CAPTURING REGIONAL BENEFITS FROM SCIENCE AND TECHNOLOGY: THE QUESTION OF REGIONAL APPROPRIABILITY*

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The term 'appropriability' usually refers to the ability of a business entity to capture benefits from its investment in science and technology. In this paper it is suggested that governments should focus on regional appropriability, the ability of the region they govern to capture benefits from science and technology. Regional appropriability, although in one sense a matter of common knowledge, has not been extensively discussed in the scholarly literature. This paper suggests four factors which may be important in determining whether benefits can be captured by a region. They are, first, local manufacturing; second, intellectual property protection; third, the relatively immobile nature of a broadly skilled workforce; and fourth, "contexted technology", that is, technology which links into existing industrial strengths.

Keywords: Technology policy, regional development, research policy, high technology, innovation policy, industry assistance.

THE NATURE OF THE PROBLEM

Most national governments have policies to support and stimulate research and development (R&D). So do many governments of regions within nations such as state or provincial governments in federal systems. For instance, the Government of Western Australia in 1988 introduced the Western Australian Research and Development (WARD) grants scheme[1] and recently the Queensland Government has established the Queensland Grants for Research and Development scheme along similar lines.[2] Other states in Australia have different mechanisms for the same or similar purpose of stimulating R&D; for instance, Victoria has the Strategic Research Foundation and the Centre for International Research on Communication and Information Technologies.

Potential benefits from R&D are many and varied. They include social and cultural effects as well as economic ones. Undoubtedly, however, the main objective in the cases mentioned above is to stimulate innovation in industry. Thus the WARD scheme "is designed to enhance

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the capability of the Western Australian business sector to successfully develop new products and processes and thereby secure expanding domestic and export markets."

Clearly the assumption is that, for the industry of a country or region to be competitive, it needs an R&D base. The strength of this assumption is something of a puzzle, since it has been known since the work of Williams in the 1960s that the benefits from R&D are not necessarily localised even to the extent that they remain within the nation where the R&D is performed. Williams showed, for a number of countries, that the percentage of GNP spent on R&D is not correlated with the rate of economic growth.[3] The USA and the UK, for instance, showed high expenditures on R&D but low growth, whereas Japan showed low R&D but high growth. Looking at the facts, it would seem almost as though the things that Japan was doing, especially the building up of an industrial infrastructure, were enabling it to direct the flow of the benefits arising from R&D in US laboratories into its own manufacturing system.

Even Ergas, in his sophisticated discussion of national technology policies, treated each country as a block and did not consider flows of resources or benefits across national boundaries.[4] Despite some attempts to relate the development of technology-based industry to regional or urban forms, such as the work of Willoughby and Blakely on the biotechnology industry in California[5], the geographical dimension of science and technology policy is not well developed.

In work we have been doing on the distribution of Commonwealth R&D funds between states, we have found some uncertainty as to the reasons why it should be a matter for concern if a state gets less than its proportionate share. In federal systems it is usual for tension to arise over the demand for equity, or fair shares all round.[6] In the case of R&D it is often argued that concentration of effort is needed to achieve the most efficient utilisation of resources. It is commonly believed that some kinds of R&D need a certain minimum size or critical mass to be effective. There is no agreement as to how far this is applicable to all R&D, but there can be no doubt that some facilities are so big that not more than one state in a federal system can have one. In such cases, there is frank competition between states and open lobbying to secure the prize. A recent example from the United States was the semi-conducting super collider[7] and an obvious recent example from Australia is the Multi Function Polis, at least in the sense that the MFP concept is usually interpreted.

In the case of the MFP the scale of the proposed investment, together with the multiplier effect arising from it, is in itself enough to constitute a substantial regional benefit. For R&D funding schemes, however, the amounts in dollars are usually less. In this case the prize is not so much the Federal grants in themselves but rather the downstream benefits that are believed to arise from local R&D.

This is the assumption we examine here. It depends on the concept of regional appropriability, which is different from appropriability as that term is normally used. Appropriability usually refers to the capacity

of a firm to capture the benefits from its investment in technological change.[8] Ergas implies the same basic sense in extending the concept to appropriability by industry at a national level.[9] The assumption that economic growth in a region (such as a state in a federal nation) is caused or partly caused by R&D in that region underlies attempts to use R&D as a tool of regional development. If the assumption is valid, well and good — but if it is not, policies based on it may be ineffective or even counterproductive.

