# 3. Choosing Good Science in a Developing Country

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*Models for national systems of innovation generally involve the interaction of a strong science base with local industry. However, in developing countries the term 'science base' may be over-optimistic. Instead, at best we have isolated peaks of scientific excellence. Is it possible to optimise this configuration of peaks to support national development? Or is the useful coupling of scientific endeavour to developmental goals inevitably scale-dependent, with science in low GDP per capita countries linked only to global knowledge paradigms somewhat remote from the local concerns? This paper outlines a system for generating a research portfolio which uses local advantages to generate world class science.*

## Introduction

There are two basic principles underpinning government support for scientific programmes:

1. The programme can contribute towards addressing social or economic goals.
2. The programme is potentially world class and can contribute to leading edge global knowledge.

Increasingly, particularly in developed countries, these principles tend to overlap. Fiercer competition brought about by globalisation and the rapid growth of information technology and biotechnology has led to the shortening of the innovation cycle. The new global economy is more dependent on knowledge than ever before and it is obviously new knowledge that delivers competitive advantage. How should developing countries position themselves with respect to the knowledge economy, which depends critically on the national research portfolio, and on linkages between this portfolio and the national system of innovation?

I would like to introduce the central question addressed in this paper by quoting from a lecture given by Sir William Stewart, former Scientific Advisor to the British Prime Minister. According to Stewart 'Britain does 5 per cent of the world's research and tries to maintain sufficient competence in the other 95 per cent to be able to move into it if necessary'. Is this a viable strategy for

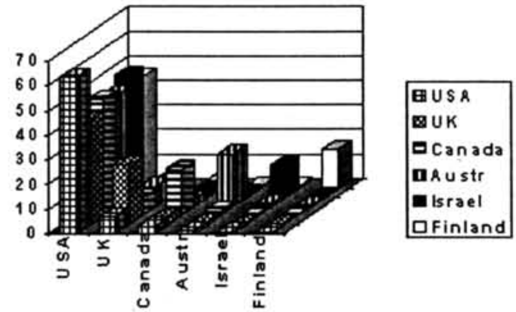
South Africa, which does about 0.5 per cent of the world's research, and for other catch-up nations? It seems unlikely that we will be able to cover all possibilities within the remaining 99.5 per cent from our much narrower base. This realisation has stimulated a discussion on whether government has a responsibility to optimise the national research portfolio and if so, what criteria should drive this optimisation. Should we choose, and if so, how?

I begin by discussing international trends in science-industry linkages and move on to depict the most serious constraint on South Africa's entry into the knowledge economy, namely human resources. Finally, I attempt to set out a framework for determining a national science portfolio and to show how it could be applied to South Africa.

## Science-Industry Linkages

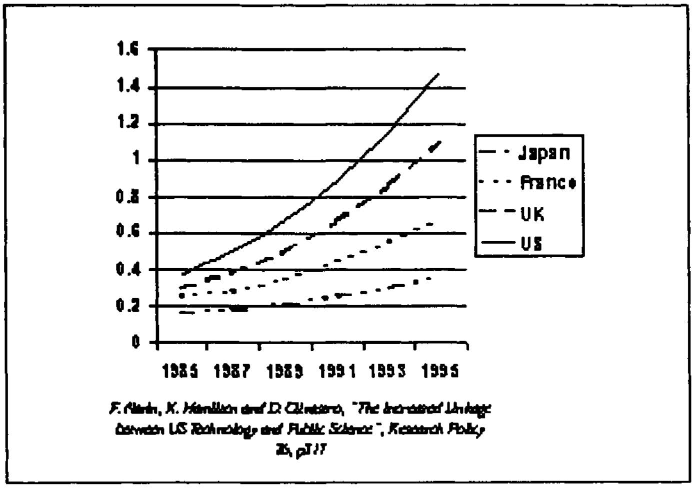
It is a widely held belief among both scientists and economists that public science is a driving force behind technological and economic growth. Recent research has shown that 73 per cent of the papers cited by US industry patents are public science, written at academic, governmental and other public institutions; only 27 per cent are written by industrial scientists. A strong national component of this linkage has also been found, with each country's inventors preferentially citing papers written in their own country by a factor of between two and four. The pronounced diagonal in Figure 3.1 depicts this clearly. The growth in linkage has been rapidly increasing (see Figure 3.2). In general, the cited papers are from the mainstream of modern science; they deal with basic issues, appear in influential journals, are written at top-flight research universities and laboratories, are relatively recent and supported by National Institutes of Health, National Science Forums and other public agencies.

