THE CRITICAL BARRIERS TO THE MORE EFFECTIVE APPROPRIATION OF RESEARCH RESULTS

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Summary

The research conducted in this country ranks high by international standards in terms of quality, and on a relative basis, in terms of quantity also. The same cannot be said for technology development. A variety of measures including level of industrial R&D expenditure, employment of qualified R&D staff in industry, applications for patents and balance of trade in technology intensive goods all indicate an extremely low comparative national performance. Why the difference?

The explanation offered in this paper suggests that the barriers to the more effective exploitation of Australian research results by Australian industry cannot be overcome by adjustments to the organisation or funding of research. They are a consequence of the 'marginal' nature of our science and technology structures.

Marginal science and technology structures are defined by the lack of connection between science and technology activities and the production sector. In this situation research takes the form of a 'welfare' function, rather than an investment. The self-reinforcing separation of supply and demand is reflected on the one hand by the emphasis on basic research and the loose connections between goals of research and economic and social needs. On the other hand, the production system, with its dominance by overseas companies and low commitment to local development, produces little demand which could influence or reorient the research system.

Under these circumstances, the answer to the Conference title must be:

i) those whose career structures rest on publications;
ii) foreign companies and economies; and
iii) Australia, but only in terms of prestige.

Only policy measures which recognise and are directed to changing the marginal state of Australian science and technology are likely to make a contribution to the development of a system capable of sustaining our economy and our research capability into the future.

Introduction

The title of this Conference - Science Research in Australia: Who Benefits?, reflects an interesting shift in the perception of the place of scientific research. It is not so long ago that to ask such a question would have been to demonstrate one's naivety. Of course everyone benefits, directly or indirectly, from scientific research. In a typical statement, ASTEC has argued:

> Basic research is an intellectual and cultural activity, contributes to national status, and is important in the education and training of scientists and technologists. It is also an investment for the future in terms of the economic, social and other benefits that may flow from it. (1)

However increasingly the institutions of research are being required to make the case for the benefits that nation receives in return for the considerable funds provided, and their research is being directed more in accord with what are perceived to be national needs.

In order to set about determining who benefits from scientific research in Australia, it is necessary to go beyond a simple commonsense checklist comprising researchers, industry, the government, the economy, workers, consumers, etc. Otherwise we are in danger of presenting little more than the cases of the various interest groups. What we need is some systematic model which places the scientific research system in a framework of the economic, political and social needs, and structures, of Australia. A list and description of the various institutions making up the 'science and technology system', of the sort which has been provided elsewhere (2), does provide some indication of the system's operation. However it is the flow of resources - financial, human and knowledge - between the various elements which is critical to its effectiveness, and to any description of it.

Towards a Model of the 'Science and Technology System'

Let me start with some quotations the author and subject of which for the moment I wish to keep anonymous:

1. "The level of R&D is low, rarely exceeding 1% of GNP. However, the quantitative deficiencies of R&D are less serious than the fact that the R&D is unconnected to the social organization in which it is carried out. In the advanced countries, most R&D is on subjects which are connected directly or indirectly with national goals, like defence, social development, or prestige. Scientific development is reflected in the development of industrial and agricultural technology and, in general, in the growth of production. Here on the other hand, most scientific research is irrelevant to the basic problems of the region. This lack of a connection between the goals of scientific research and the needs of society is a characteristic which is even more important than low rates of expenditure on research. (3)

2. Industrial technological research is practically non-existent. Whereas in developed capitalist countries between 60 and 70 per cent of R&D is undertaken by the private sector ... here the proportions are reversed.

