THE RELEVANCE OF THE NATIONAL SYSTEM OF INNOVATION APPROACH TO MAINSTREAMING SCIENCE AND TECHNOLOGY FOR DEVELOPMENT IN NEPAD AND THE AU

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1. Purpose of the Paper

This paper is intended to illustrate the usefulness and attractiveness of the National System of Innovation Policy Framework. It was used initially in highly developed countries, usually with small science and technology capacity relative to their competitors. It was subsequently developed in South Africa and China (PRC) in the setting of economies in transition with large developmental challenges. It has also been used effectively in developing countries, (Latin America and the Middle East) to provide sound and sustainable approaches to drive positive results. A National System of Innovation (NSI) can be defined as “a network of institutions in the public and private sectors whose activities and actions initiate, import, modify and diffuse new technologies”.

A fuller definition is “a system of interacting private and public firms (either large or small), universities and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social and financial, inasmuch as the goal of interaction is the development, protection, financing or regulation of new science and technology to enhance quality of life and sustainable economic growth”.

The National System of Innovation approach focuses on the outputs of the system and the benefits that accrue to citizens and the society – rather than emphasing processes like “research” or institutions, such a “centres of excellence”. This is not to say that these are not important, but the NSI focuses on the harmonious and aligned interaction of all elements and linkages in the system to ensure effective and sustainable outcomes and impacts.

This has important implications for countries:

1) Every nation has a “de facto” system of innovation which may be more, or less, effective;
2) The actions taken by each nation to strengthen its system of innovation should not be informed by external “flavour of the month” policies but by an assessment of the most favourable set of actions given the resources available and the current condition of the NSI;
3) Every country will therefore have a different and disctinctive policy framework that serves its interests while remaining connected to the broader regional and global processes of innovation.

There has been considerable academic discussion of systems of innovation. In practical terms however focusing on *the stakeholders and functions* of the system of innovation permits rapid assessment of the current condition of the NSI and the design of policy interventions that are effective and sustainable. This approach allows the “mapping” of the NSI in a way that is accessible to policymakers and the actors in the system.

This paper will outline the concepts that underpin a national system of innovation and indicate why it is preferable to the older “R&D system” and “science and technology system approaches”. It will also be contrasted with “programmatic” policy interventions which take a one size fits all view of developmental challenges.

The South African experience of working with the NSI approach will be described as well as the experiences, more briefly, from a range of developing countries.

Critical weaknesses that tend to characterize the NSIs of developing countries will be described briefly, recognizing that different countries will respond differently within their NSIs to these challenges.

The use of indicators and indices that can describe the effectiveness and scale of the NSI is discussed.

A proposal for an NSI based approach to mainstreaming science and technology in the development agenda of NEPAD will be made. It will be argued that such an approach respects individual country approaches while at the same time providing a context for sub-regional and regional interventions to support national and regional systems of innovation.

2. National Systems of Innovation

a) The concept

The phrase *"system of innovation",* as it is used in this paper, *is a metaphor* - a powerful metaphor for describing the many interactions among many participating institutions, organisations and firms, most of which "formally" operate independently of each other. A national system of innovation, therefore encompasses some interactions which are co-operative and others which are competitive. It is essential to recognise that, in a "system of innovation", there is no single entity with the power to control the workings of the system, but there are many which exert significant influence, and there are often key points of leverage for government to strengthen and enhance the performance of the system as a whole.

It is important at the outset to understand that the relationship of research and development to technological innovation is neither simple nor linear. In addition to the obvious direct contributions of novel ideas that underpin commercialisable applications, indirect contributions through the advancement of knowledge and scholarship are equally important features of a system of innovation. Both types of scientific/technological activity also support the provision of highly trained personnel, and the building of a broader capacity for the generation, dissemination, accessing, application and interchange of knowledge. A key question for public policy revolves around the relative allocation of resources to the various modes of doing research, innovation, or technology transfer from external sources for any one economy and at any one point in time.

The use of the concept of a national system of innovation as a framework for policy is an attempt to signal a radical departure from the current situation and understanding, replacing the old with a new view of the role and status of the sciences, (including the social and human sciences), engineering and technology in national development. The perception by many countries that technical change is the primary source of economic growth means that economic and S&T policies have to recognize as central concerns the two processes - innovation, and technology diffusion - which are the agents driving that technical change.

For the purposes of analysis, a national system of innovation can be thought of as a: *set of functioning institutions, organizations and policies which interact constructively in the pursuit of a common set of social and economic goals and objectives, and which use the introduction of innovations as the key promoter of change.*

The four key interests, then, of any country can be thought of as being:

- to ensure that it has in place a set of institutions, organizations and policies which give effect to the various functions of a national system of innovation;
- to ensure that there is a constructive set of interactions among those institutions, organizations and policies;
- to ensure that there is in place an agreed upon set of goals and objectives which are consonant with an articulated vision of the future which is being sought; and
- to ensure that there is in place a policy environment designed to promote innovation.

The elements of a national system of innovation - the individuals, organizations, and policies - are to be found in most countries. What distinguishes a successful from an unsuccessful national system of innovation is its capacity to promote constructive interactions among these many elements to overcome past patterns of lack of coherence, deep fragmentation of effort, and often enormous imbalances in access to resources. This capacity, in turn, has to spring from the mindset of the individuals and organizations within the system - it is not something which can be created by decree.

The importance of interactions within a national system of innovation was underscored in a major OECD Report[1] when it was argued that:

> *"The interactive character of the innovation process calls for organizational structures and mechanisms to ensure the appropriate interactions and feedback inside corporations as well as among various institutions that make up the national system of innovation. For both analysis and policy, this model underscores the importance of co-operation between firms and institutions, and, thus, the role played by links and networks involving different organizations. The growth of inter-firm alliances represents a major change in the area of innovation. These emphasise, in particular, the increasing symbiosis between science and technology, the pervasive nature of some key contemporary technologies, and the synergy and even fusion of some technologies."*

Three principal reasons underlie the utility of the concept of a 'national system of innovation' as a basic framework for policy analysis:

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1 "*Technology and the Economy: the Key Relationships*" OECD, Paris, 1991

1. It affords an opportunity to think of means for the promotion of coherence and integration among national activities;

2. It offers a means of identifying what needs to be done without automatically tying the necessary functions to any particular institution or organization which is currently in place; and

3. It focuses attention on 'innovation' - on doing new things in new ways - rather than simply on the production of knowledge or human capital, for instance.

b) A ‘functional approach’

Much academic work has been undertaken on systems of innovation and this research has, in general strengthened the notion that policy interventions within this approach can be better designed and are more sustainable that interventions at lower levels in the system.