**Figure 3.1. Percentage Research Article Citations in US Patent Applications by Country**




"Science and Industry Linkages", Australian Research Council Report, 2000.

**Figure 3.2. Citations from Patents to Papers versus Time (smoothed)**




The linkages are much stronger in 'new economy' areas than in 'old economy' areas. For example, the average number of citations of research articles per US patent application differs by a factor of approximately 200 between the fields of biotechnology and machinery parts (see Figure 3.3). This indicates that basic science will play an increasingly important role in global competition. Unfortunately, the linkage between science and industry in what the OECD terms 'catch-up' countries, such as South Africa and Brazil, is much weaker. The rate of application for US patents is much lower to begin with and the national components are less significant. Where good science exists, it tends to be linked to programmes in developed countries. Local industries generally purchase technology and related know-how from abroad rather than connect to local scientific thrusts. Towards the lower end of the development spectrum there is an almost total disjuncture between science and industry. The only way that scientific programmes contribute is via human resource development; scientists leave science and join industry and the thinking processes they have acquired are of assistance in the new environment. The 'scale-dependence' of industry-science relationships is summarised pictorially in Figure 3.4. Given the increasing science-dependence of innovation, and consequently of economic development, three key issues facing developing nations are:

- How to increase the scale of scientific activity;
- How to optimise the portfolio of scientific activities;
- How to generate linkages between science and industry.

**Figure 3.3. New Economy is Dependent on Basic Scientific Research**

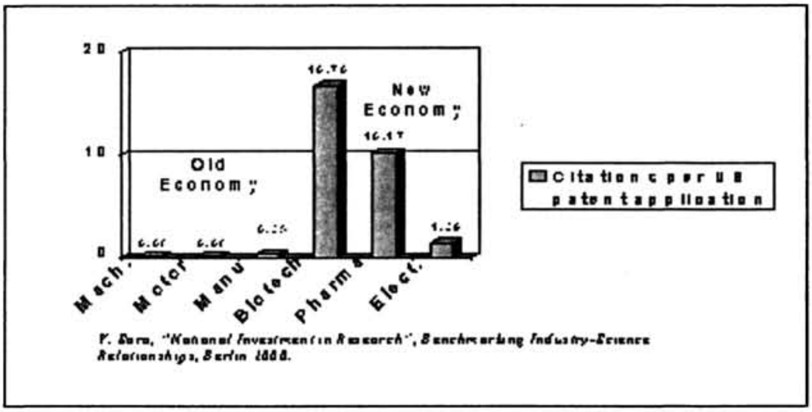
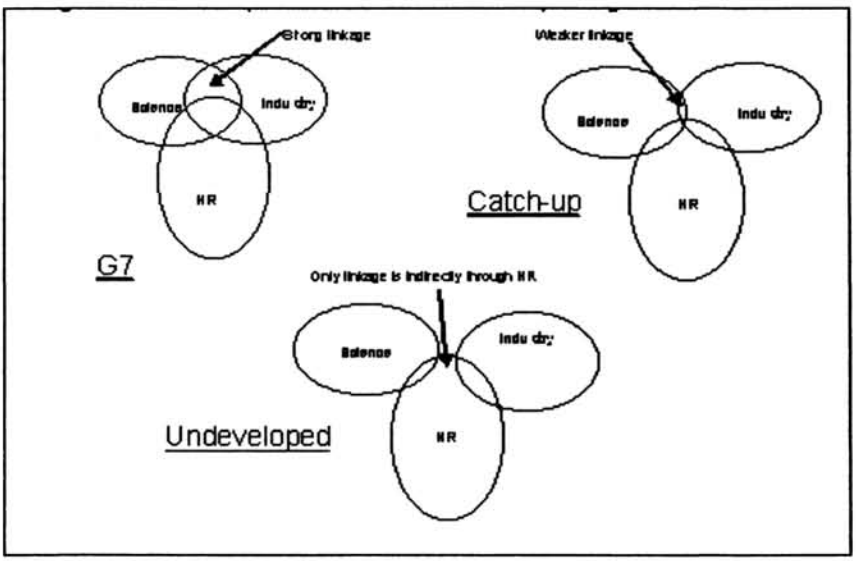