3. The pattern of R&D activities also reflects the lack of social relevance. In advanced countries far more is invested in applied and development research than in basic research. The ratio of these expenditures is 9 to 1 in France, England and the United States and about 4 to 1 in the rest of Western Europe. Here on the other hand, these ratios are more like 1 to 4 or 1 to 9. It is estimated

that much more is spent on basic research than on applied research and development. At the same time, because applied research is so weak, there is practically no interaction between the different types of research and between research and production. The few basic research centres of quality are generally closely connected with the scientific systems of great powers (both in the type of research they do and, in many cases, in the sources of funding they use). They function as isolated enclaves which do little to encourage local R&D. (4)

4. The characteristics of the production system hinder the creation of scientific and technological capacity ... The industrial sector includes local workshops, and small factories, and a foreign sector of technologically more advanced industries and greater volume of production. In this kind of production system, which is characterized by a very reduced market for industrial goods, demand for local scientific or technological capability is very limited. The foreign firms import technology from their headquarters abroad. The few 'modern' local industries import technology in bulk, in one go, and do not adapt it to local needs, nor do they keep pace with international technological development. (5)

Now the question is, to what country or countries do these comments apply. Let us review the major points:

- Low level of R&D overall;
- Low proportion of R&D conducted by industry, high proportion by government;
- Much more basic research than applied research and development;
- Little interaction between research and production;
- The production system, with its dominance of technologically advanced sectors by foreign firms, generates little demand for local scientific and technological capability;
- Lack of connection between the goals of research and the needs of society.

One could argue, very persuasively, that all of these criteria apply to a significant extent to the Australian science and technology system today. In fact, the argument was written to describe the situation of Latin American countries in the late 1960s. I am not seeking to demonstrate that Australia is underdeveloped. What I wish to claim is that the scientific and technological structures of Australia are more like those of developing countries, that this has the effect of 'marginalising' science and technology activities, and the important implications for policy concerning the promotion and use of science and technology are considerable.

The Concept of Marginal Science and Technology Structures

The concept of marginal science and technology (S&T) structures has its origin in studies of developing countries. There has been a great deal

of debate over and analysis of the roles of science and technology in development. During the late 1950s and 1960s, the lack of an adequate science and technology capability was regarded as one of the key barriers to development (6) and considerable resources were devoted to establishment and expansion of this capability.

In more recent years, a science and technology capability has come to be seen as insufficient to guarantee development on its own. This shift in thinking resulted from the larger number of spectacular non-successes, if not downright failures, that followed the devotion of considerable resources to building up this capability. In addition the linear model whereby 'science discovers, technology applies, and economy grows', which lay at the heart of the argument for establishing the S&T capability, was itself coming under increasing attack from economists and policy analysts in many contexts. (7)

More recently attention has shifted to linking the science and technology capability effectively to the production sector, and to explaining why there appear to be substantial barriers between the two. Clark, among others, has argued:

> planning science in conditions of underdevelopment has an additional qualitative dimension - namely that of reconciling on the one hand the activities of research workers qua scientists, who often take as their paradigm the orientation of 'Western science', and on the other hand the objective requirements their societies have, which may require technical solutions of a different order. (8)

Cooper (9) has suggested that the alienation of scientific institutions is a function primarily of the underdevelopment of economic structures and that attempts to apply social engineering to the scientific sector alone are bound to be less than successful.

In essence marginal S&T structures are those in which there is little or no connection between S&T activities and the production sector. (10) The latter is not engaged to any significant extent in technology development nor does it create a demand for locally produced technologies. Furthermore

> the lack of pressures on science from the local economy means that the main determinants of research orientation are the individual decisions of research workers; and these research workers take their lead from the international orientations of research. (11)

Consequently research is largely a consumption good, rather than an investment as is the case in truly industrialised countries. In other words, though the rhetoric of justification for expenditures on science and technology may be in terms of economic return, the reality is that they are welfare functions, funded by governments because they are considered important needs of the nation (and particularly needs of the community of researchers). A high level of foreign ownership of industry, particularly the technology intensive sectors, is both a reflection of and contributor to the marginalisation of S&T structures.

Marginal S&T Structures in Australia

What evidence is there that it is appropriate to consider the S&T system in Australia as marginal? Let us return to the six characteristics of marginality.

