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THE ROLE OF TECHNOCAL CHANGE
IN AUSTRALIAN ECONOMIC PERFORMANCE

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DISCUSSION PAPER NO. 166

March 1987

G.P.O. Box 4, Canberra 2601, Australia
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THE ROLE OF TECHNOLOGICAL CHANGE
IN AUSTRALIAN ECONOMIC PERFORMANCE*

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DISCUSSION PAPER NO. 166
March 1987

ISBN: 0 949293 81 4
ISBN: 0725 430X

* Revised Version of the paper presented to the Conference: Recent Australian Economic Growth, held in honour of Professor H.H. Grun, 24-26 November 1986, ANU.

** The authors wish to express their appreciation of the library and secretarial support provided by the Office of the Economic Planning Advisory Council (EPAC) during the preparation of this paper.

It should be noted, however, that the views expressed in the paper are those of the authors and should not be attributed to the Office of EPAC or the Australian Science and Technology Council (ASTEC).
ABSTRACT

Comparisons of growth in total factor productivity with other OECD countries indicate that Australia's economic growth has relied more heavily on inputs of labour and capital and correspondingly less on improvements in technology. At the same time, technological changes elsewhere have had important, and recently negative, effects on the Australian economy: improvements in agricultural productivity and the less resource-intensive nature of industrial growth have contributed to a sharp decline in the Australian terms of trade.

To diversify Australia's export base, the manufacturing and service sectors need to be more skill and technology based, but Australia's technological performance has lagged seriously behind other OECD countries. The observed weaknesses in a wide range of indicators of research and innovation effort cannot be attributed simply to differences in the pattern of production, but can be linked to an unfavourable environment for innovation.

Australia's relative isolation and the legacy of inward looking industry policies have reduced competitive pressures. The availability of protection has allowed sectional interests to become entrenched, hindering the rapid adoption of new technology. At the same time, weak linkages between the largely publicly funded education and research systems and industry have led to relative underinvestment in commercially oriented training and research.

These weaknesses are capable of correction by well-directed policies. Since 1983, a new and consistent pattern of policies for industry and technology has begun to emerge, including macro-economic policies to improve incentives for investment; fiscal incentives for R&D and venture capital; fostering closer linkages between education, research and industry; integrating the Australian economy more closely with competitive world markets; and reviewing work and management practices which may inhibit productivity at the enterprise level. There are some early and encouraging signs of a positive response to this more positive direction of policy.
SUMMARY

This paper seeks to draw together the implications of technological change in Australia and elsewhere for economic performance and policy formation, against the background of the currently unsustainable balance of trade and the need to maintain Australia's recently improved competitiveness.

Technological change is interpreted to be the combination of new or improved products or processes which increase the productivity of both labour and capital (total factor productivity)

- In comparison with other OECD countries, Australian growth has relied more heavily on increased inputs of labour and capital and correspondingly less on advances in technology.

At the same time, technological changes elsewhere have had important, and recently negative, effects on Australia.

- Dramatic improvements in agricultural productivity, combined with restrictions on international trade, have diminished the markets for Australia's agricultural exports.

- Technological changes are also transforming the manufacturing and services sectors; world economic growth is becoming less natural resource intensive, reducing market prospects for mineral-based exports.

- Rapid technological advances by the newly industrialising countries of East Asia have progressively eroded the competitiveness of Australia's post-war manufacturing base.

To compete on world markets Australian manufacturing and services will need to be more skill and technology based.

Although the pressure for better technological improvements has mounted during recent years, Australia's performance has lagged badly behind other OECD countries.

- Section 3.1 presents a range of indicators of technological performance, including public and private research and development outlays and the balance of trade in high-technology products.

- While Australia compares well in terms of basic research, there is a marked weakness in the ability to take commercial advantage of new discoveries.
- The differences in research and innovation effort cannot be attributed simply to differences in the pattern of production.

Three important features of economies which are likely to determine the pace of innovation and technical improvements are:

- **Demand,** which provides the incentive to innovate: sectors of production catering for large, sophisticated markets are more likely to record a relatively rapid rate of technological change;

- **Technological capability,** which determines the ability to generate and/or take advantage of new innovations: this will depend on the standard of educational and research institutions and the effectiveness of interactions between them and industry;

- **Industrial structure,** which can determine the incentive and willingness to innovate: the strength of competitive pressure will determine, to a significant extent, the incentive for firms to apply new technology.

