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The New Context for Science, Technology and Innovation: New Approaches to the Structure and Governance of Research

A Position Paper on the Future Directions, Role and Structure of Research Councils

by

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1. The Central Role of Science, Technology and Innovation (STI) in the Future of Nations

There is a long-established understanding, recognised even by neo-classical economists, that STI play a central role in the modern industrialised economy. More recently, the concept of the knowledge economy has been developed to reflect the extent to which the generation and application of knowledge has become a central driver of economic performance and improved social outcomes.

Each decade witnesses extraordinary advances in science, providing the basis for profoundly enhanced understanding of phenomena as diverse as the complex operations of the human body, global climate patterns, the structure of materials at the atomic level, the sequence of the human genome and the structure of the universe. On this basis, a remarkable range of capability-extending technologies have become available.

At the same time, the challenges that Governments and people are facing are placing ever greater demands on STI. Solutions are sought to the problems of adequate food, water and energy supply, to the multifold issues associated with an ageing population, to housing supply and efficient transport, to personal and national security, to carbon capture and climate change. Every one of these issues will require very significant technological advances, which can only be achieved by substantial investment in an effective STI capability.

STI policy has also evolved. Previously, the primary rationale for and emphasis of public policy was framed in terms of addressing various forms of 'market failure', such as inadequate, or an inability to capture, returns on investment – hence the justification for public funding for research. As a consequence, the major focus of STI policy for years has been on supporting STI research and education. Progressively, concerns about the return to the nation from frequently substantial funding have seen an additional focus on two additional aspects: the quality of the research supported and the extent to which the benefits flow into the local economy.

While this framework is still deeply embedded in conventional economic thinking, those more familiar with the extent of the contribution of technology as an endogenous driver of economic growth have moved to an approach based on the concept of 'national innovation systems' (NIS). This model shifts the emphasis from just the production of new knowledge to the systematic interactions between existing knowledge, research, invention, potential markets, the production process and economic framework conditions.

In this view, the role of government STI policy is significantly expanded to address the relative strengths and interactions between all components of the STI system. Building strengths in any specific component may produce limited, and even negative consequences, if they are not effectively linked with the other components of the national innovation system.

Strengthening the NIS and its performance needs to be conducted with an awareness of the changing forces that are shaping the future of STI systems.

2. Forces Shaping the Future of STI Systems

There are a wide range of forces shaping the future of the STI system. These can usefully be divided into those operating largely internal to the NIS, though it is recognised that many of these may be substantially influenced by global pressures and trends, and those originating very substantially from the external environment.

In addition, a relevant set of policy trends is reported in the OECD STI Outlook 2010 (see Annex 1)

2.1 Internal forces

Despite the previous argument, the level and source **of investment in R&D and more broadly innovation** remains a powerful driver shaping the operations of the STI system. While it is apparent that there is no single ideal level of national expenditure, the OECD average for R&D of a GERD/GDP ratio of 2.4% provides an appropriate target range.

Equally significant is the extent of business investment in R&D. The clear message is that "efficient innovation systems are firm-centred" and that a major challenge for industrialising countries is to enhance the capacity of their industry to absorb knowledge and technology. Again the OECD average of BERD/GDP of 1.7% provides a target.

Almost every aspect of R&D and innovation requires the input of skilled people. **Human resources in science and technology (HRST)** play a central role in creating new knowledge through:

- research;
- developing and improving new materials, products and devices;
- designing, engineering and tooling up production processes;
- running tests and collecting data; and
- adapting and adopting technologies within in the workplace.

In fully industrialised countries, the HRST production is significantly, though far from perfectly, shaped by the industry demand for these resources. In industrialising countries it is not uncommon for supply to be well ahead of demand, leading to under-employment of STI graduates. The focus of policies needs to be strongly on increasing demand and absorptive capacity in industry and commerce.

Access to and **availability of adequate infrastructure** is an increasingly important force shaping the operation of STI systems. One element is the ICT and broadband connections necessary to facilitate the increasingly network- and interdisciplinary-based approach of contemporary R&D. Another is the extent to which modern computational power is a key to many areas of research including the emerging area of scientific simulation. Access to the leading-edge and often very expensive tools of research is an increasingly powerful driver of international collaboration.

