, where the ILO function is an integral part of the university administrative system, there may be higher level tasks undertaken. However, it is clear that these particular models have not been deliberately chosen as part of a definitive strategy, by the institution, to develop linkages with industrial firms. Rather, the process has been largely reactive, reflecting current administrative models or, in some cases, being driven by European funding initiatives to work with industry

One of the main barriers to develop increased collaborative links with industry was a lack of internal resources at both an individual and institutional level. On an individual level, academic staff does not have time to establish and undertake collaborative projects with industry in addition to their teaching and administrative duties for the university. In addition, the emphasis on traditional outputs for academic work, such as publications, has meant that collaborative industrial R&D is not valued, except as a source of income. Therefore, there is a distinct lack of motivation to undertake applied research or technology development activities related to industrial needs. The study identifies that the general lack of academic recognition for commercialisation and rewards for publications, as opposed to patents, had been a major barrier in many countries.

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preferential access in state of the art digital infrastructure; they receive 10 years tax holidays etc. The Indian ICT industry grows by 15% per year for more than a decade.

On an institutional level, it was considered that there was not enough emphasis, especially in terms of internal funding within the university, to sufficiently develop linkages with industry. It became apparent that there was a lack of a proper infrastructure for developing academic-industry collaborative activities, especially in the marketing of research expertise. It was felt that universities were not proactive enough, with not enough promotional activities to ensure businesses' awareness of the expertise available.

Another finding was the gap of knowledge, by researchers and industrialists, about each other's organisational cultures. These cultural differences are mainly down to a lack of communication by both researchers and industrialists about the advantages (and disadvantages) of collaborative activities. It was therefore evident that there was a need to set up guidelines as part of a policy for industry working with a university, with a particular need to increase awareness, and to market the university in a more professional light. The reasons why this potential has not been fully realised include a lack of information about these activities, coupled with the fact that such arrangements have never been previously considered by university authorities. This was identified as one area where policy makers can influence further developments by providing more information on the potential benefits of such relationships.

An interesting finding was that increasing pressures to institutionalise entrepreneurship (especially informal activities such as consultancy) within the university environment may actually result in a decrease in these activities. This was the case in Ireland, where universities have tended to exert little control over university-industry links and, as a result, entrepreneurial activities have developed naturally as a result of the needs of both the individual academic and the industrial firms. Therefore, whilst academic entrepreneurship in Sweden has been encouraged as a result of 'top-down' strategies through institutional reforms and initiatives, the Irish approach has been one of 'laissez-faire'. As a result, academics have been allowed to develop their own initiatives relative to their own interests which were affected adversely when universities tried to formalise relations.

BOX 10: US policies – MIT

Consultancy is much more of a core activity at MIT than it is in UK universities. The opportunity to perform consulting work is built into its faculty employment contract, which only covers nine months of the year. The rest of the time can be filled by consultancy work. MIT provides strong financial incentives to academics to bring in industrial research income. It also removes teaching responsibilities for those who bring in more than $2m, and administrative responsibilities for more than $4m. MIT recognises the need for clear policies to avoid conflicts of interest within this framework.

The study demonstrated that academic entrepreneurship is not merely relates to the development of 'campus companies' or 'spin-off firms'. The study suggests that the most effective forms of technology transfer are consulting and contract research and hence it suggests that the whole issue of the development of 'campus companies', at least in relation of effective technology transfer, needs to be considered in more detail. This echoes the findings of the OECD reports[37][38] which find that revenues from patents and licenses are almost always minimal. In the USA gross revenues from licenses represent less than 3% of R&D funding of the USA universities and less than 2% of R&D expenditures in public laboratories. Furthermore net revenues are much smaller and often negative. For example in 1997-98 the CSIRO in Australia spent AUD 4.7 millions for legal and patent portfolio management costs compared to the AUD 5.26 million income from patents.

The study suggested that increasing the efficiency of collaboration between universities and existing high technology firms is a priority and it made a number of recommendations for funding related to facilitating the interface activities.

An investigation in the UK (HMSO 2003, Lambert Report)[39] aimed at identifying trends in the relationship between universities and Industry and assist in the development of relevant policy.

The investigation identified that two broad trends are reshaping the way that companies are undertaking research around the world. The first is that they are moving away from a system in which most of their research and development (R&D) was done in their own laboratories, preferably in secret, to one in which they are actively seeking to collaborate with others in a new form of open innovation.

The second trend is that business R&D is going global. Multinationals are locating their research centres in their most important markets, especially if those markets happen to contain centres of outstanding research. Their home country is no longer the automatic first choice for their R&D investment.

The report argues that "These trends have big implications for universities, which are potentially very attractive partners for business. Good academic researchers operate in international networks: they know what cutting-edge work is going on in their field around the world. Unlike corporate or government owned research facilities, university laboratories are constantly being refreshed by the arrival of clever new brains."

The major finding of the investigation is that the major challenge in the UK lies on the demand side. "Compared with other countries, British business is not research intensive, and its record of investment in R&D in recent years has been unimpressive. UK business research is concentrated in a narrow range of industrial sectors, and in a small number of large companies. Hence technology transfer from universities is hampered by lack of demand for their know-how."

The Review recommends that the Government should continue to invest in a permanent and substantial third stream of funding (three year funding based on business plans), while simultaneously monitoring and evaluating the outputs from its investment. Such funding should enable universities to build up their capacity to:

- Engage in networking and other outreach events with businesses, including SMEs.
- Market their research and teaching to business.
- Establish business liaison and technology transfer offices to provide advice and to negotiate consultancy, contract and collaborative research and license agreements.

- Establish spinout companies.
- Provide entrepreneurship training for science and engineering graduates.
- Provide work placements for students in industry.

The Review identifies that management, governance and leadership within the university system needs to function properly if technology transfer is to function successfully. The review emphasizes efforts to strengthen executive management. It identifies that many universities have developed strong executive structures to replace management by committee, and have raised the quality of their decision-making and of their governance. Strategic planning and the process of resource allocation have been improved. The Review suggests that the sector has reached a point where a voluntary code of governance should be developed, to represent best practice across the sector. It recognises that it will not be appropriate for all universities to comply with such a code: in such cases, they can explain in their annual report why their particular arrangements are more effective.