  - The size of firms, or their ability to co-operate, can be important in determining their capacity to bear the risks of R&D efforts.

  - The flexibility of the industrial structure and the workforce can enhance the ability of countries to take advantage of technological developments.

Australia does not measure up well in terms of these criteria.

- Its small population and geographical isolation constrain the size of the domestic market. The legacy of inward-looking industry policies has reduced competitive pressure and limited the awareness of evolving world market patterns and tastes.

- The protection of a wide range of industries has permitted sectoral interests to become strong, entrenching resistance to structural changes associated with the introduction of new technology.

- Weak linkages between educational institutions and industry have led to relative underinvestment in commercial or scientifically oriented training. Mid-career skill formation is less than adequate and rigid occupational structures

...often fail to provide incentives for skill upgrading.

These characteristics help to explain Australia's relatively weak technological performance during recent decades.

- Fortunately, most of these weaknesses are amenable to correction by consistent and well-directed policies;

- During the last few years, there has been considerable progress towards the evolution and implementation of sound policies for industry and technology.

Important ingredients of recent policies include:

- Macro-economic policies to enhance competitiveness and improve incentives for the investment which is needed to modernise Australia's capital stock and to respond to new trading opportunities.

- Policies to encourage the efficient transfer of technology, with an emphasis on improved techniques of management.

- Powerful fiscal incentives to encourage private sector research, stressing the need for closer links between research institutions and industry.

- Education and training policies have also sought to forge closer links between educational institutions and industry and to raise participation rates in relevant disciplines.

- Industry policies to integrate the Australian economy more closely with world markets, including a gradual reduction of protective and regulatory barriers to enhance the incentive for innovation.

- Strong encouragement is being given to reviewing management and work practices as well as occupational structures to help increase the flexibility of industrial structures and work patterns.

There are some early and encouraging signs of a positive response to a more coherent set of outward-looking policies. Nevertheless, a long and sustained effort will be needed to make good the past deficiencies in technological performance.
1. INTRODUCTION

The recent, particularly sharp decline in the terms of trade is causing severe economic difficulties for Australia. The associated widening of the current account deficit and the rapid growth of external debt require a significant adjustment task for the remainder of the decade. The scope for economic growth and reducing the still unacceptably high rate of unemployment will be limited by the need to bring about a significant and sustained improvement in Australia's balance of trade in goods and services (1).

The recent external shock to our economic system has, nevertheless, had one important benefit - by drawing attention to the continuing vulnerability of the Australian economy to factors well beyond our control, the difficult trading environment has focussed discussion on the need to diversify the base of the Australian economy.

During the past decade, there has been a gradual shift of public opinion in favour of integrating the Australian economy more effectively with world markets. This emerging strategy is in sharp contrast to the past pattern, where the costs of inefficiencies in the manufacturing and service sectors were borne by the more efficient primary export sectors.

The current low prices and the bleak medium-term outlook for almost all of Australia's traditional exports have, made it abundantly clear that we cannot defer, yet again, the difficult decisions which are needed for structural change. There is widespread acceptance of the need to become more competitive in all of our productive activities.

The recent depreciation of the Australian dollar (A$), accompanied by remarkable wage restraint, has brought about a record level of price competitiveness for Australia's manufacturing and service sectors. Successful economic adjustment depends on Australia's ability to take advantage of this opportunity and to maintain this new-found competitiveness.

The desirable long-term strategy for growth is to maintain competitiveness, consistent with an adequate incentive to invest (2) and a gradually rising standard of living for Australia's workforce. This will require sustained improvements in productivity. Some improvements can be obtained by a reallocation of resources between sectors, but substantial sustained gains will require improvements in technology. The challenge facing a relatively small country like Australia has been summarised by Walsh (1986, p33) as follows:

'... it is the new high technology fields which offer the most scope for economic growth: furthermore it is

In order to promote the effective development or acquisition of new techniques and their application to productive processes as well as the development and marketing of new products, it is helpful to understand the importance of technological change in the process of worldwide economic growth and the implications of technological changes here and elsewhere for Australia's past performance. These issues are dealt with in Section 2.

Section 3 shows that, despite the importance of technology in determining economic performance, Australia's efforts to develop new technology, or to apply existing technology, do not compare favourably with other developed countries. In order to improve technological performance, it will be important to understand the nature of the process of technological change and the forces that drive the process. Section 4 presents a brief analysis of these and comments on why some countries appear to perform consistently better than others.