However academic analysis needs to be complemented with practical policy development in order be effective. This need for practical measures has led to the use of a functional approach to describe the elements of a system of innovation. This permits actors and stakeholders within the system to identify their distinctive roles and understand their relationship to others in the system. The net result is the potential for better articulation, identification of gaps and challenges and greater agreement, at least in principle, on the future requirements for the system.

Central Government Functions

- Policy Formulation and Resource Allocation at the National Level;
- Specialised Advisory Functions
- Regulatory Policy-making; and
- National S&T and innovation international relations at the bi-lateral and multi-lateral levels

Shared Functions

- Financing of Innovation-related Activities;
- Performance of Research, Development and Innovation;
- The Creation of Linkages and Knowledge Flows;
- Human Resource Development and Capacity Building; and
- The Provision of Technical Services and Infrastructure.

These functions are elaborated below in table 1 (Exclusive Functions of Government) and table 2 (Shared Functions).

This detailed treatment should be understood as a “Table of Elements” like the periodic table. Not all elements are of equal importance, but leaving out elements, or not recognising classes of elements can lead to an unsophisticated view of how the whole system articulates. The periodic table analogy is also useful as we know that the “rules of combination” of elements are as important as the elements themselves in the practical “chemistry” of the system.

It is the contention of this paper, that frequently interventions on “research” or “human capital” or “technology transfer”, for instance, have limited impact or sustainability (or unintended consequences) because they do not take into account the other elements and relationships within the system of innovation.

Table 1: Exclusive Functions of Government

Policy Formulation
• Policy Making for Science, Technology & Innovation
• Formal Statement of Government Policies and Strategies
• Translation of policies into an integrated science and technology public budget proposal
• Policy coordination, with the objective of "securing framework conditions that are conducive to innovation", including:
  • *competition policies to enhance innovation-driving competition but also to facilitate collaborative research*
  • *education and training policies to develop the necessary human capital;*
  • *regulatory reform policies to lessen administrative burdens and institutional rigidities*
  • *financial and fiscal policies to stimulate the flow of capital to small firms;*
  • *labour market policies to enhance mobility of personnel and to strengthen tacit knowledge flows*
  • *communications policies to maximise dissemination of information and enable the growth of electronic networks*
  • *foreign investment and trade policies to strengthen technology diffusion on a global basis*
  • *regional policies to improve complementarity between different levels of government initiatives*
• A Strategic Advisory Function relating to the formulation of national science, technology and innovation policies.
• National Technology Forecasting and Foresight
• Development of National Indicators relevant to the NSI
• Access to sources of expert scientific advice on major or urgent (controversial) issues of public policy
• Policy implementation

National Resource Allocation
• Resource Allocation for Science, Technology and Innovation;
• Implementation and Operation of the Science and Technology Budget, at least as an information tool
• Design and Use of Policy instruments to finance and encourage S, T & I activities
  • ***Support of S, T & I within Government***
  Budgetary Allocations
  Creation of technology and business incubators and technology services
  Competitive Granting Systems
  Sale of S, T & I services
  Use of Performance Contracts between Ministries and their laboratories
  Creation of Government-Owned Contractor-Operated (GOCO) facilities
  • ***Support of S, T & I outside Government***
  Competitive Granting Systems (Grants and/ or loans)
  Contracting for technical services, including R&D
  Creation of technology and business incubators and technology services
  Use of Government Purchasing Power
  Venture Capital linked to equity or royalty schemes

Creation of Tax Incentives • Establishment of Rules for Financial Administration **Regulatory Functions** • Policy for standards, metrology etc. • Policy for intellectual property; • Policy for protection of health, safety and the environment. • Governance norms for institutions and programmes involved in ST&I • Mandating and receiving surveys for national statistical purposes related to ST&I indicators
National S&T and innovation international relations at the bi-lateral and multi-lateral levels • Negotiation, finalisation, operation and review of bi-national agreements • Multi-lateral negotiations with ST&I impact (e.g. WSSD, WSIS, WIPO etc) • Securing ODA in support of the national system of innovation • Stimulating international and regional S&T capacity (e.g. ICSU, TWAS, Trieste System, CGIAR)

Table 2: Shared Implementation Functions (Involving all actors stakeholders)

Financing of Innovation-related Activities

• Statistical data on Sources of financing S, T & I
  • Financing by government
  • Financing by private sector
  • Financing by universities or other tertiary education bodies
  • Foreign bilateral financing
  • Foreign multilateral Financing
  • Domestic financing of Foreign S,T & I
  • Financing of government S,T &I activities;
  • Financing of private sector S,T&I activities;
  • Financing of university S,T & I activities;
  • Use of government purchasing power;
  • Financing of foreign S,T &I activities;
  • Foreign (bilateral) financing of domestic S,T&I activities;
  • Multilateral financing of domestic S,T&I;

Performance of R&D of all kinds; general overview;
• Statistical data on performance of Research, development & innovation
  • Performance of R, D & I in government
  • Performance of R, D & I in Private sector
  • Performance of R, D & I in Universities
  • Performance of R, D & I in other bodies (eg NGOs)
• Performance of R&D in government institutes and laboratories;
• Performance of R&D in Universities;
• Performance of R&D in private sector;
• Performance of R&D in State Corporations;
• Creation of innovative goods, processes and services;

***R,D&I – Research, Development and Innovation**

Creation of Linkages and Knowledge Flows

- Networks, joint ventures or consortia for R&D;
- Networks, joint ventures or consortia for exploitation of intellectual property;
- Mechanisms for evaluating , acquiring and diffusing best-practice technologies;
- Mechanisms to link R&D outputs to practical use, including brokerage services;
- Technology extension services for SMEs;
- Business and Technology Incubators;
- Support for IPR securement or defence;
- Linkages to regional interests, programs and activities within the country;
- Linkages to international S&T activities;

Human Resource Development and Capacity-building Functions

- Programs and facilities for the education and training of S&T personnel at levels of engineer, researcher and manager;
- Programs and facilities for the education and training of S&T personnel at level of qualified technician;
- Programs and facilities for the education and training of skilled workers;
- Programs and facilities to upgrade teaching of science and technology in the school system;
- Programs to promote international training of S&T personnel;
- Programs to promote improved management of technology;
- Mechanisms to maintain the vitality of the national S&T community;
- Stimulation of public interest in and support of national initiatives in S&T;
- Building an innovation culture by:
  - Helping firms improve their management of technical change;
  - Improving incentives for new firm start-ups.
- Public Institution Building for Science, Technology and Innovation:
  - Definition of public purposes to be served by institutions;
  - Creation of institutional capacity, capability and competence in S&T;
  - Creation of financial regulations covering institutions involved in S, T & I activities.