BOX 11: US investment in university research

Twenty years ago, total research spending in the both the UK and the US represented around 2.4 per cent of each country's GDP. But in the following two decades, their paths have diverged sharply. By 2001, US spending was up to 2.8 per cent of GDP, while the UK share had declined to 1.9 per cent.

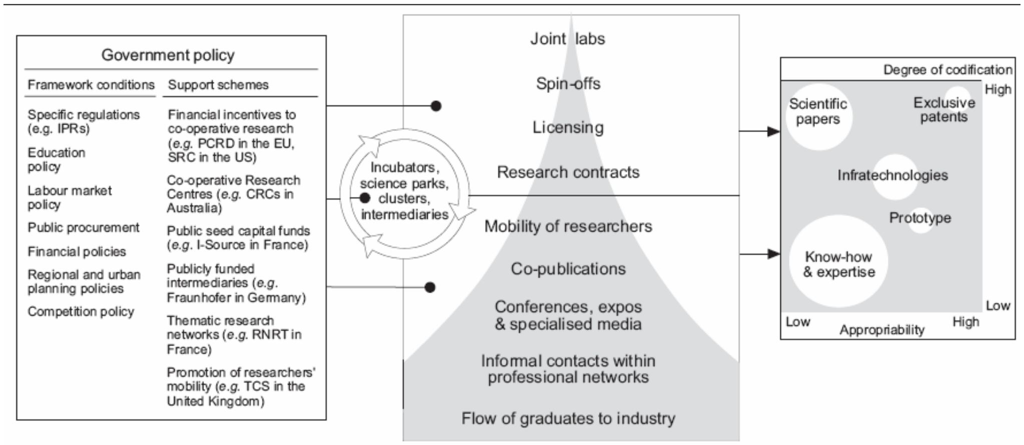
University-based research plays a critical role in the US system of technological innovation, and funding has grown at a rapid pace in real terms. Much the biggest share – roughly three-fifths – comes from the federal Government, which put a total of $19.2bn into university research in 2001. The largest increase in federal funding since 1970 has come from the National Institutes of Health, and more recently the Department of Defense has also been increasing its contribution. Industry funds around 7 per cent of total research spending in US universities, and has been the fastest growing source of funding for academic R&D over the last 35 years. Over a fifth of total university spending on R&D last year was classified by the National Science Foundation as applied research – an enormous investment in applied knowledge.

One of the great strengths of the US university system lies in the scale of its endowment funds – endowment income and unrestricted gifts have been another rapidly growing source of research funding in recent years. Research by the Sutton Trust emphasizes the growth of overall endowment funds.11 Twenty years ago, Harvard was the only university with an endowment of more than $1bn, whereas now there are 39 institutions. Oxford and Cambridge would each come in at around 15 on the US list, but no other UK university would make it into the top 150.

Cutbacks in state funding and the setback in the stock market mean that many US universities are less prosperous than they were. However, their financial resources still look daunting when seen through UK eyes. The University of Southern California, for example, has set up a war chest to recruit 100 star academics in the next three years. It has put aside $100m for the purpose.

OECD[40] has also investigated the issue. The report analyses the changing role of industry-science relationship in national innovation systems, identifies forms of technology transfer (Figure 4) and identifies benchmarking indicators for monitoring and assessment. The report emphasizes that the most important mechanisms of technology transfer are flow of graduates to industry and informal contacts and that licensing, spin-offs and joint labs are the tip of the iceberg. The indicators identified include: size and orientation of public research; absorptive capacity of the business sector; size and functions of intermediaries; government incentives and programmes; regulatory framework; financial flows between public and private research organisations; labour mobility and other knowledge flows. The report identifies that in a globalised world foreign firms usually make more use of public research institutions than local ones and it suggests that governments should consider how to exploit this phenomenon.

Figure 4: Mechanisms for University-Industry Technology transfer



BOX 12: Dynamic decision-making
The University of Strathclyde was one of the first universities to shake up the way it made decisions. In its 1986 assessment of effective decision-making following the Jarratt Report, it concluded that the traditional approach "presented formidable obstacles to change" and that "'hard times' demand 'hard choices' which would require a more focused administration". Over the next decade, the university consolidated schools and departments into four major faculties, devolved budgetary authority and responsibility to deans, reduced the number of committees, and created a University Management Group (UMG) of academics and administrators.

Strathclyde's UMG demonstrates a number of important best practices with regard to management teams. First, they meet either weekly or bi-monthly to ensure important decisions that need consultation are not delayed unnecessarily. Second, they are made up of senior managers from both the academic and administrative sides of the university. Third, they practice cabinet-style, collective decision-making. Individuals act in the interest of the institution and not that of the group they represent. In Strathclyde, the five deans of the university all sit on the UMG, and, unusually, two lay members of the governing body (the chair and the treasurer) and the head of the student union are invited to attend. The collective and transparent nature of executive management at Strathclyde has created a broad level of trust in the senior team.

Furthermore the report describes a number of efforts internationally to exploit the production of patentable inventions in universities. An approach used in a number of countries is the subsidization of patent filling and maintenance costs. For example, the National Science Council in Taiwan reimburses universities 70% of the total patenting expenditure. Furthermore NSC supports financially the establishment of IP offices, technology transfer offices and technology licensing offices.

The distribution of royalties is also used as a policy tool (incentives). In a number of countries greater share is granted to individuals. In the University of California inventors enjoyed 40% of net royalty revenues (1997). At Warwick University in the UK, academics can receive up to 75% up to a certain threshold, after which the share drops to 50% for the researcher and 50% for the institution. In France inventors receive 50% of the royalties. In Korea 60% is allocated to researcher. In Japan, the Japan Science and Technology Corporation to which university inventions are transferred, bears the costs of patent applications and renewal. If the commercialisation is successful, JST returns 80% of royalties to researchers.

The report makes the following policy recommendations.

- *"Giving greater priority to basic and long-term mission-oriented research in government S&T programmes*[f]. Basic and long-term research- whether motivated by scientific curiosity or by the challenges facing industry and society- produce new scientific and technical knowledge that is increasingly important in driving innovation. Changes in business R&D strategies are generally accentuating longstanding disincentives for private industry to invest in fundamental research, thus heightening the need for government support.