A key governance ability of an STI system is that of **effective targeting of research resources**. This requires a capacity to set **thematic** priorities, by focussing on knowledge and application areas of national significance and with substantial potential for innovative outcomes. It is important to recognise that priority setting should not be at the expense of the national research capacity. A dual funding strategy, which provides institutional block grants to nurture the foundational capacity, and targeted funds awarded on a competitive basis is generally seen as most appropriate.

But there is also a requirement to be able to set effective **structural** priorities, which identify the components of the innovation value chain (eg R&D subsidies, networking though clusters, venture capital, etc) which are most appropriate to be supported, and by how much, given the particular characteristics and stage of evolution of the national STI system.

Another significant issue where achieving an appropriate national balance is crucial is the somewhat paradoxical emphasis on **knowledge production versus knowledge adaptation**. Researchers need to be engaged in cutting -edge research which can only be assessed and improved through exposure to the international scientific community in a continuous fashion. However, their greatest economic contribution may be less in the value of the new knowledge they produce, than in their capacity, based on this expertise, to play a leading role in knowledge adaptation.

For every country in the world with the exception of the US (and perhaps China in quite a few years), the majority of knowledge is necessarily produced elsewhere in the world. Hence the crucial need for a strong national STI capacity in knowledge adaptation, which relies on identification, interpretation, adaptation and application of knowledge generated elsewhere. This is not a second-rate job appropriate to lesser trained or talented scientists and engineers. Rather, it is a critical endeavour for the best minds.

A strong national adaptation capacity, as well as R&D capacity, is closely related to the **extent of effective cooperation and collaboration among researchers, and between all components and members of the national STI system.** There is an apparently universal tendency to operate within the boundaries and mindsets of disciplines and institutions, even though there is abundant evidence that the majority of significant innovation occurs at boundaries. Hence the need for specific measures to facilitate, measure and reward purposeful collaborative activities.

A particularly important aspect of collaboration in the STI system is that dealing with interaction between knowledge producers and potential knowledge users. The barriers of culture, experience, priorities, non-proximity and language are all well rehearsed. Similarly exhortations to researchers to get in touch with industry, and vice versa, have proved largely fruitless. **The most effective model of linkage designed to improve the commercial returns from the R&D investment appears to be that based on purpose-designed intermediaries** – organisations with the function and skills to build appropriate linkages tailored to specific needs and capabilities. The strength and fit of these intermediaries is an increasingly crucial component of an effective national STI system.

With the continuing growth and predominance of the service sector in many economies, it has been recognised that **a significant level of innovation in the design and delivery of these services does not result from conventional R&D-based innovation**. Technologies more frequently play the role of enablers rather than drivers. In these circumstances,

systematic support for innovation based on design, branding new business models etc, which are particularly applicable to the services sector, are an important issue.
Another important driver of STI policy is concerned with **fostering of innovation within all levels of government, including the intelligent use of procurement, out-sourcing and regulation to foster innovative solutions and capabilities**.

The pursuit of innovation, largely driven by the pressures of global competition, has, somewhat ironically, often been promoted by governments who are dominated by practices and procedures of another era. While getting around regulations, legally, may constitute effective innovation, it is perhaps a poor use of scarce resources. A better situation would be one in which regulations provided appropriate protection, without drastically hindering the possibility of innovation.

In addition, as governments have major procurement requirements for goods and services, it is worth examining whether this market power can be put to use to foster innovation, in addition to the standard 'best value for price' requirement.

2.2 External forces

The emergence of new global players and value chains, together with the impact of the increasing convergence of new technologies, increase the **importance of effective coordination of STI policy at regional, national and international levels**. At a regional level, it may be appropriate to foster hubs and clusters with their own international goals and context. In support of both adaptation and HRST objectives, the fostering of strong levels of international engagement are appropriate. Available mechanisms include joining international consortia in appropriate major projects and fostering a flow of students and researchers in and out of the country.

In the face of global competition, the need for an **effective and appropriate framework and capability for intellectual property rights (IPR) protection, management and exploitation** is paramount. It should be recognised that the framework for international negotiation of IPR has become a rather contested space. Previously, the industrialised countries largely developed a set of institutions and agreements that provided a reasonably solid foundation for the management of IPR. This approach was strongly supported by Brazil and India in previous decades on behalf of the G77.