Technical Service and Infrastructure Functions

- ***Establishment, operation and maintenance of***:
  - Information services (including libraries, data bases, statistical services, a system of indicators);
  - Communications systems, including reliable Internet access and national research and education networks;
  - Technical services including product testing, trouble shooting, calibration, resource surveys;
  - Facilities for metrology and standardization;
  - Vices to promote and stimulate improved industrial design;
  - Mechanisms to promote productivity and/or competitiveness;
  - A system of awarding, recording and protecting intellectual property;
  - Mechanisms to ensure the protection of safety, health and the environment.;
  - Special facilities (e.g. incubators, science parks);
  - Major national facilities for research.

Stakeholders in the National System of Innovation

Stakeholders are as important as the "functions" in a system of innovation. This becomes evident when interventions are being designed, when existing programmes or institutions are reviewed, or when the relationship between stakeholders changes as a result of governmental policies or external factors such as donor requirements for National Indicative Plans, for instance.

The tendency is to respond to each of these types of events on their own merits without broadly considering the stakeholder environment. The NSI approach explicitly recognizes the stakeholders and considers their interests, contribution (and power) within the system. The typical stakeholder groups which exist in the setting of a national system of innovation are outlined below.

Stakeholder Groups within a National System of Innovation and typical members

Government

- Central policy and financing agencies;
- Relevant Parliamentary or Governmental Committees;
- Public research institutes (science councils) and/or other government S&T institutes;
- Specialised regulatory agencies (medicines control, ethics bodies, GMO registration, patent offices);
- Government agencies for technology diffusion and incubation;
- National departments including those with regulatory functions;
- State corporations;
- Provincial and local government;
- Economic development agencies in government;
- Defence forces, especially their technical support groups;
- Government advisory mechanisms and statistical agencies;
- Registering bodies (e.g. Engineers, Health practitioners).

Business

- Large local corporations;
- Local subsidiaries of trans-national corporations (TNCs);
- SMEs in the formal sector;
- Business associations;
- Micro-enterprises in the informal or subsistence sectors;
- Venture capitalists.

Education and Training institutions

- Universities;
- Technical Colleges;
- Teacher training institutions;
- Primary and secondary schools;
- Other education or training institutions including apprenticeship organizations.

Multipartite National Bodies

- National consultative bodies and mechanisms dealing with economic and social policies.

Organized Civil Society

- Labour unions, especially those dealing with technical change;
- NGOs, including those delivering technical services and sectoral policy advisory bodies interested in technical change;
- NGOs involved in S&T education;
- Professional and Academic Societies

International Partners and Agencies

- Treaty partners providing major budget support to core government programmes in the national budget and regional programmes(e.g. EU-ACP under the Cotonou Agreement);
- Bretton-Woods Financing Agencies which can impact macro-economic and micro-economic policies (World Bank, IMF, Development Banks);
- Multi-lateral global institutions (primarily UN and its agencies and the WTO and its agencies and their specific ST&I initiatives and programmes);
- Other countries in the region, especially the participants in their national systems of innovation;
- Developed countries, including both the participants in their national systems of innovation and their Official Development Assistance Agencies;
- Foundations (e.g. Gates, Ford, Mellon, Kellog, Wellcome Trust);
- NGOs especially those with global reach or strong regional presence;
- Specific major S&T programmes (e.g. Trieste system, EU Framework Programme, Millennium Science Initiative);
- International treaty bodies in respect of arms control, nuclear proliferation, etc.

c) 'Mapping' functions and stakeholders

In order to deal with the inherent complexity of the functional and stakeholder views these can be greatly simplified for analysis and review by using mapping of these domains. Mapping – usually in tabular form - can rapidly provide insight into the current dynamics and challenges of a national system of innovation, while focusing attention on the interventions and points of leverage rather than detailed "textual descriptions" of every element or relationship in the system.

This approach was first used extensively in the policy process in South Africa that led to the Green and White Papers on Science and Technology collectively titled "Preparing for the 21st Century". The methodology developed uses the mapping metaphor to gain insight into a national system of innovation. It is important to explore how far the metaphor can be taken in practical policy development.

The mapping hypothesis, developed by Jim Mullin, is that an effective and useful map of a system of innovation is a set of data placed on a matrix defined to by two sets of parameters - the *functions of the system* and the *stakeholders in the system.* The metaphor can be carried further in that there can be thematic maps - for example the elements of the map can be constituted of factual statements: "a certain stakeholder either does or does not have responsibilities for some specified functions".

Alternatively a map can portray expert judgements about how well or poorly a certain stakeholder performs a certain function: "the function is absent" or, say, "the function is world-class".

In addition, the "scale" of the map can be changed – at one level the map might represent public research institutions as a group, while at another the stakeholders might be individual public research institutions compared with respect to core functions they might perform.

The virtue of this type of approach is that it is easily accessible to non-specialists, and can be "re-used" in future policy development or exploration without reworking the whole policy approach in detail.

An exploration will be made of the use of this type of methodology, including the types of mapping that were developed (as examples) to inform a discussion of the impact of such an approach on national policies and strategies, financing agencies.

d) Fact-based policy and strategy development

One of the key dimensions of policy in respect of science, technology and innovation is the ability to reach effective judgements on the future options based on proper analysis and benchmarking of systems at the institutional and governmental levels.

It is an absolute fact that a country that invests, say, 3% of GDP on their R&D system will have higher capacity, be more flexible and cover a wider range of knowledge and research than a country that invests 0.3%. It is also true that the number of trained engineers per 1000 of the workforce is a good measure or proxy for the capacity of a country to make infrastructural investments and grow technically based businesses. The investment level is a leading indicator – sustained investment at high or low levels will have clear long-term consequences. The number of engineers is a lagging and/or current indicator – it reflects historical investment and current employment levels in the economy.

