Science councils in South Africa

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The CSIR celebrated its 60th anniversary in 2006 by taking a long, hard look at its continuing role in South Africa. This paper was written by the CSIR Fellows, at the invitation of the Department of Science and Technology, to capture some of the thoughts that were raised by that process. Its purpose is to contribute to the national discussion on how best to organize a system of innovation for a developing country, like South Africa, with aspirations to be a respected competitor in selected high-technology areas.

There is compelling evidence that the creation of science councils†, starting in South Africa with the CSIR in 1946, had a catalytic role in establishing the strong and diverse science, engineering and technology (SET) base that exists in the country today.[1] But now that we have many large universities with strong research capacity and traditions, a private sector with substantive and well-resourced research and development (R&D) capabilities, and hundreds of agile, low-overhead technical entrepreneurs, what is the role for science councils?

Virtually all scientifically advanced countries have some portion of their SET capacity in partly government-funded, dedicated research institutions, despite having followed different development paths to get to that point. This is empirical evidence of a sustained role for science councils, even after their initial function as a development intervention has been achieved. This article explores what the future role of science councils in South Africa might be, and in doing so touches on issues such as how they might be funded, governed and staffed, and how to optimally balance public expenditure between the various mechanisms of supplying the R&D needs of the country.

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Innovation, risk, and its relationship to size of organization

In an increasingly knowledge-based and globalized economy, winning countries need to be able to 1) develop their own knowledge in selected areas, and 2) rapidly identify, adapt and adopt knowledge developed elsewhere, in order to solve important problems and exploit emerging opportunities. The 'easy' technical problems have already been solved, so carving out a significant SET niche in the modern world generally requires large and sustained investment. R&D is, by definition, an uncertain business. While it can be demonstrated retrospectively that the occasional brilliant success more than pays for the hundreds of failures, it takes a certain scale of investment to play successfully in such a high-stakes, high-risk game. Some categories of R&D, notably those that require multidisciplinary capabilities or expensive and sophisticated facilities, or where the outcomes are particularly uncertain, soon

†We use the phrase 'science council' as shorthand for a variety of public sector, not-for-profit R&D organizations, generally established by statutes, and dependent to a greater or lesser degree on public funding. In South Africa this includes, among others, the Council for Scientific and Industrial Research (CSIR), the Medical Research Council, Agricultural Research Council, Human Sciences Research Council, Council for Geosciences, Mintek, and the Nuclear Energy Corporation of SA. Legally, it includes the National Research Foundation and the Water Research Commission, which, as research funding agencies, operate somewhat differently from the other councils. By extension, many of the arguments offered here for science councils also apply to institutions such as museums, national collections (such as the South African National Biodiversity Institute), and national facilities such as the South African Astronomical Observatory. Elements of this discussion apply to operational agencies within government with a high technical content, such as Standards SA or the Department of Environmental Affairs and Tourism's Marine and Coastal Management. In other countries, equivalent organizations are called national laboratories, quasi-government research organizations and similar names. In effect, university-associated but research-focused (rather than teaching-focused) units have similar attributes.

escalate to a point where they are too risky for organizations of the size of most South African university departments or private sector R&D departments, given that R&D is not their primary mandate. A solution is larger-scale organizations, with directed R&D as their central purpose: in other words, science councils. Where the cut-off lies between 'top-down' directed research, and 'bottom-up' competitive granting is continuously shifting, as equipment within a domain becomes cheaper, universities and corporations grow, and as research domains mature. We can attempt some order-of-magnitude estimates, based on contemporary experience in South Africa. Emerging topics require full-cost support in the region of R20 million per year over a period of about ten years—a scale of investment that is hard to muster within a single university, and is only palatable to the local private sector once the commercial outcomes are fairly clear. Given that the success rate within a given domain is low and unpredictable, and that many such domains can legitimately be regarded as high priorities, a relatively stable national R&D organization needs a portfolio in the order of a billion rand of turnover annually.

National facilities and advanced human capacity development

A similar argument applies to advanced R&D facilities. Although such facilities are economically important at a national scale, they can seldom be made to pay their way in a financial sense (that is, as self-funding enterprises, where user fees cover the operating cost, the depreciation of the instruments, insurance, the salaries of the technical specialists who operate them, and a sufficient profit margin to make them an attractive investment). World-class researchers cannot be trained or retained in the country if such facilities are not available, but few universities can afford to maintain them for teaching purposes alone. Having invested in a cutting-edge facility, presumably after a well-informed decision-making process, the capital expenditure represents a sunk cost to the funder. The only way to realize the full economic potential of the investment is to maximize the use of the facility, which in turn requires dropping the cost-to-user to marginal levels. Thus a large part of the core costs must be covered by the public purse. Operating these facilities successfully and safely requires a high level of technical proficiency, which needs specialist skills that are not easily sustained in a university structure, since the operators are neither teachers nor researchers, although they are indispensable to both.