However increasingly, there are valid concerns about an inherent bias in favour of the interests of the developed nations. In addition, the apparent effectiveness of the more recent strategic approach of China and India to IPR, involving a highly planned approach to innovation, creativity and IPR, supported by significant resources for planning and implementing IP strategies, suggest a comparable stance, appropriate to the country, may be required..

In a global knowledge economy, there exists the potential for the application of creativity and innovation at almost every location and intersection. It is not just the knowledge emerging from the formal STI institutions that matters. It is the application of creativity, embodied in entrepreneurship at all levels and corners of an economy that provides the resilience and change that underpins a competitive global economy.

There is wide agreement and action on the part of many countries that **a new set of platform technologies are emerging that have the potential to significantly transform economic and industrial activity into the future. This is largely seen as occurring at the interface of nanotechnology, biotechnology and cognitive science, enabled by continuing advances in ICT.** While head-to-head competition with the US, EU or China may not be appropriate, it would nevertheless be prudent to invest in building the kind of local capacity which can underpin an effective adaptation response. This would provide the basis for at least informed purchase and identification of local applications.

A range of major future challenges have been identified in Section 1. One appropriate response to the forces that will drive these demands is to **establish both capacity and implementation mechanisms to ensure the effective application of STI capabilities to major global and national challenges, such as environmental sustainability, energy supply, water supply, food supply and climate change**.

3. New Patterns of Structure and Governance for STI

The forces shaping the future of STI systems described in the previous section are inevitably impacting on the structure and governance of the STI system.

Firstly, with the growing wide range of issues requiring a technology-enabled response, and the recognition of the importance of demand in shaping innovation to address challenges, the **traditional centralised STI governance apparatus appears increasingly limited**. Of course there will be a continuing need for a relatively modest centralised mechanism to fund and manage the core activities of the STI system – basic research and STI education.

However, the major national issues which require STI support, such as health, food production, transport, environmental management, security, and even immigration, are properly the responsibility of other Ministries and Departments. This creates the need for an overarching body, along the lines of a Presidential or Ministerial Council, where the implications of emerging technologies for various portfolios can be explored and the role of the national STI capacity in assisting the response to major challenges considered. Implementation can then be organised within the appropriate portfolios.

One further implication of the way in which STI has become a horizontal facilitator and change agent across government is the need for all Government Departments to have an adequate level of STI and policy-related expertise within their organisation.

A second force for change in the structure and governance of the STI system is that associated with the shift to 'open innovation'. The previous, and still continuing 'closed innovation' was largely based on the generation and adaptation of knowledge by specialists within a company in accord with judgments about which new products are likely to appeal to the market and the customer. Concerns about strategic positioning in markets, commercial confidentiality and control of IP ownership precluded the notion that important knowledge and innovation could be sourced from outside the company.

Under the pressures of global competition in the knowledge economy, there are two major limitations in the closed innovation model for companies: they cannot generate sufficient knowledge from their necessarily limited resources, and they cannot predict sufficiently rapidly or reliably what markets and customers will want.

The rapidly growing open innovation approach relies on sourcing of knowledge from wherever it can best be generated anywhere in the world, determined by talent, infrastructure, focus, local need or demand. Codified knowledge can be readily accessed in this digital age, provided the necessary capability to identify, locate, evaluate and adapt exists. But tacit and context-specific knowledge is, by its nature, local and can only be accessed by having a physical presence in this space. Furthermore, given that components of the required knowledge will need to be sourced from different locations, combining the knowledge to achieve competitive advantage becomes a key competence.

This is placing a premium on the capability of a national STI system, supported by appropriate policy, to facilitate access to the global pool of knowledge, the negotiation of access on suitable terms, and the development of a sound knowledge integration competence.

A second aspect of open innovation is the need for companies (indeed all organisations) to become more open not only to knowledge, but also to customers, suppliers and competitors. It is argued[1] that in many industries, technology has become more of an enabler than a driver. A key new driver of innovation is the informed and empowered customer demanding a customised response to their specific needs, wherever they are located across the globe. The response under open innovation rests on the direct engagement of customers and users into the co-design and co-creation of new products, facilitated by a range of communication technologies.