- *Ensuring appropriate frameworks for intellectual property rights*. Governments must establish clear rules and guidelines with regard to the intellectual property resulting form publicly funded research, while granting sufficient autonomy to research institutions. A good practice is

[f] This recommendation is also supported by empirical studies which show that a minimum threshold of basic research is required before technological innovation takes off at national level. (Américo Tristão Bernardes and Eduardo da Motta e Albuquerque (2003) "Cross-over, thresholds, and interactions between science and technology: lessons for less-developed countries" Research Policy 32, 865-885).According to the findings of Bernardes et al (2003) South Africa should double its outputs from basic research before the country's innovation system will take off.

to grant intellectual property rights to the performing research organisation while ensuring that individual researchers or research teams can share in the rewards. An interim conclusion is that a good practice might be to grant IPR ownership to the performing research organisation but to ensure that researchers enjoy a fair share of the resulting royalties. Globalisation of research accentuates the need for additional efforts to harmonies IPR regimes and practices at international level. Currently, far too much time is wasted in attempting to work out the details and differences in the patenting and licensing policies of different countries.

- *Matching supply and demand of scientific knowledge.* Regulatory reforms related to IPR's and the licensing of publicly funded research should be complemented by measures (such as the establishment of technology licensing offices, public/private partnerships in funding R&D, stimuli for co-operation with business, and support for spin-off formation) that stimulate business demand for scientific inputs and improve the ability of public research organisations to transfer knowledge and technology to the private sector.

- *Improving the governance of universities and public laboratories*. Public laboratories can be made more responsive to emerging needs by establishing new mechanisms for priority- setting and funding that reflect industry input and tie funding to performance, as well as by strengthening their links with the training and education system. Additional efforts to break down disciplinary boundaries will enable them to better engage in emerging scientific and technical areas. In many countries, universities would benefit from greater autonomy in decision making coupled with more programmatic R&D funding. Institutional support remains important but more competitive funding instruments are needed to improve the quality of research results while ensuring that fields of science of high economic importance receive attention.

- *Safe-guarding public knowledge*. Setting clear rules on IPRs is key but not sufficient to achieve a balance between commercial aims and the research and teaching mission of the public research institutions. Governments must ensure sufficient public access to knowledge form publicly funded research. It must also acknowledge the risks to the research and innovation system that may result if the IP protection granted is too strong and non-exclusive licensing too rare. Finally, ethical guidelines for and by public research institutions are necessary to prevent or resolve conflicts of interest among the institutions and researchers involved in collaboration with industry.

- *Promoting the participation of smaller firms.* Young technology-based firms play a key role in linking science to markets. Governments rightly attach priority to encouraging spin-offs from public research to stimulate innovation. Spin-offs fill a gap between research results and innovative products and services. They are also a means for universities to broadly license technology. However, there is also a case for public support and incentives to existing SMEs and especially those in mature industries in order to help them link up with the science base and enhance innovation capacity.

- *Attracting, retaining and mobilizing human resources.* Strong demand for highly skilled personnel increasingly extends across borders, raising concerns about a "brain drain" in some countries in which the loss of one or two key individuals can undermine research capabilities. For companies and research institutions, keeping talent requires investments in in-house training, career growth potential as well as excellent research working conditions. To attract students at university, graduate programmes must better integrate interdisciplinary and contacts with industry in training and research. For governments removing barriers and disincentives to mobility and flexibility in research employment is also essential. Worker mobility is a critical element of industry-science relations and can be enhanced by regulatory reforms that allow public researchers to work more closely with private industry.

- *Improving the evaluation of research*. Evaluation of publicly funded research must evolve in response to the considerable expansion of the commercialisation activities of universities and public research institutes, and evaluation criteria must take into account that excellence in research and training of graduates has become, at least in some disciplines, more tied to applications in industry. Evaluation criteria need to recognise the quality of the research, its potential social and economic impact, and the value of university research in educating students. In this area, national initiatives should be complemented by further efforts at international level to develop benchmarking indicators and methodologies, and promote the use of foreign expertise in national evaluation."

While university-based alliances attract particular attention in the field, governments are also keen on promoting international partnerships. Traditionally, there have been three main objectives of publicly supported international partnerships: i)tackling global-scale issues such as climatic change, oceanography, renewable energy and space exploration (i.e. mega-science projects); ii) promoting socio-economic/regional co-operation in R&D through bilateral agreements; and iii) technology transfer and co-operation, mainly between advanced and developing countries and as part of commercial/trade agreements.

The Intelligent Manufacturing Systems Initiative (IMS)[g] aims to set the appropriate manufacturing quality standards and intellectual property rights for international co-operative R&D. This project illustrates the important role of government collaboration in what initially began as a private/private partnership. A key feature of the IMS initiative is its use of an extensive feasibility study and the development of terms of reference for intellectual property rights. Obtaining support from national governments and tapping into national umbrella organisations made the screening and selection of projects more effective.

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g Terms of Reference for IMS were adopted in September 1991 and a secretariat was established by the six Participants: Australia, Canada, the European Community (EC), the five participating EFTA countries (Austria, Finland, Norway, Switzerland and Sweden), Japan, and the USA.

At the EU level, various mechanisms exist to promote international partnerships in R&D and technology development. The EUREKA initiative aims to raise the competitiveness of European industry by funding projects which increase co-operation between firms and universities/research institutes in areas of advanced technology. Similarly the INNOVATION programme brings universities and small firms together around specific projects. The EU's Framework Programmes for international partnerships are now moving away from sectoral based research to projects that require a high degree of inter-disciplinarity and involve several Member States. Recently, another aim of cross-border partnerships is the promotion of networking among and between actors of national innovation systems (e.g. between international consortia of firms and universities, business-to-business relations).

A recent OECD[41] report argued that the increasing pace, scale and complexity of enterprise alliances at the global level raise a number of issues for policy makers. Efficiency gains derive from synergy effects among firms which are able to continue to operate at arm's length. OECD points to the positive effects of strategic alliances in terms of firm performance and profits as well as social (economy-wide and consumer) benefits. For example, learning effects of alliances can raise social welfare by equalizing worldwide knowledge. On the other hand, there is the possibility of anti-competitive effects in cases where alliances bring together the leading competitors in a market. Firm-level benefits may also vary among allied firms since larger partners may derive more of the profits than smaller partners. Moreover, a range of barriers, such as information and resource gaps, may prevent smaller firms from participating in international alliances to the same extent as larger enterprises.