Section 5 suggests that Australia has most of the characteristics which tend to lead to poor technological performance. However, this need not be a cause for long-term despondency. As outlined in Section 6, the poor legacy of past policies is being increasingly widely recognised and many of the policies required to promote more rapid technological improvements have been recently put in place.
2. TECHNOLOGY AND GROWTH

'[A] sustained high rate of growth depends upon a continuous emergence of new inventions and innovations, providing the bases for new industries whose high rates of growth compensate for the inevitable slowing down in the rate of invention and innovation, and upon the economic effects of both, which retard the rates of growth of the older industries'


2.1 THE IMPORTANCE OF TECHNOLOGICAL CHANGE

This paper adopts a quite broad definition of technology; technological change involves much more than the invention and production of new goods or services such as the micro-chip or electronic funds transfer. It also involves much more than the adoption of new mechanical processes in order to improve the quantity or quality of output produced from given resources.

Technological change is interpreted to encompass improvements in the organization of production. In many cases, such improvements can yield dividends greater than improvements in the process of transferring or combining materials: this is reflected by the increasing attention being paid to management processes such as new approaches to labor management. More effective management of the work force, which allows a more effective use of skills (e.g. by changes in inefficient occupational structures) in part of the process of technological change which can bring about a more effective use of scarce resources.(3)

Efforts to assess the contribution of technology to economic growth, which date back to the seminal works by Abramovitz (1956) and Solow (1957), have sought to distinguish between growth attributable to increasing growth of inputs and the more efficient use of these inputs. The latter can also be described as changes in total factor productivity, (TFP); changes in this measure capture the effects of all the means of bringing about technological improvements.

Perhaps the best-known and most ambitious efforts to measure the contribution of improvements in total factor productivity (and the contribution of various influences to such improvements) were carried out by Denison (1962 and 1967). Such work (particularly international comparisons) is fraught with difficulty, partly due to problems in the measurement of capital. Nonetheless, Denison's work and follow-up studies have shown that the component of growth which cannot be attributed simply to increases in the factors of production is large - often over half. Moreover, the contribution of improvements in total factor productivity has varied considerably between countries.

Denison (1967) found that 42 per cent of US economic growth during the 1950s could be attributed to improvements in total factor productivity (i.e. improved efficiency in the use of labour and capital). By comparison, almost two-thirds of North-West European countries' growth was estimated to be attributable, on average, to improved TFP; a similar proportion has been estimated for Japan.

This evidence suggests that efforts to improve the efficiency with which factors of production are used can have an important bearing on long term economic performance. Gruen (1986) and IAC (1982) have summarised the evidence on total factor productivity performance in Australia.

Studies by Robertson (1978), Kaspura and Waldon (1980) have sought to isolate the contribution of TFP improvements to Australian economic growth. As noted by the IAC (1982):

'The results from these studies are similar. They point to the fact that total factor productivity growth is important in that it accounted for about one third of Australia's post-war growth. This share of total growth is similar to that of the US, but somewhat lower than that of most European countries.'

These studies suggest that, in aggregate terms, Australian economic performance has been relatively factor-intensive and has benefited correspondingly less from technological improvements (4). This is one of the factors which can help explain the relatively mediocre performance of the Australian economy in the post-war years as discussed by Gruen (1986) and by Bowrick and Nguyen (1986).

Australia's unimpressive productivity performance in recent years and the present economic difficulties are not attributable entirely to relatively slow improvements in the use of capital and labour. While technological developments have contributed greatly to the long-term economic history of Australia, the nature and pace of post-war technological changes elsewhere in the world have had important, and often negative, implications for Australia.

2.2 WORLDWIDE TECHNOLOGICAL CHANGES AND IMPLICATIONS FOR AUSTRALIA

Much of the rapid growth of incomes per head in both Australia and Argentina during the 19th Century can be attributed to the burgeoning demand for both food and raw materials derived from extensive temperate agriculture. This growth in demand was created by the technological breakthroughs of the industrial revolution which began in England and spread through Western Europe and North America. The sharply reduced transport costs due to improvements in shipping technology also made an important
contribution to the competitiveness of these Southern Hemisphere producers.

The sharp divergence in the fortunes of Australia and Argentina since 1900 are due to many factors. It is important to note, however, that Duncan and Fogarty (1984) attribute significant importance to the substantially greater effort and resources devoted in Australia to improving agricultural production technology (2).