The environment of open innovation is placing new demands on structures and governance systems designed under the previous assumptions of publicly-funded research being clearly either a public or private good capable of being produced only by expert researchers. One implication is that, while science and technology-based knowledge, information and skills will remain critical, knowledge and skills of a different kind about knowledge integration, design, and behavioural responses may be just as important. One strategic challenge to be determined is whether this capability should be integrated into the STI system, or developed as a distinct capability outside it.

A third force for change results from the internationalisation of research. The need to establish strong international STI linkages and engage with international STI programs, requires not only special schemes of support within the existing STI system, but also a preparedness, and ability, to forego some elements of national control in order to be welcomed into international consortia as a full partner.

4. The Changing Role of Research Councils

Traditionally, Research Councils have had the primary role of managing the complex process of identifying and funding the highest quality research across all disciplines. Commonly this involves a process of proposal submission according to established guidelines, peer-based

[1] For example, OECD, 'New Nature of Innovation', 2009.

evaluation, and the allocation of funding from a pool always far too small to match the demand. Secondary functions have included the promotion of collaboration with international partners and with industry, either by inclusion of these as criteria for success, or through separate funding schemes. Typically, they also make some input into national STI policy.

Increasingly, in the face of the sorts of changes identified above, Research Councils are moving to adopt a more strategic and proactive approach to their responsibilities. This can include:

- capacity and network building in key areas;
- identification of national challenges and facilitation of the formation of appropriate multi-disciplinary teams;
- facilitation of the merging of research groups in different universities;
- support for intermediaries to facilitate more effective diffusion and technology transfer.

An excellent example of the variety of the strategic approach of Research Councils is provided by the Research Councils UK (RCUK), the strategic partnership of the UK's seven Research Councils. The traditional role includes supporting high quality research over the full spectrum of academic disciplines, fostering international collaboration, and providing access to top quality facilities and infrastructure.

But in addition, it:

- engages a range of key stakeholders, including Government departments and agencies, and Local Authorities, in a continuing process, to identify and address the needs of potential users of research;
- identifies and supports key areas of interdisciplinary (cross- Council) research, including in the areas of e-infrastructure, ageing, digital economy, energy, global food security, and nano-science;
- works in partnership with the UK Technology Strategy Board to target support for collaborative R&D projects and knowledge transfer partnerships in key technology application areas, to support rapid commercialisation of emerging technologies and to promote business access to UK research facilities;
- establishes national Science and Innovation Campuses around existing Research Council facilities to attract research organisations, universities and new and established businesses with a relevant technology focus;

Also, the Economic and Social Research Council has fostered research in the social science disciplines focusing on key emerging technologies and their impacts.

On this basis it can be argued that it is appropriate for Research Councils to significantly broaden their responsibilities to extend significantly further along the value chain beyond the focus on fostering quality research and researchers to incorporate more of the environment in which that knowledge and associated capability is made available to and applied by a wide range of potential users. This would require the building up of the necessary new areas of expertise within the Research Councils.

5. Evaluation and Impact

Public management theory has provided a powerful rationale and driver for the effective cost-benefit evaluation of all government-funded projects. This has been extended to research, and more generally STI. However, because of the very nature of research, for which the results cannot be known in advance, the practices of research evaluation have developed largely independent of mainstream cost-benefit evaluation.

Nevertheless, the rationale is essentially self-evident. Large and increasing amounts of public funds are directed to research and there is a proper concern to ensure that an adequate return is being generated, the money is well spent, and the funds flow to those researchers (and institutions) best able to deliver results.

There are various types of evaluation:

- *Ex ante* evaluation is conducted prior to research, in order to assess its potential significance and likelihood of success. This process has a long history, largely captured within the peer review process favoured by almost all research funding bodies, complemented by some evaluation of previous performance (in publication and grant winning).
- *Ex post* evaluation is carried out after research has been completed and is intended to assess output and impact. In some countries this is applied to all or a majority of projects, and is an important input into the next round of ex-ante evaluation. In other cases, the approach is selective, designed largely to demonstrate value for money of a program, or a whole funding scheme, to those outside the STI system eg auditors, politicians, etc.
- Summative evaluation involves making judgements about the performance of an individual, unit, or organisation by comparison with others of the same or similar type. The results can then be used to guide subsequent allocation of funds. This 'performance-based' funding has become increasingly used, particularly for the allocation of block research funds to units or institutions.
- In formative evaluation, the aim is to provide feedback on performance as a learning device to assist in improving performance.
- In addition, evaluation can be applied to the various processes used in allocating research funds or managing research performance.