Thus it needs to be examined whether the benefits of alliances are higher than their costs from the social as well as the private perspective, and what policies are needed to help realize the possible gains and to minimize the social costs.

Technology Transfer in South Africa

Since 2004 a new public higher education landscape has been established in South Africa. It consists of 22 public institutions: 11 universities, five `universities of technology' and six `comprehensive institutions'. In addition, two National Institutes for Higher Education are in the process of being established in Mpumalanga and the Northern Cape.

The new landscape incorporates a new institutional nomenclature, notably the terms `university of technology' and `comprehensive institution'. Universities of technology are institutions formerly known as technikons, and so re-designated in October 2003. Comprehensive institutions combine both university-type and technikon-type programmes, and in some instances result from a university-technikon merger.

Universities operate within the country's national system of innovation which is relatively of low R&D intensity. In South Africa[42] gross expenditure on R&D as percentage of GDP is around 0.8% while the relevant average OECD[43] figure is 2.33% and in a number of countries the relevant figures exceed 3% (e.g. Sweden 4.27%, Finland 3.4%, Iceland 3.04% etc). During 2003 the higher education sector[h] performed 20.5% of the total research in the country and industry 55.5% of the total. Despite the high share of business enterprises R&D (BERD) in the country's R&D expenditures, BERD as percentage of GDP in South Africa (0.44 %) is substantially lower for that of the OECD countries (1.62 %), indicating a low propensity of the business sector to undertake research and development activities.

Twenty three percent of the higher education R&D expenditure is supported with funds from the business sector[44]. This is an exceedingly high dependence on business. Table 4 show that the average percentage of HERD financed by industry in the OECD countries is 6.3%. The highest dependence is that of Korea where HERD financed by industry is 14.3 %.

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h The 1997/98 figures (DST, 2005) showed that the higher education sector was performing 12% of the country's R&D. Different approaches in the collection of data may be responsible for that discrepancy.

Table 4: Percentage of HERD financed by industry

Countries	Most recent data	Countries	Most recent data
Australia	4.9	Mexico	7.8
Austria	1.7	Netherlands	6.5
Belgium	10.9	New Zealand	5.8
Canada	9.6	Norway	5.1
Czech Republic	0.7	Poland	6.3
Denmark	1.9	Portugal	0.8
Finland	6.7	Slovak Republic	0.3
France	2.7	Spain	8.7
Germany	11.3	Sweden	5.5
Greece	5.0	Switzerland	5.1
Hungary	4.4	Turkey	19.4
Iceland	10.9	United Kingdom	6.2
Ireland	5.3	United States	5.7
Italy	4.0	***South Africa***	***23.1***
Japan	2.3	European Union	6.5
Korea	14.3	**Total OECD**	6.3

Looking inside the higher education sector we can identify constraints impending technology transfer as well as research and development activities. Tables 5 and 6 show the way academics distribute their times[45].

Table 5: Time distribution of academics in "research intensive" universities

Activities	**% time spent by Prof & Ass Profs** (127)	**% time spent by other academics** (157)
Undergraduate time	18.92	35.68
Postgraduate courses	11.49	10.43
Supervision postgraduates	14.76	7.34
Self education	6.28	7.89
Special studies	1.29	0.74
Patent	0.16	0.10
Data collection	2.24	3.48
Testing	1.21	1.55
Health	2.61	2.69
R&D	11.65	9.87
Innovation	1.35	1.11
Continued education	4.06	3.54
Art work	0.69	0.12
Administration	22.28	15.26

Table 6: Time distribution of academics in "non research intensive" universities

Activities	**% time spent by Prof & Ass Prof (24)**	***% time spent by other academics (35)***
Undergraduate time	15.92	*37.20*
Postgraduate course	10.67	*10.69*
Supervision postgraduates	17.21	*5.74*
Self education	7.04	*4.94*
Special studies	1.54	*0.97*
Patent	0.00	*0.09*
Data collection	3.17	*2.97*
Testing	2.00	*3.14*
Health	0.83	*2.91*
R&D	14.54	*5.80*
Innovation	1.46	*2.74*
Continued education	3.25	*3.69*
Art work	0.04	*0.14*
Administration	*23.17*	*18.94*

The tables show that the most time consuming activities are administration and activities related to undergraduate teaching. R&D activities consume between 12% and 15% of the time of professors and associate professors and between 6% and 10% for senior lecturers and lecturers. Patent related activities and innovation related activities were identified to occupy less than 3% of the time of academics. These figures are substantially lower than for similar activities abroad. Furthermore academics declared that they wish to reduce the time they spend on administration and undergraduate teaching and spend more time on research and innovation activities.

The report suggested that "the limited time South African academics spend on R&D and other innovation activities coupled with their desire to spend more time in those activities has policy implications. For example, university administrations can streamline their operations and provide administrative staff at faculty and departmental level so that can free their academics from administrative duties (currently occupying more than 20% of their time) to spend more time on research and innovation activities".

The South African government recognises the importance of technology transfer and the collaboration of the various stakeholders within the national system of innovation and has established a number of relevant programmes. Probably the most important are the "Technology Stations Programme" and the Technology and Human Resources for Industry Programme (THRIP).

Technology Station Programme (TSP) was developed by Department of Science and Technology in order to strengthen and accelerate interaction between Universities of Technologies and SMME's. The Universities of Technology act as hosts to the Technology Stations by providing a sound institutional, organizational and legal framework. The Tshumisano Trust is the implementation agency for the TSP. The Trust provides technical and financial support to Technology. The Technology Stations in turn offer technical support to existing SMMEs in terms of technology solutions, services and training. The German Technical Cooperation Agency (GTZ) is one of the Trust's Stakeholders and it contributes towards skill development for the Technology Station staff members. To this end GTZ funds exchanges and visits by experts from Germany and visits to Germany by Technology Station Staff. The DST commitments are R18 million per year.