**Figure 3.4. Scale-Dependence of Science/Industry Linkages**




## Human Resources Constraints

Science is a highly globalised activity. Even in advanced economies such as Germany and Canada there is a worrying trend of the best scientists being drawn towards the highly dynamic US system. To counteract this trend the affected countries are attempting a range of interventions. For example, Canada has set aside funds to create 2000 university chairs in science and engineering over the next five years. Both France and Germany are in the process of radically overhauling their legislation for the purpose of promoting science-industry linkages in line with the highly successful US Bayh-Dole Act. In South Africa recent studies show attrition rates of approximately 11 per cent per annum from government laboratories and 15 per cent per annum from universities for researchers. Of those who leave, about 5 per cent of the government laboratory scientists and about 22 per cent of the academics emigrate. Given the current fiscal environment and skills scarcity, the vacant posts are not automatically filled.

South Africa spends approximately 0.69 per cent of its GDP on research and development This figure does not compare well with the OECD average of 2.15 per cent. Nevertheless, it is interesting to note that the average expenditure per full-time equivalent researcher in South Africa is about $100,000 – more than the equivalent figures for Australia and New Zealand and about 70 per cent of those for Canada and Japan. The reason for this apparent contradiction is the extremely low number of full-time equivalent researchers in the labour force, approximately 0.72 per 1000, compared with 10.1 for Japan and 4.8 for Korea. The indicators for countries such as Turkey and Mexico are very similar to those for South Africa. This clearly implies that any strategy for improving research outputs from 'less developed countries is unlikely to succeed unless it incorporates a bold human resource acquisition, development and maintenance plan. Individual researchers in such countries suffer less from underfunding than they do from a dearth of colleagues'.

## Choosing Niche Areas

It is often said that governments are bad at choosing research priorities. This is less a criticism of the acumen of government officials than a consequence of the fact that detailed planning can never capture the quicksilver nature of innovation. Nevertheless, technology foresight studies have become the norm rather than the exception over the past decade in developed countries. Japan has a regular five-year cycle and the UK is beginning its second exercise. Increasing interest is being shown in non-OECD countries too, with South Africa, Thailand and the Commonwealth Science Council taking the lead. The methodology underpinning these studies involves creating a shared vision among decision-makers and within key sectors regarding the threats and opportunities likely to be faced in the future and how to respond to these in terms of broad portfolio planning. It does not pretend to forecast the details of actual technologies.

In 1998 a review (somewhat similar to Britain's Forward Look) was conducted of the South African national system of innovation. From this review a set of criteria emerged for recognising what were termed 'core competence clusters'.

A core competence cluster is an effectively functioning set of infrastructure, technology, capabilities and platforms that provides outputs to clients and stakeholders which they can appropriate and evaluate. A nation's technological competitiveness rests on an appropriate portfolio of such clusters.

Criteria for recognising core competence clusters were also developed. In general they should:

- Provide a global competitive edge
- Be sustainable
- Be hard to emulate
- Have multiple applications
- Attract international collaboration and investment.