The typical metrics that have been applied to research focus on assessing quantity, quality and importance or impact of the output. The range of typical metrics includes:

- quantitative indicators, particularly drawn from bibliometrics, viz ratings of the quality of a journal in which a paper is published, and the citation rate for a paper, and occasionally economic impact measures;
- qualitative indicators, most notably drawn from the judgments of peer review, and descriptive measures of economic (or other) impact;
- outstanding accomplishments;
- findings from special case studies and analyses.

Many problems have been identified with these, purportedly objective, measures of research, particularly when they are applied on a comparative basis. For example, what might be regarded as exceptional performance in one field of research, might not define high performance in another. Outputs also vary in their nature between fields.

The problems become even greater when it comes to assessing impacts. A great deal of research has focussed on this issue, but there has been no progress in overcoming the problems of attribution and time-lag. Fundamentally, there is no simple linear connection between a piece of knowledge and its possible impact, and no way of assessing what proportion of the consequent returns should be attributed to the research output, against all the other contributing factors.

However, a number of important conclusions can be tentatively drawn.

The metrics that are applied in any evaluation need to be congruent with the objectives of the activity that is being assessed. Bibliometric and peer review metrics are appropriate to the evaluation of the quality of the output of research, but can provide no guide to impact. If impact is considered to be important, it is necessary to draw on the various metrics of impact eg patents awarded, commercialisation income, etc, as imperfect as they are.

Research evaluation exercises appear to have a time-dependent effect on research performance. Geuna and Martin[2] have made a persuasive case for a three-phase impact. In Phase 1, when a new system of evaluation is being introduced, new processes have to be established, and a great deal of new effort expended on collecting and processing the necessary data, the costs are likely to far exceed the benefits. In addition, they may produce many unintended consequences, as players game the actual or perceived new arrangements.

In Phase 2, with an established process and rules, broadly understood, and with institutions having established their own appropriate mechanisms, it is likely that benefits exceed costs ie travelling up the learning curve has established new norms and procedures across the system.

In Phase 3, in which the overall system continues, it would appear that the whole process enters a phase of diminishing returns. The major changes to the research capacity have been achieved, poor performers have been weeded out, all players are familiar with how they need to perform to score well, and relatively little change (if that is the intention0 occurs as a result of the evaluation.

Finally, while accountability will inevitably require that some form of evaluation continues, experience is showing that **far greater benefit can be obtained from evaluation which is summative rather than normative** ie the emphasis is on learning how to perform and manage better, rather than providing apparently objective measures of performance.

Annex

Policy Trends Identified in OECD STI Outlook 2010

[2] Geuna, A., & Martin, B. R. (2003). 'University research evaluation and funding: An international comparison', *Minerva*, *41*(4), 277-304.

- A "greening" of national research and innovation strategies.
- Emerging economies – from China, Brazil, Russia and South Africa – increasingly focus on innovation as a means to move up the value-chain.
- The governance of STI remains a key issue on national agendas but also with regard to international collaboration to address global challenges.
- Re-investing in the science base as essential to future innovation.
- Focusing support on key research areas and enabling technologies.
- Reform of funding mechanisms for research institutions *continues* to link budget allocations to performance.
- Full-cost economic recovery for public research funding is gaining ground.
- Direct and indirect support to business R&D and innovation continues to increase.
- Countries continue to adjust R&D tax credits in order to increase impact and effectiveness.
- Demand-side innovation policies such as innovation- friendly procurement and standards, are receiving growing attention.
- Fostering industry-science relations is an area of continuing reform and policy experimentation.
- Policies to support knowledge networks and markets are emerging.
- Support for non-technological and user-driven innovation, including in services, is increasing in some countries.
- Human resource development and capacity building remain important for innovation.
- The international mobility of students and young researchers and other highly skilled expatriates remains a high priority in OECD countries that compete for foreign talent.
- A broad-based approach to evaluation is developing that takes into account the qualitative impacts on the economy.