The use of indicators and indices to measure the state of systems of innovation has become pervasive in the developed world and is increasingly used in emerging economies and the developing world.

Indicators have great value in pointing to the similar features of the Science Technology & Innovation (ST%I) landscape in different countries as well as signalling important differences that can be linked to long term performance or stasis.

One characteristic of a number of developing nations is the lack of reliable data on the national system of innovation and this leads to "invisibility" to policy makers, partners and donors resulting in underestimation of the importance of ST&I, lack of insight into the national system of innovation's dynamics and trajectory, and a focus on institutional level interventions that may be neither wise nor sustainable.

3. Experience in using the functional framework as a basis of analysis

a) The South African experience

In the run up to the first democratic elections following the release of Nelson Mandela (1990-1994) the science and technology system in South Africa was in ferment. Existing resource recipients (defence, nuclear research and energy, for instance) were experiencing sharp budget declines. Institutions, in some cases, tried to anticipate conditions after democracy, others rapidly re-negotiated institutional positioning or governance. Others took a "wait and see position".

The Cabinet of the democratic South Africa had, for the first time a Minister responsible for Arts, Culture, Science and Technology. This allowed the Department of Arts, Culture, Science and Technology to come into being. The landscape was highly contested, with proposals for the future of the system ranging from "shut everything down and start again" to "don't try to fix something that is not broken".

In this setting large numbers of interventions were being proposed, based on anecdotal insights into policies, (or parts of policies), usually based ion experience in other countries (usually developed countries).

South Africa, because of the nature of its history, was developing a consultative and inclusive culture of governmental policy-making and it was in this setting that the process of developing a Green paper (consultative framework) and White paper (policy framework) was proposed.

This process was financed by the International Development Research Centre (IDRC), Canada.

The Green Paper

The Green paper was published in January 1996, and represented the first major policy consultation developed explicitly using the national system of innovation approach.

This approach recognises that the innovation process, and the positive outcomes from this, contributes to national good in a number of direct and indirect ways. Among the goals of a well-functioning system of innovation identified were:

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- Providing coherence, coordination and focus to SET activities through establishing national social, environmental and economic goals as their foundation;
- Developing a clear and common understanding of the roles, responsibilities and accountabilities of different stakeholders within the system, including government;
- Establishing a process and targets for achieving equity in all SET activities;
- Maximising and redirecting benefits to the population instead of to a minority;
- Redirecting spending and SET production capacity from defence to civil/commercial needs;
- Increasing the productivity and employment capacity of the economy and ensuring that the country's industrial structure is competitive within the regional and global economies;
- Developing an enabling and cost-efficient infrastructure;
- Ensuring that there is debate on the social impact of SET that takes into account equity considerations and economic growth;
- Constructing a more inclusive and consultative approach to policy decision making and resource allocations to and within the SET system;
- Implementing the principles of sustainable development;
- Facilitating the creation of a SET culture in our society that will enable and empower citizens to value scientific knowledge and view the SET system as an important source of informed choices about development;
- Promoting and supporting the generation of knowledge and curiosity based activities."[χ]

The achievement of this set of goals was of such a nature that the approach offered by the relatively new national system of innovation framework was regarded as essential.

"Given the fragmentation and lack of coordination of the present SET system, a new policy will have to promote interaction and cooperation between the bodies that make up the SET system such as industry, the science councils, universities and government departments, in order to achieve national goals and objectives. The Green Paper suggests that the most appropriate framework for such interaction and co-operation would be a national system of Innovation (NSI) and for the creative and productive use of its products." [χ]

The Green Paper provided some key "maps" of the system which were debated in the subsequent consultative process that led to the White Paper on Science and Technology.

The first map was an analysis, shown in **Figure 1**, which endeavored to show the relative importance of different functions of the system of innovation (Government Functions and Implementation Functions) for different stakeholders.

A second "map" outlined the government stakeholders in some detail, **Figure 2**, in respect of their functions within the system of innovation. This served to clarify the current view of the actors.

It is notable, with the benefit of hindsight, that no special role was accorded to the then Department of Arts, Culture Science and Technology relative to other government departments. However, at the time, this map was used extensively to identify where specific functions would be represented – and this resulted in a far more effective policy debate than had been possible when stakeholders engaged in policy discussions without seeing the roles of other players in context.

These mappings proved useful in the broader conceptualization of the system, but their usefulness was greatly enhanced by "dropping" the analysis to a level where different stakeholders could interrogate their special roles and frame policy responses around these. This was exemplified by a fuller consideration of implementation functions as shown in **Figure 3** below.

South Africa had a single budget vote, called the "Science Vote", which was used at that time, to provide core financing for a number of "Science Councils" which performed a range of functions. The use of the stakeholder/function" analysis for this institutional grouping is shown in **Figure 4**. As can be seen from the analysis a "group" that a first glance seemed to be similar proved to have very different core functions on examination through the lens of the national system of innovation.

Readers familiar with the South African NSI will be able to note a number of important changes that arose from this analysis. These changes resulted from broad agreements reached through the public consultation process that preceded the drafting of the White Paper on Science and Technology, which was accepted by Cabinet and published in September 1996.

Figure 1: The relative importance to stakeholders of the functions of a national system of innovation

	Core Functions of Government		**Implementation Functions**			
	Policy and resource allocation	***Regulatory (policy level)***	***Financing (performance level)***	***Performance***	***HRD and capacity building***	***Infrastructure provision***
Government	Key Function	Shared function - some standards set by government, some by business	Extensive involvement in supporting both business and tertiary education institutions	Extensive involvement	Some involvement in post graduate training	Extensive involvement
Business	Some advisory function	Shared function - some standards set by government, some by business	Extensive involvement as source and recipient	Key Function	Some involvement in post-graduate training. Should be important in life-long learning	Some involvement
Tertiary education	Some advisory function	Advisory?	Key recipient	Extensive involvement	Key Function	Some involvement
Other educational institutions	No involvement	No involvement	Recipient	Limited	Key Function	Some involvement
Multipartite Bodies	Key function as advisors	Advisory?	No involvement	No involvement	No involvement	No involvement
Organised Civil Society	Key Function as advisors	Advisory?	No involvement	Limited function	Some involvement?	No involvement
Interested outsiders	Some may have an advisory function	Some important at global level	Some have this as a key function	Possible partners	Possible partners	No involvement