This set of considerations applies not only to sophisticated equipment, but also to relatively prosaic, but nevertheless essential and technically specialized functions such as the maintenance of national reference collections such as herbaria, gene banks or insect collections, and observation systems such as weather stations, seismographic networks, satellite image archives and fisheries stock assessments. They also apply to a degree to the 'pilot plants' that are necessary to scale-up promising, newly developed processes before they become commercially viable. The Pebble-Bed Modular Reactor is a current example, and the early development of the Sasol coal-to-liquid fuel process is an example from the past.

The innovation continuum: from discovery to application

It is well understood that the path from a bright idea to an innovation with social or commercial impact is long and uncertain, and becomes more and more expensive the closer the development gets to implementation. It is hard for a single organization to span this entire continuum effectively—it requires 'interfacial organizations' that can act as translators between fundamental research and operational delivery. There is often a three-way clash of cultures between 'academic' environments, government entities, and commercial organizations. Academic institutions place their highest priority on curiosity and truth, while government agencies simply want implementable solutions that work (and as soon as possible, please!). Companies are strongly focused on return to shareholders, which emphasizes delivery, to specification, on time and within budget. Interface organizations, such as science councils, have to be able to connect to all these cultures in the innovation chain. This requires a particular culture of their own, characterized by pragmatism, project-orientation and transdisciplinarity.

The gap between primary knowledge generation (which classically, but not exclusively, occurs within universities) and the knowledge needs of society (including the commercial and public sectors) has been referred to as the 'Innovation Chasm'. There are many discrete steps in bridging this gap, rather than one giant leap. The simple distinction between 'pure' and 'applied' research does not do justice to the actual dynamics of the research process. A linear notion of science proceeding from basic to applied is increasingly questioned—often 'basic' breakthroughs arise from the pursuit of very applied questions.[2] The OECD identifies nine 'Technology Readiness Levels' (TRL). TRL 1 to 4 are typically thought of occurring largely in universities, but the serendipitous nature of science means that they often happen in science councils as well. TRL 5 to 7 increasingly depend on the type of R&D environment offered by science councils: multidisciplinary and full-time professional staff with both advanced SET and application domain knowledge. TRL 8 and TRL 9 are largely the domain of users, often in the private sector, but may still need some science council support.

SET support to government entities requires organizations with a suite of special characteristics. These include being seen as impartial and trustworthy, at the forefront of a range of applicable technologies and familiarity with the user's application domain, terminology and culture. These attributes require a stable body of professional scientists and engineers who have made their careers in the application domain, which in turn needs a reliable and sustained source of funding, coupled with a carefully-crafted mechanism to provide strategic direction and prioritization of projects. Organizations providing this kind of support are termed 'sector-specific science councils'. Whether they are best organized as divisions within an umbrella council, or as stand-alone bodies, depends on the balance between economies of scale that accrue from a generic approach on the one hand, and the sector-specific operational needs on the other—a topic we touch on later.

Maintaining a stable pool of knowledge workers

An important function of science councils is to help attract and develop the next generation of professional SET personnel. This they do by awarding bursaries, providing internships and vacation work, offering opportunities for pre-graduate and post-graduate research projects and, crucially, through providing early-career employment and experiential training. World-class R&D workers do not emerge from graduate study programmes fully formed. They require several years in a stable and structured environment, rich with mentors and coaches, to build the confidence, track record and networks needed to be competitive.

Building an expensive system for generating highly skilled individuals at master's and doctoral level is wasted if those individuals do not have employment and career opportunities after they graduate. There is a strong suspicion that the slow pace of race and gender transformation within the R&D sector in South Africa is at least partly due to the perception by bright young students that finding work as a research scientist or engineer is hard, and, if you get it, unrewarding compared to other opportunities that additionally require a shorter training period. Science councils create employment demand, a visible career path, and a pool of skills that can be drawn into industry or academia as needed. There is probably a necessary 'inefficiency' or 'redundancy' in this system: it cannot be clear beforehand exactly what skills will be needed, and in what numbers, and skilled people cannot be quickly generated on demand. There needs to be a relatively large and diverse pool of technical specialists, with skills kept honed by working in a challenging environment, to be deployed when needed. Science councils fulfil this function.