The rapid growth of the Japanese economy during the post-war period is largely attributable to the increases in total factor productivity noted above. These increases were, to a large extent, brought about by Japan’s adoption of an increasingly wider range of technologies in many cases through the acquisition and (perhaps equally importantly) the subsequent enhancement of techniques first applied elsewhere. The resulting strong performance of the Japanese economy generated the massive demand for fuel and minerals which facilitated the considerable diversification of Australia’s exports away from an extremely high dependence on agricultural products in the early post-war years. Australia’s ability to respond to this demand benefited greatly from improved techniques of extracting and transporting mineral resources.

Other technological changes have not been so beneficial to Australia. The dramatic improvements in agricultural technology in the post-war years have reduced the agricultural import requirements of Europe and of the world’s poor countries. Even the most densely populated poor countries have achieved, or can shortly achieve, food self-sufficiency. While Western Europe’s agricultural output is being artificially boosted by heavy subsidies, it is unlikely to become a significant importor, even if existing distortions are removed. The major remaining agricultural deficit area is the USSR; but, it is quite possible that its deficits will be eliminated progressively during the coming decades by policy improvements to encourage better use of good agricultural resources. Although agricultural trade will remain important, it is likely to be more specialised and far less dominated by the low value-weight products which currently represent the bulk of Australia’s agricultural exports: this suggests the need for R&D efforts to encourage diversification and specialisation of agricultural production.

Technological changes, recently based on advances in microelectronics, information transmission, robotics, biotechnology and new materials are also transforming the manufacturing and service sectors. In adapting to these new products and processes, the pattern of world economic growth is becoming less natural resource intensive (6). This phenomenon has been reflected by the slower growth of Japanese demand for raw materials relative to overall economic growth. The expected rapid growth of East Asian economies during the next few decades can offset, to some extent, the slower growth of present sources of demand. On the other hand, the increasing adoption of improved mineral exploration, extraction and handling techniques by Australia’s developing country competitors (such as Brazil) will continue to make the world mineral markets extremely competitive.

As discussed by FitzGerald and Urban (1986), this combination of factors has led to a situation of over-supply in almost all of the world commodity markets of importance to Australia, contributing to a long-term decline in our terms of trade at a rate of about 1 per cent per year since the turn of the century.

Recognition of these trends has underlined the desirability of diversifying Australia’s exports in order to participate more fully in the fastest growing areas of world trade, namely elaborately transformed manufactures and services. Technological capability is crucial in these fields.

While the rapid adoption of new technologies by the newly industrialising countries (NICs) of Asia will help to boost demand for our traditional exports, the process will bring pressure to bear on more and more of Australia’s present manufacturing and service activities. Australia is already uncompetitive in products with a heavy reliance on unskilled and semi-skilled labour. In the past, much of this work has been done in Australia and other developed countries for quite some time. However, the rapidly improving educational base of the East Asian countries and the continuing improvements in communication are leading to an acceleration of technological catch-up.

The factors which are contributing to faster technological diffusion are also leading to shorter ‘product cycles’, shortening the lag between innovation and mass production of successful products. This tendency was recognized by Vernon (1966), who applied the concept of the product cycle to international trade and investment. He postulated that, as a product matures, standardisation tends to occur. Lowering production costs then takes the place of concern about product characteristics; differences in labour costs favouring the location of production in lower skilled and lower wage cost areas. More recently, Rosenberg (1982) has remarked:

‘Although abundant unskilled or semi-skilled labour may offer only limited opportunities in the early stages of new-product development (when skill requirements are typically high), they may offer much greater cost advantages when the product matures and the production technology has stabilised’ (7).

In these circumstances, it is not likely that there will be any set of products from Australia’s manufacturing or services sectors which can be expected to retain long-term comparative advantage. To compete on world markets,
particularly with lower labour cost nations in our region, our manufacturing and services sectors will need to keep evolving. They will need to become increasingly specialised and exports from these sectors will need to be based on newly-developed Australian technologies or on Australia's ability to acquire and adapt technology NIC competitors.

To sum up, the accelerating pace and diffusion of technological change around the world underline the need for rapid technological change to maintain competitiveness in all the sectors of the Australian economy. The first step in assessing the prospects for responding to this challenge is to look at Australia's recent efforts in terms of improving technology.