The Technology Stations that fall under the control of the Trust are:

- Tshwane University of Technology: ***Electronics and Electrical Engineering, Complemented by IT***
- Central University of Technology, Free State: ***Metals Value Adding and Product Development.***
- Tshwane University of Technology: ***Chemistry and Chemical Engineering***.
- Mangosuthu Technikon: ***Chemistry and Chemical Engineering***
- Vaal University of Technology: ***Materials and Processing Technologies***.
- Nelson Mandela Metropolitan University: ***Automotive Components***.
- Cape Peninsula University of Technology: ***Clothing and Textile***.
- University of Johannesburg: ***Metal Casting Technology***.
- Durban Institute of Technology: ***Reinforced and Moulded Plastics***
- Cape Peninsula University of Technology: ***Agri-food Processing Technologies***

The Technology and Human Resources for Industry Programme is a collaborative effort between government and industry. Industry and DTI share the costs – and therefore the risk – of developing commercial technology on a R2 to R1 basis (industry: DTI). The DTI's support may be doubled if a project supports certain THRIP priorities[i]. The programme is managed by the National Research Foundation.

The THRIP objectives are:

- To increase the number and quality of people with appropriate skills in the development and management of technology for industry.

- To promote increased interaction among researchers and technology managers in industry, higher education and SETIs, with the aim of developing skills for the commercial exploitation of science and technology. This should involve, in particular, promoting the mobility of trained people among these sectors.

- To stimulate industry and government to increase their investment in research and technology development, technology diffusion and the promotion of innovation.

Funding takes place in the following ways:

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[i] The DTI's financial support for a project may be doubled, if it supports any of the following THRIP priorities:

- To support an increase in the number of black and female students who intend to pursue technological and engineering careers;
- To promote technological know-how within the Small, Medium and Micro Enterprise (SMME) sector, through the deployment of skills vested in HEIs and SETIs;
- To facilitate and support multi-firm projects in which firms (including at least one BEE) collaborate and share in the project outcomes;
- To facilitate and support the enhancement of the competitiveness of black owned enterprises through technology and human resource development.

- Firms and THRIP invest jointly in research projects where project leaders are on the academic staff of South African Higher Education Institutions.

- THRIP matches investment by industry in projects where researchers/experts from Science, Engineering and Technology Institutions (SETI) serve as project leaders and students are trained through the projects.

- Technology Innovation Promotion through the Transfer of People (TIPTOP) schemes promotes the mobility of researchers and students between the industrial participants, HEIs, and SETIs involved in joint projects. Four TIPTOP schemes are available. These are:

    - The exchange of researchers and technology managers between HEIs, SETIs and industry.
    - The placement of SET graduates in firms, while they are working towards a higher degree on a joint research project.
    - The placement of SET graduates in small, medium and micro enterprises (SMMEs).
    - The placement of SET skilled company employees within HEIs or SETIs.

The programme is in accordance with international best practise. Similar programmes are run in the majority of the OECD countries with the best known being the LINK Collaborative Research Scheme[46] in the UK and the Advanced Technology Programme in the USA.

The above mentioned incentives should be set in the context of implicit incentives in the funding formula[47] of the higher education sector.

Table 7: Distribution of budget totals for 2004/05 to 2006/07

	Distribution of budget for 2004/05 (R'million)		Provisional distribution of MTEF budgets				Increase on budget provision for previous financial year		
			2005/06 (R'million)		2006/07 (R'million)		2004/05	2005/06	2006/07
	R' million	%	R' million	%	R' million	%	%	%	%
1. Block grants	**8568**	**87**	**9143**	**87**	**9716**	**87**	**8.30**	**6.70**	**6.30**
1.1 Teaching inputs	5496	56	5866	56	6233	56	8.00	6.70	6.30
1.2 Institutional factors	573	6	611	6	649	6	11.40	6.70	6.30
1.3 Teaching outputs	1374	14	1466	14	1558	14	7.90	6.70	6.30
1.4 Research outputs	1125	11	1200	11	1276	11	8.50	6.70	6.30
2. Earmarked grants	**809**	**8**	**860**	**8**	**1779**	**8**	**-20.00**	**6.30**	**9.10**
2.1 NSFAS	578	6	638	6	938	6	6.10	10.40	13.80
2.2 Interest & redemption on loans	146	1	131	1	726	1	-8.70	-10.30	-12.20
2.3 Foundation programmes	85	1	91	1	115	1	30.70	6.80	6.30
3. Institutional restructuring	**502**	**5**	**550**	**5**	**97**	**5**	**119.20**	**9.60**	**3.30**
TOTAL	**9879**	**100**	**10553**	**100**	**11592**	**100**	**10.70**	**6.80**	**6.30**

The universities in South Africa are funded according to a formula which distributes resources according to a number of determinants (numbers of students enrolled, number of students graduating, number of publications etc).

The table indicates that approximately R10 billion were received by the higher education institutions during 2004/05. Teaching inputs and outputs are supported with grants valued at R 6.87 billion and research outputs with grants valued at R1.2 billion per year.

Legislation and regulations, in overlapping the technology transfer arena, also determine the success of efforts to transfer technology from public research institutions to industry and government organisations[48].

The fiscal environment is an important component of the national system of innovation influencing the research intensity of the economy and consequently technology demand and transfer. The tax environment not only affects the propensity of local firms to undertake research and development but it is also a powerful instrument in attracting research funds from abroad. Israel and Canada have developed a R&D industry by attracting international funding through tax incentives.

Table 8: Country comparisons on the basis of B-Indices (1999-2000)[49]

Country	Large company	Small company	Country	Large company	Small company
Australia	0.890	0.890	Japan	0.981	0.937
Austria	0.878	0.878	Korea	0.918	0.837
Belgium	1.012	1.008	Mexico	0.969	0.969
Canada	0.827	0.678	Netherlands	0.904	0.613
Denmark	0.871	0.871	New Zealand	1.131	1.131
Finland	1.009	1.009	Norway	1.018	1.018
France	0.915	0.915	Portugal	0.850	0.850
Germany	1.041	1.041	South Africa	1.031	1.031
Greece	1.015	1.015	Spain	0.687	0.687
Iceland	1.028	1.028	Sweden	1.015	1.015
Ireland	0.937	0.937	Switzerland	1.011	1.011
Italy	1.027	0.552	United Kingdom	1.000	1.000
			United States	0.934	0.934

Table 8 compares the tax environments in South Africa and a number of other countries. The yardstick is the B-index. The B-index is the ratio of the present value of project related before tax income to the present value of project related costs at which an R&D project becomes profitable for the firm that undertakes it- that is the critical benefit-cost ratio. Under ceteris paribus conditions, the lower the value of B the greater will be the amount of R&D undertaken in that country. South Africa has one of the highest B-indices in the world. The consequence of the high index is that businesses do not have an incentive to support innovative activities in the country and even when they recognise its importance they will undertake their R&D in countries with more competitive fiscal environments. The situation affects particularly adversely small and medium enterprises which usually do not have the expertise and capacity to acquire know-how from abroad[j].