1. Low level of R&D - That the level of R&D in Australia is low by international standards is now sufficiently well known not to require yet another comparative Table to justify it. Throughout the past decade R&D expenditure and employment has slowly but steadily declined, until the former is now less than 1% of GDP, placing us very much in the little league in OECD. (12)

2. Low proportion of R&D conducted by industry, high proportion by government - Again there is little room for debate over the applicability of this criterion. The business enterprise sector is now responsible for only about one-fifth of R&D in Australia, and government support has increased from 62% to 76% of the total over the decade. (13)

3. Preponderance of basic over applied R&D - The high proportion of research conducted in the government and higher education sectors is reflected in the high proportion of research which is characterised as basic. Gannicott (14) has noted that 28% of R&D funds are spent on basic research, a higher proportion than any other OECD country. The most recent figures available (1978-79) show 18% on 'pure basic research' and 15% on 'strategic basic research'. (15)

4. Little interaction between research and production - There are a number of indicators which suggest this description applies to the Australian scene. In addition to the low level of R&D performed in industry, it also contracts out only 5.9% of its R&D needs and only 3.4% is spent in Australia. (16) In other words industry makes little use of the very considerable research infrastructure. In addition, the record of successful commercialistion by Australian companies of products or processes developed within Australian research organisations is extremely limited. While there have been some notable successes, there are far more cases of exploitation, if at all, by overseas companies.

5. Little demand for local science and technology by the production sector - We have already noted the low demand. In addition it is evident that the technology intensive sectors are heavily dominated by foreign-based firms. Moreover, while these firms conduct a significant proportion of R&D, it is almost all directed to adapting technology developed overseas to local conditions and markets. (17)

6. Lack of connection between the goals of research and the needs of society - Only for this criterion is there significant reason to doubt its application to Australia. In general it can be argued that the objectives of the research, or at least that part which has clear objectives, are related to national needs. However it is worth noting that over the decade the percentage of R&D devoted to economic development has declined from 60 to 45%. (18)

It is reasonable, therefore to conclude that the S&T structures in Australia are marginal and that policy formation and evaluation needs to take this into account.

Development of Marginal S&T Structures in Australia

The development of a marginal S&T system can be traced to the colonial heritage of this country. Sagasti has developed a model of the role of imperial science in assisting and restraining economic development. In his model there was: (19)

> (1) a colonial (pre-industrial stage of metropolitan science from the eighteenth century to the early nineteenth century, followed by (2) a stage of Western science from the 1850s to the 1930s, in which dependent economies were manipulated to increase colonial integration through world markets and in which the extension of knowledge, through education, remains dependent on the metropolis. This gave way to (3) a slow progress of independent industrialisation, especially after World War II, by means of the substitution of imports, which has, since the 1960s, been overtaken by (4) concerted economic controls by European governments and multinationals, rendering dependent economies vulnerable to wider patterns of international trade.

MacLeod, in extending Sagasti's model, has noted:

> it is clear that imperial science, viewed from the centre, was an integral part of the changing policies of colonial development; that problems chosen as 'important' were determined by the interests of the imperial power; that the practice of science in the Empire was influenced by changing ideologies of empire. (20)

Thus it was that the objectives and programme of research in Australia were largely set by the Imperial power, or were shaped in accord with the interests of Empire. This neat division of labour - "cultivating mines and forests in the colonies and theoretical physics in the metropolis" (21) is reflected in the extent to which the concern to increase agricultural and pastoral productivity shaped the formation of the Australian research system. Given the highly atomistic nature of this industry (at least then) research support was institutionalised in centrally funded research organisations. This rationale provided the basis for the establishment of the Council of Scientific and Industrial Research (CSIR), on the British model, and its subsequent growth as the Commonwealth Scientific and Industrial Research Organisation (CSIRO). While there have been many adaptations since then to both CSIRO and government policy, the form of the Australian research system, with its extremely high level of government funding, and performance, of research, reflects our colonial origins.