Figure 2: The roles of government stakeholders in the functions of a National System of Innovation

	Core Government Functions		**Implementation Functions**			
	Policy and resource allocation	***Regulatory (policy level)***	***Financing (performance level)***	***Performance***	***HRD and capacity building***	***Infrastructure provision***
Policy Agencies	Key role	Shared function (with private sector)	Supervision	Limited involvement	No involvement	No involvement
Parliamentary Bodies	*Their key role*	Another important role	Supervision	Supervision	Supervision	Supervision
Science Councils	Some advisory role	Some advisory role	Some have a key role	Most have extensive involvement	Mixed levels of involvement	Some play important roles
Departments	No role	Some have a role	Some finance R&D outside government	Some may perform R&D	Currently limited	Some involvement in some cases
State Corporations	Limited	No role	Some contract out R&D activities	Some are important performers	No involvement	No involvement
Defence Force	Dominant role within sector	Limited involvement	Key role within the sector	Extensive involvement	Some involvement	Some involvement
Other S&T Institutes	Some have an advisory role	Limited	Limited?	Key role	Limited	Some involvement?
Advisory Bodies	Their key role	Should contribute	No role	No role	No role	No role
Other levels of government	No current role	A local role?	Limited	No role?	Limited	No involvement

The White Paper

The White Paper identified the requirements that the NSI should meet, the clear articulation of the national system of innovation role players and the specific policy interventions to strengthen the system.

The journey over the period from 1997 to the present has involved the implementation of these recommendations within this framework and the development of the capacity of the system to meet the goals of the policy. The review of institutions, the completion of a major national foresight project and the establishment of policy advisory structures, public understanding programmes, new competitive financing systems and the targeting of enhanced technology diffusion capacities (such as Manufacturing Advisory Centres, Incubators and innovation support programmes) have all been achieved through the consensus achieved in the NSI.

More recently the National Biotechnology Strategy has led the introduction of technology and innovation missions to underpin industrial strategies, and social strategies for poverty reduction.

The ongoing analysis of performance of the system led to the National R&D strategy of 2002, which is based on the NSI approach and addresses the new challenges faced by the system as we approach 10 years of democracy in South Africa.

The NSI approach has proved robust and of ongoing value in scripting a consistent and coherent set of interventions that build the system as a whole. In the process our understanding of the NSI itself has deepened and strengthened.

Figure 3: South Africa: Stakeholders and implementation functions of a National System of Innovation

	FINANCING			**PERFORMERS**			**HRD AND CAPACITY BUILDING**		**INFRASTRUCTURE**		
Stakeholder	Agency *(the South African term for a grant allocation function)*	Incentives	Purchasing	Research Development and Innovation	Linkages and Networks	Transfer and Adoption	Tertiary Education and Training	Institutional Capacity Creation	Regulatory	S&T Information	Intellectual Property
Science Councils	Some involved	FRD THRIP	Some implement policy	Most involved	Most actively involved	Some involved	Some involved	Some involved	Some involved	Some involved as system managers	Some producers
Government Departments	Some involved	One has Admin Role	Some implement policy	Some involved	Some involved	Some involved	Limited involvement	Limited involvement	Some involved	Users	One manages system
State Corporations	Contract for R&D	Eligible User	Some implement policy	Most involved	Some involved	Some involved	Limited involvement	Limited involvement	Affected by policy	Users	Producers
Defence Establishment	Contract for R&D	Client firms eligible	Active use of policy	Highly involved	Growing interest	Involved with Defence industry	Some involvement	Some sectoral involvement	Not involved	User and producer	Producer and purchaser
Tertiary Education	Recipient	Some activities eligible	Not affected	HWUs and a few others involved	Involved, especially HWUs	Limited role to date	Key function	Some role plus need help	Subject to some regulation	Producer	Need policy to handle issues

Figure 4: South African NSI: Science Councils and the implementation Functions of a National System of Innovation

	Financing		**Performers**			**HRD and Capacity Building**		**Infrastructure**	
	Agency *(The South African term of a grant allocation function*	Use of Purchasing Power	Research Development and Innovation	Creation of Linkages and networks	Transfer and adoption of Technology	Tertiary Education and training	Institutional capacity creation	Regulatory service provider	S&T Information Service Provider
ARC	Yes	Possible	Yes	Limited	Limited	Post graduate	No	Yes	No
CSIR	No	Active	Yes	Yes	Yes	Post graduate	Yes	Yes	Yes
FRD	Yes – the principal function	For equipment	National Research Facilities	Yes	No	Agency	Yes	No	Yes
CGS	No	Possible	Yes	Yes	Limit	Limited	No	No	No
HSRC	Yes	Not likely	Yes	Yes	Limited	Agency Function	Yes	No	Yes
MRC	Yes	Possible	Yes	Yes	Yes	Post graduate	Yes	Yes	Yes
Mintek	No	Possible	Yes	Yes	Yes	Post graduate	Yes	No	No
SABS	No	Possible	Limited	Yes	Yes	No	No	Yes	Yes

The Science Councils covered in this Table are the Agricultural Research Council (ARC), the Foundation for Research Development (FRD), the Council for Geosciences (CGS), the Human Sciences Research Council (HSRC), the Medical Research Council (MRC), the Council for Mineral Technology (Mintek) and the South African Bureau of Standards (SABS). This configuration existed in 1997 in South Africa.

b) The Chinese experience

The Peoples Republic of China has also made use of the NSI approach in developing its science and technology policy. This was based on a review undertaken over 3 weeks at a senior level as part of an IDRC sponsored process, by the Chinese Government, to strengthen the management capacity and coherence of the system.

One of the great challenges in the Chinese review was to grasp what was going on in a system in which there were more than 25,000 and perhaps as many as 32,000 "R&D" institutions in the country, together with many governmental programs at the central, provincial, and in some cases even at the municipal level.

Within the Central Government, the State Science and Technology Commission, SSTC, (now reorganized as a Ministry) was responsible for a dozen major financing programs. Table 5, reproduced here from the country review, undertook a mapping of the eligibility key stakeholders to gain access to the different policy instruments in place to exercise SSTC's financing function.

This table shows the type of high level analyses that may be applicable to regional assessments in the context of Africa and the African sub-regions, that may be achieved with relatively inexpensively. This sort of approach should be preferred to ad hoc aggregation of incremental "bottom up" policy studies. These have proven difficult to systematise or integrate at higher levels.