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[j] The tax credit of 150% for research and development announced by Minister Manuel (15 February 2006) follows close consultations with the private sector. The package has been developed jointly by National Treasury and the Department of Science and Technology. It forms part of Government's economic programme of action which was announced last year.

Procurement is a demand side determinant of innovation.*50* By being a more intelligent customer and by being more open to new approaches from the outset, government can stimulate the market for innovative products and encourage the growth of innovative and dynamic businesses. It can also provide a means of demonstrating new products, processes and services, and help to justify investment in new skills, equipment and R&D.*51* A number of governments have adopted the approach and innovation is one of the objectives of their procurement. For example, in the UK the DTI's Five Year Programme, published in November 2004, took forward this agenda. In particular it committed the Office of Government Commerce (OGC) and DTI to:

Work together on a joint project to establish an ideas portal, `a mechanism for firms, inventors and researchers to submit unsolicited, innovative proposals to the public sector.

Working together to support the promotion of innovation in public sector procurement, including identifying significant and high profile projects where government is seeking innovative solutions.

Similarly the New Zealand Government is reviewing their procurement regulations with the objective of promoting innovation.

In South Africa procurement policy not only is not utilised for the benefit of local scientific and technological growth but in contrast is isolating government from the beneficial effects of its interaction with the higher education sector (and vice-versa).

"Preferential Procurement Policy Framework Act No 5, 2000" presents an obstacle in the efforts of universities to offer their services to Government and other organs of the State and of Government to promote innovation through

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The new tax incentive means that, with a corporate tax rate of 36%, Government will forego 18 cents of tax revenue for each rand spent on R&D. Given that the private sector expenditure on R&D currently amounts to about 0,45% of GDP, this tax credit represents a windfall of well over R 1 billion procurement . More specifically paragraph 13 (5) (a) of the Act states "Preference points may not be awarded to public companies and tertiary institutions". As a consequence universities tendering for government tenders are in a disadvantage to other competing institutions. In effect this regulation advocates that government departments and state organs under ceteris paribus conditions should prefer to award tenders and accept advice by private sector consultants rather than from academics.

The regulation, furthermore, presents an obstacle to academic institutions to coordinate their efforts in their interactions with their potential clients. Individual academics can argue that by bidding on their own they have better chances to be awarded government contracts (if for example bid through a company owned by a women or by previously disadvantaged individuals) than bidding under the banner of their university.

Discussion and Recommendations

Technology transfer is a multifaceted activity taking place through a number of approaches ranging from training students and consulting industry to establishing spin off companies and patenting inventions. Successes of particular institutions have captured the imagination of policy makers and university administrators and the "third mission of universities" has been popularized internationally.

Often technology transfer is considered as an additional way to increase university resources. However, the international experience demonstrates that technology transfer is not usually a large revenue generator. A number of US universities started with that aim, but found it impossible to make significant amounts of money and so changed their objectives. MIT, Stanford and Yale all now state that their main reason for engaging in technology transfer is to improve the public good – that is, to create the greatest possible economic and social benefits from their research, whether they accrue to the university or not.

The characterization of technology transfer as public good has policy implications. While individual institutions may or may not be interested to maximize public good, policy authorities have the responsibility and duty to do so. Governments have recognised the importance of technology transfer and have established a number of incentives and institutions to maximize benefits. Globalisation of research and outsourcing of industrial research further emphasize the importance of the issue for national and regional prosperity.

In the interface of Universities–Businesses governments establish facilitating institutions. For example, the National Research Development Corporation (NRDC) was set up in 1948 by the British Government to commercialize British publicly funded research. In 1981, it was succeeded by the British Technology Group which was set up as a publicly owned company with the same goal. As of 1992, BTG is a private company with international presence aiming at commercializing novel technologies. In Belgium, the Interuniversity Institute for Biotechnology (VIB) serves nine universities and manages their IP and technology transfer in Biotechnology. In Denmark, the government funds the establishment of joint technology transfer networks on a regional and sectoral level in order to create economies of scale and optimise the utilisation of resources. Similarly in Germany the Fraunhofer Patentstelle (Fraunhofer Patent Centre) serves not only the Fraunhofer research institutes, but also universities and individual inventors. Services include the evaluation of inventions and IPRs, the filing of intellectual property applications, technological consulting, negotiation and issuance of licenses and collecting of royalties.

However, we have argued that while the existence of interface institutions is a necessary condition it is not sufficient to create the desirable effect. Universities should have the necessary capacity and orientation (desired by clients), businesses should recognise the importance of innovation for their success and the impact of environmental constraints (i.e. regulations and legislation of relevant policy arenas such as procurement, competition, education etc) should be minimal. We have outlined how the European Commission argues that the aim of the "third generation innovation policy" is to maximize the chances that regulatory reform will support innovation objectives, rather than impede or undermine them.

In the above context the success of the comprehensive ICT related incentives in India, the support for SMMEs in Brazil and the identification that technology transfer from universities in the UK suffers from low industrial demand are indicative of best practices and approaches. Probably the most important conclusion is that nurturing technology transfer requires a comprehensive approach incorporating issues of demand, supply and interface.

Our overview of the South African scene identifies a number of issues of importance for successful technology transfer. The main points are as follows:

- The South African industry is of low R&D intensity in comparison with international standards. Furthermore the tax environment in the country is not research friendly. As a consequence one may expect that universities face limited demand for relevant expertise from local and international sources. Despite that relative small R&D intensity of business in the country the majority of heads of technology stations and directors/deans of research agree that industry in their region is interested in R&D and technical know how and they believe that there is a critical mass of demands for technologies and technical competencies by industry in the country. Furthermore both groups agree that technology transfer activities are financially rewarding for their institutions. These perceptions are probably shaped by the relative to demand capacity of the universities to satisfy industrial demand and not by the absolute or comparative to other countries figures. If this line of argument is correct universities may face capacity constraints as industrial demand for their services is increasing.