3.  AUSTRALIA'S TECHNOLOGICAL PERFORMANCE

3.1  THE RECENT RECORD

It might be argued Australia's relatively weak aggregate total factor productivity (TFP) performance reflects differences in economic structure. In particular, it may be seen as an inevitable result of Australia's natural resource-based economy. An abundance of natural resources may lead to concentration on their exploitation rather than developing efficient manufacturing and services on developing efficient manufacturing and services sectors. In order to address this issue, it is necessary to look at sectoral performance; although a full sectoral analysis of Australia's relative TFP performance is precluded by a lack of readily available data, some useful comparisons can be made for the manufacturing sector.

Tables 3.1 and 3.2 present international comparisons of both labour productivity and TFP growth in Australia's manufacturing productivity growth performance. Australia was weak during the 1960s and early 1970s. Australia improved its performance over the period 1973-1980, with both labour productivity and TFP growth in manufacturing exceeding that of Canada, the US and the UK. The Bureau of Industry Economics (1985) suggested that this was due to labour-shedding in Australian industry during a period of rationalisation, particularly between 1973-74 and 1976-77, which occurred partly in response to the 25 per cent across-the-board tariff cut in 1973. An additional factor was the oil price shock on the industrial economies of the first oil price shock on the industrial economies.

Low TFP performance may be due to relatively poor innovation performance. A recent OECD review of science and technology in Australia (OECD, 1986a) suggests that Australia has been disadvantaged by a low level of innovation. This assessment is based on international comparisons of a range of science and technology indicators which, while only providing a partial picture, present a consistent account of Australia's relative position.

The level of expenditure on research and development (R&D) is generally viewed as an important determinant, or an 'input' indicator, of innovation performance. Even with an important bearing on its ability of R&D will have an important bearing on its ability to adopt new technologies. The evidence of performance by the Office of EPAC (1986 #19 and 1987 #25), Dwyer and Alchin (1986), the OECD (1986), the Australian Science and Technology Council (ASTEC) (1985) and the Australian Industry and Technology
Table 3.1
Labour Productivity Growth in Manufacturing (a)
(Average annual percentage rates of growth and rankings)

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<tr>
<td>Canada</td>
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<td>4.2 (5)</td>
<td>5.2 (3)</td>
<td>1.7 (5)</td>
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<tr>
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<td>3.1 (7)</td>
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<td>12.1 (1)</td>
<td>6.6 (1)</td>
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<td>7.6 (2)</td>
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<tr>
<td>Germany</td>
<td>7.6 (1)</td>
<td>5.9 (3)</td>
<td>5.0 (4)</td>
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<td>UK</td>
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<td>3.7 (6)</td>
<td>2.9 (7)</td>
<td>3.6 (4)</td>
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</table>

(a) Labour productivity is defined as gross product at constant prices per man-hour.

(b) Average annual growth from 1954-55 to 1981-82 is 4.1 per cent.

Source: Bureau of Industry Economics (1985) (DIE estimates for Australia; OECD estimates for other countries).

Table 3.2
Total Factor Productivity Growth in Manufacturing
(Average annual percentage rates of growth and rankings)

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<td>UK</td>
<td>1.2 (5)</td>
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<td>3.0 (5)</td>
<td>0.1 (7)</td>
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<tr>
<td>Australia (a)</td>
<td>2.2 (3)</td>
<td>1.7 (7)</td>
<td>1.0 (1)</td>
<td>2.7 (4)</td>
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(a) Average annual growth from 1954-55 to 1981-82 is 2.1 per cent.

Source: Bureau of Industry Economics (1985) (DIE estimates for Australia; OECD estimates for other countries).
Council (AITC) (1985). A brief account of this evidence is presented below.

Among OECD countries, Australia has a low proportion of gross domestic expenditure on R&D (GERD) as a proportion of GDP. As shown in Table 3.3, Australia's GERD/GDP ratio is 1.03 per cent, which is not only well below that of large R&D performers like the US and Japan (with a median of 2.54 per cent in a group of five countries), but is the lowest ratio within the medium R&D group consisting of seven countries (with a group median of 1.70 per cent, excluding Australia). Australia's performance is also below that of a number of small R&D countries, such as Norway, Finland and Denmark. Australia's GERD/GDP ratio declined consistently between 1968-69 and 1983-84 (from 1.36 to 0.96 per cent) with some recovery in 1984-85 to the level around 1980.