The Chinese experience also indicates the importance of not treating a national system (or regional) system of innovation as a "green field site", but rather recognise the complexity of "historical accidents" and more structured policy initiatives that represent the national system of innovation.

c) The Latin American experience

<u>Chile</u>

An important review took place in Chile in 1998. The terms of reference stated that:

"The overall objectives of the study will be to review, assess and report on:

1. The policies, programs, priorities and policy instruments managed by CONICYT to promote the development and application of science and technology within Chile;

2 The interactions between CONICYT's principal policy instruments (FONDECYT and FONDEF) and other similar policy instruments supporting scientific and technological activities in Chile (particularly those coordinated within the Programa de Innovación Tecnológica) and the impact of those instruments on the performance of scientific and technological activities within Chile's universities, enterprises and governmental S&T institutions; and

3. The policy and institutional environment within which CONICYT operates.

In particular, the study will evaluate the design, management, performance and possible future evolution of FONDECYT and FONDEF with respect to:

1. The ability of those instruments to meet their established objectives relating to scientific research, technological development and human resource capacity building;

2. The performance of the instruments in assuring the quality, relevance and sustainability of the activities supported, in the light of Chile's social, economic and cultural objectives;

3. Their capacity to respond to changing needs, opportunities and research paradigms in science and technology;

4. The adequacy of their resource base, in the light of Chile's needs and macroeconomic situation;

The study will carry out the review and assessment required in the light of established "international practice."

A key result of the Chilean review was to achieve a more effective balance between cooperative and competitive scientific programmes. In the review it was recognised, that there is a core connection between patenting activity and the science base of the country – a characteristic common to many developing countries. Programmes to strengthen linkages between academic research and industry are being established. The key role played by Fundacion Chile in respect of innovation, for example, in the Salmon industry which has led to a massive increase of the capacity for exports, indicated that innovation and technology transfer can be strategically managed in the national interest by targeted agencies that are properly resourced. Follow-up studies were undertaken of a number of industrial sectors including the mining and minerals sector which was identified as having high potential for leverage through research and innovation.

<u>Inter-American Development Bank Studies</u>

The inter-American Development Bank has provided loans for S&T Programs to member countries since the 1960s. The evolution of its policy has embraced, in recent years, the challenge of managing innovation rather than just research and development.

The introduction of the innovation focus into its program of S&T Loans led the IDB to undertake country reviews of the functioning of national systems of innovation as a pre-investment tool.

The IDB reviews using this methodology have covered primarily the medium and small countries of the region –Venezuela (1998) El Salvador and Guatemala (1999) Ecuador and Panamá (2001) Perú (2002) and the República Dominicana (2003 on-going).

The concentration on this particular grouping of countries was an explicit commitment of the IDB in its S&T Strategy: "The IDB will therefore increase its S&T lending to smaller, poorer countries as a means of helping to ensure that they can also participate in knowledge-based development, in accordance with their evolving comparative advantages."

The analyses have identified the most fundamental weaknesses in the innovation systems of the countries examined and have underpinned the design of policy instruments which could address the most severe problems. Given that a common methodology has been used, it has been possible to identify common and differentiated problems. The most complex set of issues is the lack of a functioning market for technology services. This is particularly acute in the smaller countries of Central America and the Caribbean, but is also an important factor in Perú.

In the activity in Perú, the assessment of the performance of that country's public technological institutes was facilitated by use of a self-assessment tool designed in the follow-up study in Chile.

One useful feature of the use of the same analytical framework in each of the reviews is designed comparability which emerges from the assessments. The sponsor of these particular reviews, as a regional development bank, can make some relative judgements concerning needs in countries facing similar problems. This results from the standard frameworks used. It also allows the differentiation of programmes based on particular national needs. In this way the national system of innovation can be stimulated to meet both national and regional challenges, and the financial partner can have a much higher level of assurance of the sustainability of the initiatives.

The three key findings which appeared in all of the country reviews in Latin America were:

- There was no effective market for domestically generated technology or technology services because:
    - Domestic SMEs were unable, for many reasons, to convert their real technological needs into an effective economic demand;
    - There are virtually no institutions – in any sector- with an established record of developing technologies for use by SMEs;
    - There are few if any sources of funds to promote technical change;
    - There is no 'brokerage' system in place to bring the different participants together in the context of specific projects and no mechanisms available to identify shared technical needs of groups of SMEs;
- There is virtually no tradition of cooperation between either academic institutions or public technological institutions and the private sector in matters relating to technical change;
- Countries had not invested in or developed 'confidence-building measures' to bridge these long-standing gaps;
- There were considerable weaknesses (mainly related to inexperience and lack of management skills) in virtually all of the public institutions expected to play a role in attacking the systemic problems.

These findings and findings from other similar activities financed by the IDB led to the following enumeration of constraints:

- *an economic structure and policy environment that neglects developing and/or disseminating knowledge that is tailor-made for local economic conditions;*
- *absence or weakness of catalytic institutions that reduce transaction costs associated with acquiring appropriate information and knowledge;*

- *unbalanced economic rhetoric emphasizing competition but neglecting cooperation and coordination in setting up basic rules and infrastructures;*
- *too many economic agents that are not yet poised to become aggressive entrepreneurs.*

Constructing policy instruments to address these deep-seated problems should not be underestimated. The national system of innovation construct is one of alignment, steering and partnership, rather than command and control, and therefore the mainstreaming of science and technology initiatives within the framework of national budgets with consistent and consultative actions among stakeholders is important.

d) Summary and general conclusion on NSI

As can be seen from the examples described above, the NSI approach based on functions and stakeholders is attractive to developing countries because it permits clear policy and strategy interventions at a high level based on a robust methodology. Much could be said about effective processes for such reviews, but that is not the major intent of this paper. Rather it is to indicate that research and development systems, science and technology systems and related activities do not exist for themselves but form part of the delivery system of a nation that produces economic growth and improved quality of life through innovation.

Developing countries therefore, can, and should, seek to benefit from this type of policy review and, it is proposed that, in the NEPAD setting, countries reach agreement to mutually support one another and draw on international best practice to undertake targeted reviews of national systems of innovation in order to more effectively share in best practices, leverage finances and resources to strengthen national activities and achieve consensus on sub-regional and regional science, technology and innovation activities.

Figure 5: The NSI in China: The Role of SSTC and its Major Programs in Supporting the S&T Activities of the Principal Stakeholders.