- The country's higher education sector R&D is over-dependent on business enterprises funding (4-fold of the average OECD country). This dependence re-directs academic R&D away from basic and long term mission oriented research towards short term industry relevant consultancy and research. Innovation, however, is dependent on long term mission oriented and fundamental R&D. Universities without long term mission orientated and/or basic research will eventually be unable to satisfy the demands of their clients.

- There is asymmetry in incentives for academic outputs (publications) and technology transfer outputs. Academics receive a certain and defined in advance reward (financial and in terms of promotion) for publications. Rewards for technology transfer activities (e.g. patents) require time and effort in advance and the rewards are uncertain and not defined. Rational academics will prefer to spend their time on rewarding activities. While government incentives may play in important role in directing university activities, university authorities have also a number of instruments available (e.g. determinants of staff promotion) that can be utilised for the promotion of technology transfer in their institutions.

- South Africa still operates its national system of innovation on the basis of a second generation innovation policy paradigm. The paradigm emphasizes the importance of systems and infrastructures that support innovation. The third generation innovation policy paradigm makes innovation a government wide policy and aims to maximize the chances that regulatory reform in other domains (e.g. government procurement, competition etc) will support innovation objectives, rather than impede or undermine them. The example of procurement in South Africa is indicative of the neglect of monitoring the effect of regulatory reform on innovation.

- The opinion survey[52] of heads of technology stations and directors/deans of research identifies a number of possible constraints for technology transfer activities. The first, confirmed by a separate time survey, is lack of time of academics to get involved in TT activities. The second possible constraint is related to the claim by the heads of technology stations that industry lacks familiarity with work in their institutions. Although the assertion is refuted by the directors/deans of research the issue is of particular importance and should be investigated further.

Based on the above we advance the following recommendations:

- DST should establish an IP Agency. The Agency will have the responsibility to promote IP within the public research institutes domain. The Agency should provide financial support for the establishment of

IP, technology transfer and technology licensing offices within the public research institutes in the country ant it will subsidize patent filling and maintenance costs. The Agency should further undertake to provide regulations from time to time related to the distribution of royalties of the successful inventions. A substantial percentage (70%) of royalties should accrue to individual researchers until that time that there is a culture supporting patents in the country.

- The Department of Science and Technology (as the R&D coordinating Department) in collaboration with all relevant Departments should consider developing and expanding a THRIP type programme. THRIP currently is supported by the Department of Trade and Industry and it supports the mission and areas of priority of DTI. In a similar vein the programme should receive funds from the Department of Minerals and Energy, Department of Environment Affairs etc in order to support their respective missions and areas of priority.

- HESA, as the voice of the higher education institutions, should establish the necessary structures for the monitoring and assessment of the regulatory environment in which the universities of the country operate. It should utilize the produced intelligence in order to inform policy and decision makers about appropriate actions.

- HESA with support from the DST should undertake the regular monitoring of the way higher education institutions fulfill their mission related to technology transfer and disseminate the information to its members. The objectives of the effort will be: to provide information regarding the continuing development of interactions; to provide information supporting the development of public funding of the third mission of the HEI's activity; to provide to HEIs benchmarking and management information.

- DST should aim to enhance the demand side for university based industrial R&D in the country. The introduction of tax incentives for R&D may be a particular useful approach as it has the potential to attract international R&D resources in the country.

- The DoE and the DST should place priority in enhancing basic and mission oriented research in the higher education institutions in the country.

- University administrations should empower their academic staff to undertake research, development and innovation activities. Promoting decentralized approaches and supporting staff has the potential to bring the desirable effect.

- The Tsumisano Trust with the support of the DST should consider enhancing its mission to support the third mission of the universities across the total spectrum of the mission (not only for the establishment of technology station) and across all universities in the country.

Summary of Recommendations

In this chapter we present all the recommendations as appeared in the various chapters, classified according to institutions mentioned in the recommendation.

Recommendations concerning DST/NACI:

- DST should consider recommending the establishment of Chief Scientists Offices in Government Departments both nationally and provincially. The Chief Scientists Offices will be responsible for promoting effective use of science in policy making; for enhancing science capacity and quality in the fields of interest of the particular Departments and raising awareness and understanding of the effects of science and research on the Department' activities. Chief Scientists will be ambassadors for S&T integration

- DST within its mandate to coordinate national research and innovation should consider adopting an approach of "coordination through monitoring". DST should monitor the research funding activities of Government and publish the results annually. The OECD recommendations for the collection of data and the development of a report on Government Budget Appropriations or Outlays for R&D

(GABOARD)[53] and the "Annual Review of Government funded Research and Development" by the Cabinet Office[54] in the UK can be used as prototypes

- DST should monitor closely the implementation and fine development of the tax incentives for R&D scheme and its implications on other direct support schemes. The tax incentives scheme may have adverse consequences in the business sector innovation activities if applied inappropriately and/or if the government withdrew its support from existing direct incentives schemes.

- DST should monitor the progress for the establishment of research chairs at the universities with the ultimate objective of keeping the momentum and alleviating possible obstacles in the process.

- DST, within its mandate to co-ordinate the scientific and technological system, should establish an inter-departmental committee on "Critical Scientific and Technological Infrastructures". The mandate of the committee should be to investigate and make recommendations concerning policy and programmes affecting "critical scientific and technological infrastructures" such as research and training equipment, scientific and technological telecommunications, and R&D management.

  The Committee should consider among others the viability of introducing

  - the funding of "critical S&T infrastructures" as a separate line item in the governmental budget (Expenditure defrayed from the National Revenue Account)
  - approaches promoting closer collaboration on aspects of critical S&T infrastructure among organisations reporting to different government departments (e.g. academic institutions, research councils and parastatals).

- DST, in collaboration with the Department of Education should consider undertaking a drive to double the number of scientists and engineers graduating from the higher education sector within the next 10 years. Such a target will require an expected growth of 7% per year. Innovative approaches should be considered for funding this objective. A possible approach is to request the universities to develop proposals of the resources they require and they are prepared to commit in order to achieve the objective and choose to support those which contribute most in the achievement of the objective.