A PARADOX

Paradoxically, the question of regional appropriability is both well-known and neglected. On the one hand, it has in a sense long been a matter of common knowledge. Newspaper stories of Australian inventions lost to other countries are common. At times they are almost daily events. It is part of our national mythology or self image that we believe ourselves to have the ingenuity to invent things which others exploit. It seems that many other countries have similar self images. In the UK, for instance, the belief is common that we, the clever British, discovered or invented penicillin but they, the crass commercial Americans, made the profits from it.

In the scholarly literature, on the other hand, discussions of regional appropriability are surprisingly rare and scattered. We have failed to find it discussed in what are probably the two best books of portable size on the economics of innovation, both of which come from the UK: that by Coombs *et al.*[10] and that by Rothwell and Zegveld.[11] In the Australian literature, we have failed to find the point in the 1987 paper on *High Technology Industries in Australia* by the Economic Planning Advisory Council[12] or in the statement on *Technology Policy for the 1990s* by the TASC group at Wollongong,[13] or in the ASTEC paper, *National Purposes, Federal Government.*[14]

One paper which does discuss the leakage of the benefits from R&D across the national boundries is *Measuring a Country's Gains from Research* by Edwards and Freebairn.[15] Edwards and Freebairn, however, deal with rural research and they are careful to point out that their approach does not cover all classes of innovation. It covers process, marketing and organisational innovations aimed at reducing the cost of production of internationally traded commodities such as wool or wheat. It does not cover new product innovation: "to study the payoff to Australia from . . new products, extension of our analytical framework would be necessary" (p.4).

A group of three papers from the *American Economic Review* for 1988 is revealing.[16] The authors include some of the most respected American economists working on benefits from R&D and they deal with the topic at a sophisticated level, calculating rates of return and appropriability measures. They also deal with spillovers — that is, benefits from R&D which are reaped by parties other than those who performed the R&D. Both intra-industry and inter-industry spillovers

are considered. But the possibility of international spillovers is not considered — that is, the possibility of foreign firms being the beneficiaries of spillovers from American R&D is not taken into account.

This example helps to bring out some important features. If the argument of welfare economics is applied globally — that is, to the world as a whole — it may very well be the case that it is beneficial to let the results of American research be applied in Japanese industry. If Japanese industry is more efficient in doing so than American industry, world wealth will thereby be increased. The main objective of the US Government, however, is presumably to maximise the welfare of the US, since it is politically accountable to the US electorate, not to the world.

By extension of this argument, the concept of regional appropriability could well be considered the key concept in the economics of R&D for any government, whether national or state. On the other hand, it is also in a sense narrow and parochial. It considers only benefits which are, first, economic, and secondly, captured within the nation or state. Nobody, surely, would want to deny that there are benefits from research other than economic ones, or that the welfare of the world is important as well as the prosperity of the nation or state.

FACTORS AFFECTING THE CAPTURE OF BENEFITS BY A REGION

Some of the factors that bear on the ability of a region to capture the economic benefits of R&D are fairly obvious. Local manufacture of the new products is one, and it is sometimes recognised as a criterion for support of R&D. For instance, the criteria for grants under the WARD grants scheme include a preference for projects likely to lead to products which will be manufactured locally. It is a preference rather than a requirement. Because of the range of circumstances and possibilities to be accommodated, a requirement would not be appropriate.

Another factor is intellectual property. The importance attached to intellectual property matters as a factor in technology policy has increased a great deal in the last two decades. Twenty years ago, it was not widely recognised as a major factor; for instance, it does not figure in a major way in *Wealth from Knowledge,* a study of innovations in UK industry which won the Queen's Award in 1966 and 1967.[17] Now, however, it is clear that intellectual property matters are of the utmost importance.

The remainder of this paper is devoted to a more extended discussion of two further factors which, we suggest, are also important if benefits are to be captured in a region. One focusses on human resource aspects, the other on industrial linkages.