Role of SSTC	**Policy and Funding**	**Implemented with SPC and SEdC**				**Funding and Policy**	**Funding and Policy**	**Funding and Policy**	**Funding and Policy**	**Funding and policy**		**Policy**
Program/ Stakeholder	Key Technologies	Key Laboratories	Engineering Technology Research Centres	Key Industrial Projects	Industrial Technology Extension	863	Spark	Climbing Up	Torch	National S&T Achievements	Trial Production & appraisal	Agenda 21
SSTC institutes	Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes		Yes
CAS	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes		Yes
CAAS	Yes	Yes				Yes	Yes	Yes	Yes	Yes		Yes
Sectoral Ministry Institutes	Yes	Yes	Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes
Provincial STC Institutes	A Few				Yes	Yes	Yes		Yes	Yes	Yes	Yes
Municipal STC Institutes	A Few				Yes	Yes	Yes		Yes	Yes	Yes	Yes
Universities	Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes		Yes
State Enterprises	Yes		Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes
Spin-offs	Yes				Yes				Yes	Yes		
New High Tech Enterprises	Yes				Yes	Yes			Yes	Yes		
Township & Village Enterprises					Yes		Yes		Yes	Yes		
Joint Ventures	Yes			Yes	Yes							

4. Indicator-based policy development

When the construct of a national system of innovation is in place and forms the basis for policy making and strategic development it is essential to have and continuously strengthen a national set of indicators and indices that can be used to monitor the performance of the system at macro and micro levels and permit comparison to partner and competitor countries.

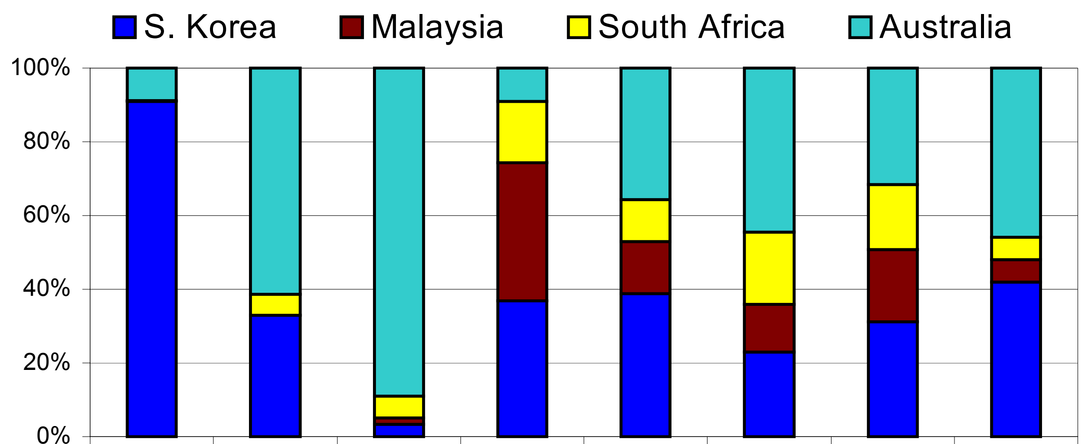
This approach was developed in South Africa in support of the National R&D strategy. For comparative purposes South Africa was compared with Malaysia, South Korea and Australia. Some of the indicators are leading indicators – they give an impression of the future health of the system – such as the number and proportion of SET postgraduate students at universities. Others are lagging indicators such as the "knowledge contribution" to economic growth.

The use of such indicators allows long-term planning and tracking of the progress of the system as well as benchmarking against the performance of other countries. A comparison between four countries has been made using the UNDP Technology Achievement Index, Human Development Report 2001 and against a basket of other indicators (**Figure 6**).

The three comparator countries, Australia, South Korea and Malaysia, have very different but well-articulated technology strategies. Australia's approach is to use research, knowledge and information technology to add value to its resource-based economy. South Korea is focused on advanced manufacturing and on creating a knowledge base for industrial innovation. The high levels of educational and post-graduate research and patent spending by Korea differentiate this strategy from all the others. Malaysia has opted to be a fast follower and has concentrated on importation of know-how through Foreign Direct Investment. Malaysia, therefore, pays less attention to research and patenting than it does to effective technology transfer and the broadening of scientific literacy in the general population. While this strategy paid evident dividends in the short term, maintain the high growth rates seen previously will probably require more aggressive human capital and research investment strategies.

Apart from providing insights into the differences of approach and progress of Australia, Korea and Malaysia, the comparison signals that South Africa has much more to do in the development of human capital and needs to stimulate higher levels of R&D and innovation spending to achieve the type of economic progress currently evident (after long-term investment) in South Korea. The comparison of these strategies also indicates that the fast-follower route chosen by Malaysia is not open to South Africa. Malaysia and South Africa have similar levels of GDP per capita, but Malaysia has not established the same level of human capital to date. South Africa therefore cannot adopt a strategy similar to Malaysia but rather has to push for a more knowledge-intensive strategy.

South Africa has a stronger high and medium-technology export profile than Australia, but also has a strong natural resources base. South Africa can therefore adopt a strategic approach that capitalises on the established natural resources base while actively pursuing stronger manufacturing, information technology and biotechnology strategies, more in line with the approach adopted by South Korea.



	Patents	Royalties/ Licences	Internet Hosts	High/Med Tech Exports	Telephones	Elec Cons	Years of schooling	Tertiary science enrolemen
Australia	75	18.2	125.9	16.2	862	8717	10.9	25.3
South Africa	2.5	1.7	8.4	30.2	270	3832	6.1	3.4
Malaysia	0	0	2.4	67.4	340	2554	6.8	3.3
S. Korea	779	9.8	4.8	66.7	938	4497	10.8	23.2

Figure 6: Comparison of the technology achievement index of four countries, normalised for the scores in the domains.

This type of analysis can be made more broadly across the whole dataset of the technology achievement index. The four groupings in **Table 3** below represent those used in the report. As can be seen from this tabulation, taking the index by itself has limited value but the indicators that inform the index have clear characteristics that can lead to important conclusions for a system of innovation – for example the high and medium technology export mix has large overlaps between differing groups but across the range mean schooling years actually differentiates groups (a measure of human capital). This emphasizes the need for developing countries to have strong human capital programmes in science and technology to leverage their economic development.