An important feature of Australia's R&D effort is that while the proportion devoted to basic and applied research is quite comparable with the OECD average, the corresponding proportion for experimental development is strikingly low (see Chart 1).

Another characteristic of Australia's R&D performance is the very low share of R&D expenditure by business (private and public) enterprises (BERD) in total expenditure on R&D (GERD) (6). During the decade to 1983-84, business enterprises provided about 21 per cent of R&D funds and carried out about 22 per cent of R&D. Although these proportions improved to reach 28 and 30 per cent, respectively, in 1984-85 (Table 3.3), these shares are still well below those in other OECD countries; the corresponding proportions (for the latest available year) for the US are 49 per cent and 71 per cent, 65 per cent and 64 per cent for Japan, with 54 and 59 per cent being the median ratios for medium R&D countries, and 32 and 36 per cent the median ratios for small R&D countries. Australia also compares unfavourably in terms of the growth trend of BERD in the OECD as a whole, BERD grew at about 5.5 per cent per annum over the period 1975-1981, compared with 1.6 per cent per annum in Australia. There has, however, been a significant improvement in level of BERD in Australia since 1981, as shown in Table 3.4.

As noted by ASTEC (1985), the level of public investment in non-defence R&D in Australia (at 0.70 per cent of GDP) compares favourably with that in medium R&D industrial countries (at 0.63 per cent of GDP). By contrast, private sector funding of R&D in Australia has been about 0.21 per cent of GDP compared with a median figure of about 0.35 per cent of GDP among medium R&D OECD countries. Australia's figure is also less than the median of 0.26 per cent of GDP for the low R&D countries (9).

International differences in economic structure can only account for a part of Australia's relatively low level of R&D as a proportion of GDP and the low contribution of

![Chart 1](chart1.png)

Source: OECD (1986a)

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<th>Year</th>
<th>Private Sector</th>
<th>Public Sector</th>
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<td>1975-77</td>
<td>216</td>
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<td>1978-79</td>
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<td>1981-82</td>
<td>240</td>
<td>51</td>
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<td>1984-85</td>
<td>387</td>
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<td>443</td>
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Source: ABS (Cat. No. 8104.0).
business enterprise (and particularly private sector) R&D expenditure in the total R&D effort. It is sometimes argued that Australia's R&D performance merely reflects the relative natural resource intensiveness of its economy. Agriculture and mining might be seen as inherently low R&D sectors, with homogeneous products and processes in which, relative to manufacturing and services, a given amount of R&D effort is more widely applicable across those sectors. The greater homogeneity of products and processes and the fact that producers in agriculture typically do not have the resources to undertake private research tends to inhibit research by individual producers. Producers could consider research as an association, but it is often more convenient to leave research to public institutions. At the same time, the government can more readily identify research needs in those sectors and undertake the research itself, knowing that the benefits can be applied widely (10).

Australia's R&D effort in agriculture more than reflects the contribution of that sector to the economy's output relative to other countries. Australia spends 17.5 cents on R&D in agriculture for every $100 of gross product in that sector, a much higher figure than other industrial countries: for example, a median figure of 6.5 among a group of thirteen other countries, with about 2.5 for the US, Germany and Sweden, about 7.5 for the Netherlands and Norway, and 9.7 for Canada. The only other country in the group with a higher figure is New Zealand at 26.0 (11).

At the same time, as shown in Table 3.5, Australia's R&D intensity (the ratio of R&D expenditure to value added) in manufacturing is only 0.8 per cent compared with about 8 per cent for the US, about 5 per cent for Japan and about 3 per cent for Canada and Norway. Of the sixteen countries for which figures are readily available only Portugal and New Zealand rank lower than Australia. The poor level of private sector R&D in Australia has particularly serious negative implications for the manufacturing sector, since it is more dependent on private R&D funding than other sectors.