MORE AND LESS MOBILE BENEFITS

The *Wealth from Knowledge* study concluded that the effects of science on innovation take place in three main ways: first, through techniques;

secondly, through trained people; and thirdly, in embodied form, that is, in technologies which embody earlier scientific discoveries.[18] Of these three mechanisms it is clear that the first and third lead to benefits which are relatively mobile geographically, whereas the second is relatively immobile.

These considerations gain added force when one takes into account the trend in recent years towards globalization of technology-based industry.[19] The implications of globalization for the problem we are discussing are obvious. It means that manufacturing, and the economic benefits that arise from it, are not necessarily co-located with the R&D on which the manufacturing operation is based. Not only large multinational companies can move their operations around the globe; small companies, too, can establish operations overseas or form strategic alliances with partners in other countries.[20]

It is necessary at this stage to extend the discussion from R&D to the broader concept of science and technology. One of us has suggested elsewhere[21] that it is a fallacy to concentrate too exclusively on R&D. In jingle form, 'There's more to S&T than R&D'. Success in manufacturing requires a broadly and deeply skilled workforce. Such skills move less readily across borders than do the skills of a relatively small number of highly specialised research workers. Furthermore, this argument is not restricted to manufacturing. Services may, in some cases at least, depend on equally widely distributed skills and therefore be relatively immobile.

The concept of 'mission-oriented' and 'diffusion-oriented' approaches developed by Ergas[22] offers a way to articulate the arguments in more detail. Ergas distinguishes between the USA, the UK and France on the one hand and Germany, Switzerland and Sweden on the other, with Japan adopting a mixture of both strategies. The USA, the UK and France are said to adopt relatively centralised policies, with a high proportion of R&D spending being devoted to defence; the technologies which are emphasised include aerospace, electronics and nuclear; government R&D subsidies are concentrated on a relatively small number of large firms. Germany, Switzerland and Sweden, by contrast, are said to emphasise decentralised policies aimed at diffusing benefits throughout industry by such means as vocational education, industrial standardisation and industry-wide co-operative research laboratories.

As a way of classifying the approaches of different *countries,* this distinction raises more problems than it solves; thus, as Ergas concedes, the USA adopts diffusion-oriented approaches in agriculture and medicine, while on the other hand Germany and Sweden have important mission-oriented programmes. The distinction is, however, valuable as a way of classifying different kinds of *route* or *mechanism* by which economic benefits may be derived from science and technology.

Mission-oriented programmes, as Ergas points out, are claimed to lead to wider economic benefits through indirect or secondary effects which are spread more widely than the direct effects which accrue to

a relatively small number of beneficiaries. The extent of such secondary effects, however, remains very uncertain. Ergas comments that the few studies that have been carried out on these elusive phenomena "come to widely differing conclusions, frequently reflecting individual authors' views of the desirability of defence spending". The undesirable effect of crowding out other research efforts depends on the size of the system; it is relatively minor in the USA because of the sheer scale of the system but it is more serious in smaller systems, and could therefore be expected to be a major factor in Australia, and even more so in Western Australia. Further, and not mentioned by Ergas, there is the possibility of a brain drain of the relatively small number of highly specialised experts which a large R&D mission generates. Foreign economies may be better able to absorb and make good use of the specialist skills. To the extent that is so, the mission may be of benefit, albeit indirectly, to competitor countries.

Diffusion-oriented programmes, on the other hand, are relatively firmly rooted in the native soil. In particular, the great depth and breadth of human capital which heavy investment in the dual system produces is less likely to be transported rapidly to other places.

LINKS TO EXISTING STRENGTHS

Diffusion-oriented policies, by their very nature, exert effects which are relatively fixed geographically. The question therefore becomes how to extract from mission-oriented policies, which typify science and technology policy as usually understood, the maximum possible quantity of secondary benefits which do not drain readily across borders.

This is the crux of the problem, but it seems rarely to be addressed. Jevons[23] suggested that new technology is more likely to be successful in promoting economic development in a particular geographical region if it is linked to existing industrial strengths in that region. He referred to this as contexted technology. Such technology has a better chance to develop than uncontexted technology because local industry provides for it two things: first, an initial market, and second, something which is perhaps even more important, a test bed for further development. Frequent contacts between those developing a new product and those using it lead, in the case of engineering products, to continuous refinements which maintain the product range at the leading edge.