Table 3: Analysis of the TAI data according to the 4 major groupings (values as for the table above):

Indicator	**Leaders**		**Potential Leaders**		**Dynamic Adopters**		**Marginalised**		**South Africa**
	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	
Technology Achievement Index	0.744	0.514	0.481	0.357	0.343	0.201	0.185	0.066	0.340
Patents	994	8	42	1	2	0	0	0	2.5 (est)
Royalties and licenses	156.6	13.0	9.8	0.0	35.3	0	0	0	1.7
Internet hosts	200	4.8	33.6	2.4	19.6	0	0.4	0	8.4
Hi/med Exports	80.8	15.4	67.4	6.1	48.9	1.2	28.5	0.4	30.2
Telephone Connections	1329	720	1212	192	366	28	39	5	270
Electricity Consumption	24607	4497	5096	1450	3832	244	337	47	3832
Mean schooling years	12	7.1	9.8	6.1	8.6	4.9	4.6	1.1	6.1
Tertiary science enrolment	27.4	9.5	17.2	3.3	8.5	1.4	3.8	0.2	3.4

Apart from the indicators found within the technology achievement index, the OECD has, over a number of years developed an indicator system based on manuals such as the Frascati Manual (R&D Statistics) and the Oslo Manual (Innovation Statistics). The consistent use of agreed indicators and the ongoing policy discussion relating to science and technology has had an important effect on the developed world consensus on the importance of R&D and innovation in their economies. However the developing world has not developed consistent sets of indicators that are comparable in respect of innovation, R&D and human capital. Measurement is patchy and not benchmarked across a number of different national economies. One of the consequences of this is that our financing department and the multilateral agencies have no insight into the state of development and dynamics of our systems of innovation, with the consequence that the function of science and technology in underpinning innovation is routinely underestimated or ignored as a powerful factor in development.

In order for consistent and coherent mainstreaming of science and technology in the context of NEPAD to be successful, it is likely that consistent action on the development of appropriate and cost-effective indicator systems at national level must be a key feature of our policy discourse. It may not be appropriate to import the statistical systems of the developed world, but there certainly must be a consistent set of indicators that would allow ongoing measurement of the national systems of innovation of African countries. Apart from anything else, this would inform our debates in respect of the diaspora, the human capital challenge, uptake of technology by firms, the role of ICT in development and the level of investment by transnational companies in R&D in our economies, for instance.

Apart from measurements at the system level, institutional benchmarking can play a very positive role in the sharing of best practices between institutions facing similar challenges and can point to new initiatives that can be taken by the institutions to improve their performance and effectiveness. In the South African setting, studies have included comparison of policies for intellectual property management, a global comparison of the pricing and costing of agricultural research as well as a series of reviews on the performance of institutions in the light of their mandate, quality of science and technology, quality of management and strategic intent. These reviews take on far greater significance when analysed in terms of the broader national system of innovation and the need to deploy resources effectively and efficiently.

5. The design of S&T Policy instruments in an African context in science and technology

Given the scarce resources available to science and technology in the present setting across our continent, consistent, concerted and coherent actions are necessary to break out of the cycle of donor dependence and knowledge attrition.

National ownership of policies to stimulate innovation that leads to economic growth and improved quality of life, is a crucial precondition for the sustainable development of our continent. Such policies can be difficult to develop and sustain, given the preference of our financial partners for a less systemic and more sectoral approach to developing financing and the negative bias that many programmes have to the utilization of national human resources in the domain of technical leadership or in support of the sustainability of programmes of intervention.

A key strategic reason to introduce policy discourse at this level is to ensure that national development plans and their sub-regional and regional equivalents are able to articulate clearly the function of science, technology and innovation in stimulating, accelerating and sustaining development.

As important as micro-initiatives are, (such as the establishment of individual centres of excellence), if such interventions are made outside the broader context of a clear national system of innovation, they will not become sustainable, nor will they be easy to replicate in other settings. This is not to say that we should not undertake such initiatives, but if that remains the level of our political and institutions will, science and technology will not be able to provide sufficient momentum to address the broader needs of our citizens and countries in respect of improved quality of life.

Funding follows the facts: or so it seems. Until the facts about our systems of innovation become well known, it will not be possible to develop a consistent and effective case for increased financing for science, technology and innovation, as immediate needs will always seem more pressing and the importation of technical assistance, far more attractive than retaining and sustaining our own science and technology human capital.

While the diaspora of African scientists and engineers certainly represents an opportunity, the tragedy is that we have lost a massive intellectual resource. A national system of innovation policy framework combines the logic of the market with the challenge of public investment in science and technology.

It is therefore proposed that the NEPAD science and technology ministerial, gives serious attention to the adoption of the system of innovation approach as the preferred organizing mechanism and policy framework at national level. It is also proposed that a permanent secretariat be established to assist countries to develop and implement an appropriate common indicator system that would measure key elements of the systems of innovation.

It is further recommended that the national sub-regional and regional interventions in respect of specific flagship programmers, and through modalities such as Centres of Excellence, be undertaken in the context of this type of systemic view and that therefore resource allocation is balanced in such a way as to allow both the policy and indicator frameworks to develop in synergy with programmatic interventions.

6. Conclusion

The national system of innovation approach has been demonstrated to be successful in framing more effective policies for science and technology and research, than has been the case hitherto. In the Latin American setting and in South Africa, consistent use of such frameworks has attracted new resources for science and technology and given policy-makers and financing institutions confidence that their investments do indeed have positive developmental and economic outcomes.

Such interventions are further strengthened where reliable and replicable surveys are undertaken to provide data and indicators of the health of research and development, innovation and human capital programmes. Great value would accrue from the use of a common set of key indicators of the health of African national systems of innovation. Apart from the obvious benefits to policy analysts, and international partners, it would signal to national government the importance of innovation based on science and technology to the well-being of the people of the nation and its economic growth potential.

The propensity to favour interventionist programmes that can distort the sustainability of science and technology in the national setting over considered strategic policy interventions over a period of years to build the flexibility, robustness and responsiveness of a system of innovation should no longer be a craving that we can indulge. This paper argues for a more coherent, consistent and high-level development of, and reflection on, policy in the setting of NEPAD. The value of the systems of innovation approach is that it is tolerant of the fragmented histories and distortions, than have arisen in the different settings – this was certainly true of South Africa. It is to be hoped that the next decade of the African journey will mainstream science and technology as an agent and an actor in the rich process of development that our partnership will deliver for the people of Africa.