The lack of connection between research and the industrial sector was reinforced by the form of development of manufacturing industry after 1945 primarily in accord with an import-substitution strategy. This required little local R&D, as the technology could be imported. Such a strategy placed no very great premium on developing the capability to compete, whether in terms of price or quality, for export markets. Hence there is a

long tradition of dependence on imported technology, and of conservative attitudes on the part of managers, government officials and politicians to the need for new ideas or products.

Hence the S&T system developed in the context of a need and government responsibility to support rural industries, a lack of interest or demand from the manufacturing sector, and an academic orientation to the research objectives and problems set by the international scientific community.

Implication for Policy in Australia

If it is accepted that the S&T system in Australia is marginal to the productive sector, and I think I have presented considerable evidence to support this view, then it is obvious that policies need to be formulated with a full awareness of this situation and with the objective of reducing it. Policies appropriate to the major OECD nations are almost certainly not going to be appropriate for a country with a marginal S&T system.

The traditional formal basis for government intervention in this area has been expressed in terms of imperfections of the free market. The assumption is that market forces most appropriately determine the investment of scarce resources, including those committed to R&D. However there are special exceptions, in the form of 'positive externalities', and market and knowledge imperfections, which justify governments playing a role. (22) However such a rationale takes no account whatsoever of a situation in which the national S&T system is marginalised. A quite different, and more radical approach, is required.

This points to the severe limitations in the effectiveness of policies which are conerned with supply-side factors, like funds for R&D, trained personnel, etc. In a marginal S&T system, supply factors are almost never likely to be determining. However the evidence is that science and technology policy, at least until very recently, has been almost exclusively concerned with supply factors. (33) Why should this be the case?

There may be a number of partial explanations. First the emergence and development of science policy has to a very significant extent been dominated by scientists who, inevitably in at least a general way, are concerned with the welfare of science. Such a concern is reflected in this Conference.

Secondly, in response to interest and pressure from scientists, governments have largely established Departments and Ministries, which have assumed, or interpreted their responsibilities, as being for Science, with the primary focus on supply elements of the S&T system. Part of this is a consequence of the sheer complexity of policies concerned with demand factors. Another reason is that demand factors overlap with other Departmental responsibilities much more than do supply factors. Given that Science Departments are typically junior in the Ministerial hierarchy, and have no powerful political constituency, which means they have to rely more on the power of their arguments and ideology than on any 'natural' authority to achieve ends, there is a tendency to concentrate on what can be achieved rather than what might be important.

However, whereas in the past both our economy and our research capability may have been able to survive with a marginal S&T system, the new socio-economic context is making that increasingly unlikely. Every policy con-

cerned with S&T needs to be framed with an awareness of the critical bottleneck introduced by the marginal nature of our S&T system, and an intention of reducing it. Demand policies may be far more complex, and require greater political will, but they are essential.

Useful beginnings may be underway in the areas of government purchasing policy and offset agreements. Both instruments offer very great potential for stimulating demand for local S&T. Support for sunrise technologies and industries through provision of venture capital, and preferential purchasing are also a move in the right direction. Policies with regard to the transfer of technology are also in need of systematic review and development.

Conclusion

Under conditions of a marginal science and technology system, the answers to the question of Who Benefits? that this Conference poses is quite straightforward:

i) those who find a career in research;

ii) foreign companies and economies;

iii) Australia, through its status as a research nation of the highest quality.

But is this enough? I would suggest that in order to justify some of the rhetoric in support of science, and of the considerable public expenditures, it is necessary to move towards enlarging the group of beneficiaries. That can only be achieved by overcoming the marginal nature of the S&T system and integrating it more effectively with a revitalised production system.

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9. C. Cooper, op.cit., ref.3, Chapter 1.

10. Since starting work on this paper it has come to my notice that Jean Moran of Griffith University has used Herrera's concept of marginalised science extensively in her Master's thesis on the history of the Australian Association of Scientific Workers.

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