Integrated solutions to complex problems

The emerging environmental, manufacturing and societal issues of 21st-century problems are characterized by complexity. The solutions require the coordinated application of many disciplines. It is possible to do this by drawing on skills from many different organizations (or different departments within one organization), but generally the missing component is the integrative inter- and transdisciplinary skills that act as the 'glue' between the various components. This is a skill in its own right, but one that is hard to sustain in an organization that is built and rewarded around disciplinary specialization. It is certainly easier to achieve within a large and diverse organization with a common culture and management system, provided that the culture and systems are specifically orientated towards collaboration and teamwork.

Emerging research areas

An analogous argument to the importance of science councils in the initial development of the science capacity of a nation can be made in a developed situation, but with respect to novel research areas. This is an ongoing need: every decade sees the emergence of new research areas. Biotechnology and nanotechnology are contemporary examples. Leaving their development to purely organic 'bottom-up' processes may eventually succeed, but speed is increasingly important if a leading position is to be attained. The development of new research areas can be catalysed and accelerated by deliberate, partly state-funded interventions which result in the rapid establishment of critical mass.

Problems with science councils

In practice, science councils in South Africa and elsewhere often fall short of these ideals. Instead of focusing on the areas of comparative advantage outlined above, they try to be universities, on the one hand, or private-sector consultancies on the other. At best this leads to sub-optimal S&T outcomes. At worst it damages both the science councils and the entire innovation system.

One of the main pathologies of science councils is short-termism. Perceiving their income to be under threat, and sure only of their budget allocation for a single financial year, they do not commit to the long-term, large projects where their advantage lies. This is mostly a self-inflicted constraint. The Medium Term Economic Framework of government gives relative stability over a three-year period, and historical data suggest that the inter-annual variation in the combined funding streams to science councils is quite small, even when there is an underlying upward or downward trend.

A related issue is risk aversion. Conscious of the need to generate short-term income, science councils tend to drift out of their core domain, which should be high-risk, pre-commercial research, into low-risk work that generates little new knowledge but a steady income. They become consultancies or technical service organizations, both of which have a necessary and valuable place in the S&T landscape, but in general should not qualify for the public funding which comes to science councils. There *are* circumstances where the skills held in the science councils may justifiably be applied to difficult, novel, specialized or nationally important consultancy or service tasks, but when these come to dominate the activities, ethos and reward systems of the councils, then something has gone wrong.

Organizations that are insulated from the rigours of the marketplace can become complacent and unresponsive to stakeholder needs. For interfacial organizations such as science councils, too much public funding can be as detrimental as too little. The optimum point is probably quite broad, situation- and mission-dependent. Internationally, examples of apparently sustainable science councils exist with between 25% and 80% baseline public funding. For South African circumstances, it seems that the level of 70% external funding reached by the CSIR in the 1990s was too high,[3] but the 20% external funding up to the early 1960s was sustainable only in a startup phase. A level closer to 50% would allow the CSIR to balance its public- and private-goods mandates more successfully.

As organizations mature and grow in size, they accumulate rules and structures. The dead hand of bureaucracy becomes increasingly dominant, and one of its manifestations is the inexorable upward creep of 'overhead' costs. Science councils are bound to satisfy both the onerous requirements of the Public Finance Management Act and the accounting demands of diverse external funders and clients. Some clients require hour-by-hour billing, which leads to the imposition of time-accounting systems quite inimical to a productive and innovative research environment. In an attempt to limit the ballooning overheads, scientific bone (such as libraries and laboratories) is usually sliced out instead of unproductive fat such as excessive administrative systems or under-performing researchers.

Historically, science councils in South Africa have tended to proliferate by budding off research domains as separate organizations (see Fig. 1). Sometimes this has been well-motivated by operational needs, but often it has been driven by the all-too-human instinct to establish independent territories. This tendency, if carried too far, undermines the benefits and economies of scale outlined above, and makes overall coordination of the S&T system more difficult. Figure 1 shows that the turnover of the CSIR as a fraction of the national gross domestic product has never exceeded 0.2%, and has fallen steeply since about 1990. Since 1992, the fraction of the GDP devoted to research in South Africa as a whole has risen from about 0.8% to nearly 1%, meaning that the fraction used by the CSIR has fallen even more steeply.