What type of core competence clusters should South Africa try to establish? The information society concept lies at the heart of the knowledge economy. Increasingly, biotechnology is being seen as equally critical. The South African Foresight study proposes that the country should invest in establishing platforms in research and development (R&D), training and technology transfer in base information and communication technologies such as: (i) access technologies, for example connectivity, low-cost satellites and stratospheric communication; (ii) spatial numeric environments; (iii) human language technologies; and (iv) security technologies. The Foresight study also recognises that biotechnology, the term given to the wide range of agriculture, industrial and medical technologies that make use of genetic manipulation of living organisms to create new products, will be a key factor in improving the quality and quantity of the world's supplies.

Clearly, we cannot afford to be on the wrong side of the information or the bio divide. The generic technologies underpinning rapid development in information technology and biotechnology are non-negotiable in the modern world. Are there other areas in which it is possible to achieve a world class standard? If so, how do we recognise them? In general we can define two additional broad features which are likely to underpin the more specific criteria for core competence clusters listed above.

- Scientific areas where there is an obvious geographic advantage. In the case of South Africa there are several of these which stand out. Examples are:
  - Astronomy where we have good access to the southern skies and the engineering capability to build telescopes locally;

  - Human palaeontology where we have excellent sites in the Krugersdorp region dating from shortly after the bifurcation between apes and humans;
  - Biodiversity where the Cape Floral Kingdom is the most diverse of all the seven floral kingdoms.

  Other possible phenomena or systems on which it has been or would be possible to base good science include the Kaapvaal Kraton (geology) and the South Atlantic Magnetic Anomaly (geomagnetism and space science).

- Scientific areas where there is an obvious knowledge advantage. Important South African examples are:
  - Indigenous knowledge where clearly the collective inherited and evolving knowledge systems of indigenous peoples constitute a national competitive advantage;
  - Technology for deep mining where geological conditions and economic imperatives have pushed South Africa to the forefront;
  - Microsatellite engineering – although large multinational consortia now dominate the communication satellite market, South Africa has retained a niche competence in microsatellites deriving from a fusion of defence spin-offs and university research;
  - Encryption technology such as spin-offs from state investment in the defence sector that have recently generated significant foreign exchange;
  - Fluorine technology where high entry barriers mean that the competence developed in the uranium enrichment programme could be turned to advantage.

These examples are intended to be illustrative rather than exhaustive. They illustrate a way of looking at science that attempts to prioritise in terms of likely outcomes, moderated by what is deemed necessary in terms of national competitiveness in the broadest sense of that term. Despite the fact that the motivations of individual scientists are generally fired by intellectual curiosity rather than by weighing potential outcomes, it is necessary for decisions to be made unsentimentally. Not to prioritise in a way that attempts to optimise impact is irresponsible and potentially wasteful. The public and their elected decision-makers respond positively to success. It is a sound strategy for scientists, science administrators and policy specialists to develop a common approach towards maximising the chances for success.

## Conclusion

In this paper I have attempted to show three things:

- The evolution and the scale-dependence of industry-science relationships;
- The critical importance of human resources to the national research and development effort;
- An approach towards optimising the national science and technology portfolio.

The space available has dictated suggestive rather than rigorous arguments. Nevertheless, I believe that there are important lessons here for the nurturing of a healthy science base in a developing country.

# PART II

The emphasis of Part II is on how a broader, more focused public understanding can lead the countries of sub-Saharan Africa to more effectively harness science and technology for the economic benefit of the individual, community and society. In one case, the selected examples demonstrate the countrywide economic benefits that have come through the problem-solving expertise of top research scientists through the establishment of a manufacturing industry in Malawi (Chapter 4). Other examples illustrate the effectiveness of problem-solving science and technology in the transformation of the informal sector of the economy in Ghana (Chapters 5 and 6). Chapter 7 eloquently presents a case for the economic value of the indigenous knowledge sectors of African societies, particularly of Southern Africa. Part II closes with a review of the economic benefits of sharing resources in science and technology in the southern region of the continent (Chapters 8 and 9).