Australia's R&D performance in the manufacturing sector is also out of line with world trends. During the decade to 1983, the share of manufacturing in GDP has declined in most OECD countries including Australia. In most cases, this has been accompanied by a greater R&D intensity of manufacturing as these countries have sought to specialise in relatively high-technology and skill-intensive activities, moving away from activities in which lower labour-cost NICs are becoming increasingly competitive. In contrast, the R&D intensity of Australian manufacturing has remained fairly constant. Private sector R&D intensity in manufacturing actually declined from 1.3 per cent in the late 1960s and early 1970s to 0.7 per cent in 1983-84 (Table 3.6) (12). Once again, this contrast cannot be explained by the composition of the Australian economy. It is also worth noting that Norway, commonly regarded as a

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<td>6.9</td>
<td>6.8</td>
<td>8.1</td>
<td>9.3</td>
</tr>
<tr>
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<td>4.2</td>
<td>4.9</td>
<td>5.4</td>
</tr>
<tr>
<td>Germany</td>
<td>3.3</td>
<td>4.1</td>
<td>4.9</td>
<td>5.4</td>
<td>5.7</td>
</tr>
<tr>
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<td>4.3</td>
<td>5.7</td>
<td>6.6</td>
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<td>4.8</td>
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<td>6.6</td>
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<td>1.4</td>
<td>1.7</td>
<td>1.8</td>
</tr>
<tr>
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<td>1.3</td>
<td>1.9</td>
<td>2.6</td>
<td>3.1</td>
</tr>
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<td>4.1</td>
<td>5.5</td>
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<td>3.8</td>
<td>4.2</td>
<td>7.4</td>
</tr>
<tr>
<td>Denmark</td>
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<td>2.1</td>
<td>2.4</td>
<td>2.7</td>
<td>7.4</td>
</tr>
<tr>
<td>Norway</td>
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<td>2.4</td>
<td>2.7</td>
<td>3.0</td>
<td>7.4</td>
</tr>
<tr>
<td>Finland</td>
<td>1.4</td>
<td>1.8</td>
<td>2.1</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Portugal</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>New Zealand</td>
<td>.</td>
<td>.</td>
<td>.</td>
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<td>.</td>
</tr>
</tbody>
</table>

(a) Measured by R&D expenditure as a percentage of value added
(b) Nearest year depending on availability

Source: OECD (1986b); AITC (1985).
Table 3.6
Private R&D Expenditure compared with New Fixed Capital Expenditure (NFCE) and Value Added: Manufacturing and Other Industries, Australia

| Year | Manufacturing | | | | Non-manufacturing | | | |
|------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|      | R&D expend. $m, 1979-80 NFCE | $ of value added | R&D expend. $m, 1979-80 NFCE | $ of value added |      |      |      |
| 1968-69 | 251.2 | 9.4 | 1.3 | 13.3 | 0.3 | .01 |
| 1973-74 | 322.1 | 15.0 | 1.3 | 87.4 | 1.8 | .10 |
| 1976-77 | 164.8 | 7.1 | 0.8 | 104.9 | 1.9 | .10 |
| 1978-79 | 173.1 | 6.5 | 0.8 | 95.0 | 1.4 | .09 |
| 1981-82 | 163.0 | 4.8 | 0.8 | 102.4 | 1.1 | .09 |
| 1983-84 | 153.5 | 7.5 | 0.7 | 117.5 | 1.6 | .10 |

(a) The 1968-69 figure relates to the mining sector only.
(b) Relates to R&D expenditure by public and private non-manufacturing enterprises.
(c) Expressed as a percentage of New Fixed Capital Expenditure by private enterprises so as to exclude public works etc.
(d) Value Added for non-manufacturing derived from Australian National Accounts.

Source: AITC (1985).

natural resource-based economy, has recorded both a substantially higher manufacturing R&D intensity than Australia and an increasing trend over time.

The relatively low R&D intensity of Australian manufacturing partly reflects the low proportion of the sector engaged in 'high technology' production, with much of Australia's industry devoted to simply transformed manufactures. International comparisons of industry structure can be made by drawing on the OECD's ranking of industries according to their R&D intensity and their grouping into high, medium and low intensity categories (13). As shown in Table 3.7, Australia has a low proportion of high R&D intensity industries in manufacturing, which account for 7.4 per cent of production manufacturing, which account for 7.4 per cent of production compared with an average of 11.0 per cent for the eleven countries making up the basis of the OECD's intensity groups. Canada and Belgium have a lower proportion at around 5.5 per cent. Australia's proportion of medium R&D intensity industries is approximately the same as the group average at around 32 per cent, but its low R&D intensity proportion is a little higher (62 per cent compared with 57 per cent).

These differences between countries in industry structure influence the relative R&D intensity of the manufacturing sector as a whole. As indicated in Table 3.7, Australia's industry structure in terms of R&D intensity accounts for 16 per cent less business R&D than the average for the countries considered. With BERD/GDP in Australia being 79 per cent below the average, this highlights the inadequate input of business R&D in manufacturing.