- Expansion of the higher education sector will be constraint in the short term by lack of appropriate number of academics. DST and HESA should motivate to the Department of Home Affairs the introduction of "speedy immigration visas" for academics who may wish to come to South Africa in fields of high priority. A complementary approach is to provide incentives for the repatriation of South African academics abroad. A five year tax holiday with repatriation financial assistance and possible NRF research support may attract a number of academics who are already familiar with the South Africa system.

- DST/NACI should develop in regular intervals (e.g. biennially) the "South African Science and Innovation Indicators". The report should present quantitative descriptions of key aspects of the scope, quality and vitality of the country's science and innovation enterprise. The report should be submitted to Cabinet and Parliament and should be publicly available for public and private policy makers. The NSF "Science and Engineering Indicators" could be used as blueprint.

- DST/NACI should consider approaching the European Commission (Innovation Policy Directorate of DG Enterprise and Industry) with the objective of participating in the Trend Chart programme activities. Such participation not only will market the country's innovation system internationally but it will also provide the necessary discipline and benchmarking expertise required in the monitoring of the national innovation system.

- DST/NACI should consider creating a fund supporting long term research on issues of science and innovation policy. Currently the only support for science and innovation policy research is coming from NACI's procurement activities. While NACI's approach is supporting to a certain extend the existing expertise in the field in the country, the lack of institutionalised long term support constraints the development of new expertise in the field of science and innovation monitoring and assessment.

- DST should establish an IP Agency. The Agency will have the responsibility to promote IP within the public research institutes domain. The Agency should provide financial support for the establishment of IP, technology transfer and technology licensing offices within the public research institutes in the country and it will subsidize patent filling and maintenance costs. The Agency should further undertake to provide regulations from time to time related to the distribution of royalties of the successful inventions. A substantial percentage of royalties should accrue to individual researchers until that time that there is a culture supporting patents in the country.

- DST, (as the R&D coordinating Department) in collaboration with all relevant departments and NRF should consider developing and expanding a THRIP type programme. THRIP currently is supported by the Department of Trade and Industry and it supports the mission and areas of priority of DTI. In a similar vein the programme should receive funds from other Departments i.e. the Department of Minerals and Energy, Department of Environment Affairs etc in order to support their respective missions and areas of priority.

- DST should aim to enhance the demand side for university based industrial R&D in the country. The introduction of tax incentives for R&D may be a particular useful approach as it has the potential to attract international R&D resources in the country.

- The DoE and the DST should place priority in enhancing basic and mission oriented research in the higher education institutions in the country.

- The Tshumisano Trust with the support of the DST should consider enhancing its mission to support the third mission of the universities across the total spectrum of the mission (not only for the establishment of technology station) and across all universities in the country.

Recommendations concerning NRF

- The NRF should institutionalise the support of research and training equipment by establishing an appropriate directorate/division. The division should be funded by dedicated (earmarked) funds, by top-slicing the budget of the other directorates and by raising funds from local and international donors.

- The NRF should establish appropriate `competitive grants'/funding mechanisms promoting : the interaction between academia and industry for the development and construction of new or improved equipment; the maintenance and augmentation of the R&T equipment infrastructure; the development of the necessary infrastructures in institutions that are either lacking or are with deficient infrastructures. A programme promoting the development of remote utilisation of equipment should be considered as an urgent priority in view of its possible impact across all other programmes. Different programmes should be established for different objectives.

- DST, (as the R&D coordinating Department) in collaboration with all relevant departments and NRF should consider developing and expanding a THRIP type programme. THRIP currently is supported by the Department of Trade and Industry and it supports the mission and areas of priority of DTI. In a similar vein the programme should receive funds from other Departments i.e. the Department of Minerals and Energy, Department of Environment Affairs etc in order to support their respective missions and areas of priority

Recommendations concerning the Department of Education

- The funding formula of the DoE for academic institutions should make R&T equipment an explicit component of the formula. Furthermore, adequate funds should be earmarked for at least the next five years in order to facilitate the required replacement and upgrading of R&T equipment.

- DST, in collaboration with the Department of Education should consider undertaking a drive to double the number of scientists and engineers graduating from the higher education sector within the next 10 years. Such a target will require an expected growth of 7% per year. Innovative approaches should be considered for funding this objective. A possible approach is to request the universities to develop proposals of the resources they require and they are prepared to commit in order to achieve the objective and choose to support those which contribute most in the achievement of the objective.

- The DoE and the DST should place priority in enhancing basic and mission oriented research in the higher education institutions in the country.

Recommendations concerning HESA

- HESA, as the voice of the higher education institutions, should establish the necessary structures for the monitoring and assessment of the regulatory environment in which the universities of the country operate. It should utilize the produced intelligence in order to inform policy and decision makers about appropriate actions.

- HESA with support from the DST should undertake the regular monitoring of the way higher education institutions fulfil their mission related to technology transfer and disseminate the information to its members. The objectives of the effort will be: to provide information regarding the continuing development of interactions; to provide information supporting the development of public funding of the third mission of the HEI's activity; to provide to HEIs benchmarking and management information.

- Expansion of the higher education sector will be constraint in the short term by lack of appropriate number of academics. DST and HESA should motivate to the Department of Home Affairs the introduction of "speedy immigration visas" for academics who may wish to come to South Africa in fields of high priority. A complementary approach is to provide incentives for the repatriation of South African academics abroad. A five year tax holiday with repatriation financial assistance and possible NRF research support may attract a number of academics who are already familiar with the South Africa system

- University administrations should empower their academic staff to undertake research, development and innovation activities. Promoting decentralized approaches and supporting staff has the potential to bring the desirable effect.

Recommendations concerning TSHUMISANO Trust

- The Tshumisano Trust with the support of the DST should consider enhancing its mission to support the third mission of the universities across the total spectrum of the mission (not only for the establishment of technology station) and across all universities in the country.

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APPENDIX: Content pages of "Science and Engineering Indicators 2004" National Science Board, USA

Chapter 1. Elementary and Secondary Education

Chapter 2. Higher Education in Science and Engineering

Chapter 6. Industry, Technology, and the Global Marketplace

Chapter 7. Science and Technology: Public Attitudes and Understanding

Chapter 8. State Indicators