A comment on research overheads

There is a component of organizational costs which cannot logically be charged on a contract-by-contract basis, and is most efficiently treated as a central cost. This includes exploratory pre-contract research and capacity development, shared infrastructure such as buildings and libraries, and the transaction costs of maintaining a complex organization. These costs are, broadly speaking, 'over-

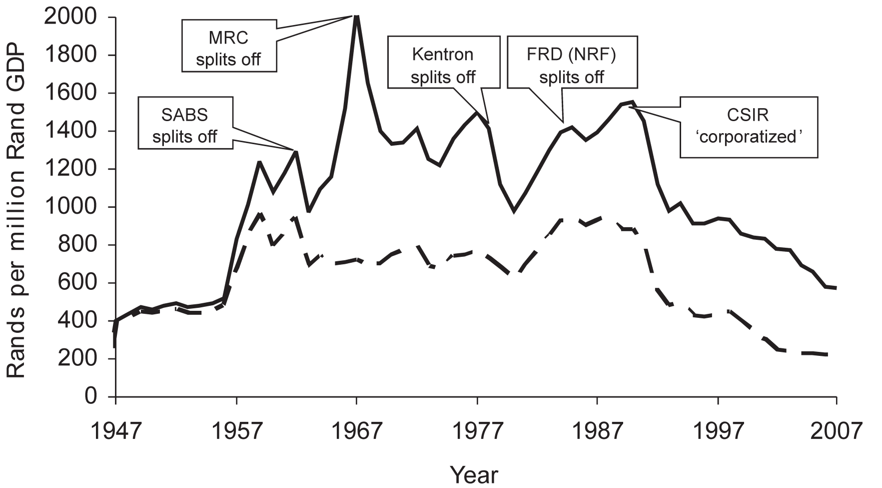

Fig. 1. The total turnover of the CSIR (——) and that originating from its Parliamentary Grant (– – –), expressed in relation to the national GDP. Four phases are discernable: establishment (1946–56); growth (1957–67); stabilization (1968–88); and reorganization (1989 onward). The CSIR is one of the oldest and largest science councils in South Africa. The evolution of its discretionary and contractual income is broadly representative of trends in this sector.

heads': but virtually all R&D clients resist paying their full share of them. They either refuse to pay certain components, or cap their contribution at a level far below the true costs. While there is good reason to be vigilant about the escalation of overhead costs in organizations that do not operate in perfect markets, and all organizations need to work hard at minimizing costs, there is an irreducible core of expenses which have to be paid by someone. Comparison of the overhead costs of science councils with those of either universities or private-sector entities needs to be done with care. Much of what science councils must pay for as overheads is hidden in other budgets (such as the education budget in the case of universities), but nevertheless comes out of the public purse. Private companies do not generally carry a burden of maintaining research infrastructure or capacity, because they rely on the science councils and universities to do so! Analysis of the cost structure of South African R&D institutions[3] indicates that the total cost of doing research in a science council lies between that of performing research in a university or in the private sector, and that the spread between the three types of organization is only about 20%.

Baseline *versus* contract funding

One of the questions raised above (whether to provide a broadly defined line-grant to a single large science council, or to direct the funds by granting them to several smaller councils with more focused mandates) is related to the question of how much discretion the receiving organizations should get in the internal allocation of the funds provided to them. The global tendency is for funding bodies to assert more and more control on the allocation process, using arguments based on accountability. At some point this becomes counter-productive, because it lifts the decisions on the deployment of resources too far above the point at which the activities actually occur, resulting in misallocation, inefficiency and a frustratingly slow funding process.

Logical consequences of these arguments

1) Large, multidisciplinary, significantly publicly funded research and development organizations are found in all successful innovation systems, regardless of their phase of development or sophistication.
2) International experience suggests that there are many different ways of organizing such entities, which may be more or less successful in different circumstances. Continuous institutional adaptation and adjustment is, within reason, a beneficial feature of a healthy S&T system. The time-constant of change is necessarily long because the building of high-level skills and effective large-scale organizations is slow, while the possibility of rapid collapse and loss of skills is real.
3) To justify their privileged position as recipients of public funding not tied to specific projects, science councils and similar bodies need to ensure that they focus on fulfilling the role that they are best suited for: longer term, innovative and integrative research. Their project selection and evaluation systems must reflect this objective.
4) Science councils, and their stakeholders, clients and governing bodies, need to balance the needs for accountability with the requirement for efficiency and a light management touch in order to nurture a productive research environment.

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