The role of sophisticated buyers is a relatively neglected factor in the technology policy literature, in line with the general underemphasis on pull factors in innovation. When Gomory makes the pointed comment that "the United States was the leading industrial power well before it became the leading scientific power",[24] he indicates that a healthy industrial environment is important for economically effective R&D. In particular, the work of von Hippel has drawn attention to the role of lead users in the success of many innovations.[25]

In the case of Western Australia it was suggested by Jevons[26] that the existing industrial strengths in mining and agriculture can act in this

way; for instance, remote sensing, arid land agriculture and salt-resistant plants are areas which might derive strength from such interactions. Other areas of technology such as solar or marine might benefit from the geographical size and location of the state.

A possible conceptual confusion may arise which it is important to clarify. The argument is still sometimes put that, for a state like Western Australia, it is better to build on existing strengths in mining and agriculture than to venture into risky new areas such as high technology. This is emphatically not the argument we are advancing here. Indeed, it rests on a false antithesis which obscures the way forward. What we are proposing is a strategy for a way to move into high technology. Our proposal amounts to saying that promising routes into high technology industry are likely to be found by looking for technologies which have applications in those areas of industry which are already strong locally.

A well documented example comes from Denmark.[27] The Danish economy traditionally rested on an agricultural base. In moving into technology-based manufacturing in recent years, it has been relatively successful in areas such as dairy equipment because in this area there is a strong local industry. Continuous close user/producer contacts have enabled Danish manufacturers to maintain a lead in the market.

In the geometrical analogy used by Ergas, the US approach is called shifting, because it shifts the emphasis of industrial activity into new areas arising from research, while the German approach is called deepening, because it strengthens existing areas of specialisation. Adopting the same analogy, the contexted technology strategy might be called diagonal, since it involves a combination of shifting and deepening. It is a combination and not a mixture since it implies a single strategy, not two strategies followed simultaneously.

These conceptual distinctions are of more than academic interest. To take just one example, the point we are making is not quite captured by the following statement in the October 1989 Report of the Prime Minister's Science Council:

> . . . it is apparent that R&D and technology strategies which attempt to emulate those of the highly developed OECD countries are unlikely to be successful in Australia. Instead there are opportunities for increased investment of R&D in the low and medium technology intensive sector, where our industrial strength lies.[28]

What we are arguing for here is not concentration on low and medium technology intensive sectors but concentration on high technology applications to sectors which traditionally have been characterised by relatively low technology intensity.

It maybe that the effects of linkage to dominant industries are exerted through the provision of 'complementary assets' much as described by Teece[29] but applied at the level of the region rather than that of the firm. In discussing appropriability by firms, Teece points out that successful commercialisation of an innovation usually depends on using

that innovation in conjunction with other capabilities or assets. For instance, the ability to manufacture competitively may be needed, or services such as marketing, distribution and after sales support may have to be provided. Complementary technologies will also in many cases be needed.

The concepts of linkage to dominant industries and of the provision of complementary assets offer possibilities for enriching and improving the assessment of the likely commercial potential of innovations. Further specification of the nature and mode of operation of these effects is an objective of empirical work on the evaluation of innovations in which we are now engaged.

CONCLUSIONS

It is the fashion nowadays to talk about knowledge-based industry but the familiarity of this expression should not hide the fact that there is much that is not yet known about *how* knowledge leads to wealth. A clearer and more detailed understanding of this process might yield a clearer indication about what kinds of knowledge lead to wealth. Such a deeper and more comprehensive understanding might provide a firmer basis for discussing the geographical question which asks *where* the benefits will arise.

In this paper we have suggested four factors which bear on the ability of a region to appropriate the economic benefits from science and technology. They are, first, local manufacturing; second, intellectual property considerations; third, a broadly skilled workforce; and fourth, contexted technology, that is, technology which links into existing industrial strengths.

Our minds have been focussed on the problem of regional appropriability by working in Perth, Western Australia, a city which claims or admits to being the most isolated city in the world. Facing the problems in an acute form concentrates the mind wonderfully! The problem is not, however, unique to our location. Western Australia is relatively small and isolated in Australia — but equally, Australia is small and isolated in the world. We suggest there may be implications in our arguments for current policy in Canberra as well as in Perth.

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