Between the mid-1970s and early 1980s, R&D expenditure in Australia's manufacturing sector also failed to keep pace with the level of investment, despite the decline in investment performance. Manufacturing R&D expenditure declined from 15 per cent of investment in 1973-74 to about 5 per cent in 1981-82, but this was due to a faster larger real decline in investment than the decline in R&D expenditure. In contrast, the increase in the non-manufacturing ratio of R&D expenditure to investment in recent years reflects a real increase in R&D effort relative to investment (14).

It might be expected that Australia's innovative performance relative to other countries should also be reflected in 'output' indicators such as the level of patent activity. While there are serious difficulties in interpreting data on patents, it has been suggested in some studies that Australia has a relatively low level of patent activity; for example, see Johnston and Hartley (1986). On the other hand, the OECD suggests that, compared with its low relative research intensity, Australia has a high propensity to patent given the size of its industrial economy, as measured by domestic patent applications as a proportion of domestic product by industry. This is also true of New Zealand, Austria and Finland (15). Australia's
Table 3.7
Manufacturing Industry Structure by R&D Intensity of Industry

<table>
<thead>
<tr>
<th>Country</th>
<th>Share of manufacturing production by R&amp;D intensity (a)</th>
<th>Relative effect of industry structure on R&amp;D intensity (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Japan</td>
<td>13.0</td>
<td>30.9</td>
</tr>
<tr>
<td>Germany</td>
<td>11.5</td>
<td>28.8</td>
</tr>
<tr>
<td>UK</td>
<td>11.9</td>
<td>29.4</td>
</tr>
<tr>
<td>Italy</td>
<td>11.5</td>
<td>30.9</td>
</tr>
<tr>
<td>France</td>
<td>11.0</td>
<td>29.6</td>
</tr>
<tr>
<td>Netherlands</td>
<td>11.9</td>
<td>23.6</td>
</tr>
<tr>
<td>USA</td>
<td>10.4</td>
<td>32.2</td>
</tr>
<tr>
<td>Sweden</td>
<td>9.8</td>
<td>28.5</td>
</tr>
<tr>
<td>Australia</td>
<td>7.4</td>
<td>31.7</td>
</tr>
<tr>
<td>Belgium</td>
<td>6.5</td>
<td>33.6</td>
</tr>
<tr>
<td>Canada</td>
<td>6.4</td>
<td>27.7</td>
</tr>
</tbody>
</table>

(Average) 11.0 32.0 57.0 1.00

(a) High, medium and low R&D intensive industries are as defined by OECD.
(b) Relative propensity of industry groups to conduct R&D (average R&D intensity per unit of output for all countries) over 1970 to 1980 are: high 4.64; medium 1.0; and low 0.30. Summing the products of industry share of country output and the relative propensity of that industry group to conduct R&D provides a measure of the contribution of the industry structure to the country’s R&D performance.

Source: AITC (1985).

share of world patents (1.2 per cent on the basis of external patent applications) is well below the share of the world's published scientific papers that it originates (4.5 per cent). As indicated in HAPC (1986 #19), this might not suggest that Australia’s level of innovation is not sufficient to capitalise fully on local research.

An indication of the extent and direction of international technology transfers can be obtained from available data on technology transfers, focusing on the payments and receipts from the sale of technology, for example by means of transfer of patents, licences, know-how, or technical assistance agreements. Provision of know-how typically amounts to 17.4 per cent of a country’s export earnings in manufacturing; in Australia, the corresponding figure was 18.3 per cent. In 1984-85, the technological balance of payments incurred a deficit of $36.2 billion, compared with surplus of $12.6 billion. This is a ratio of 2.73. The larger than normal deficit in the trade in technology was largely due to the failure to generate an increase in receipts from exports of technology in the 1980s, resulting in a cumulative deficit of $12.6 billion.

Imported technology can complement indigenous technology to improve a country’s performance and may also substitute for locally conducted R&D, as found in AITC (1985). However, as noted in AITC (1985), this does not appear to have been the case in Australia. The decline in the number of locally conducted R&D is not accompanied by a compensating increase in imports of technical know-how (since the payments to imports of technology embodied in equipment.

The low technological base of Australian industry relative to most industrialised countries is also reflected in Australia's poor balance of trade in technology-based products compared with OECD countries in terms of per capita value of technology-based exports as well as the ratio of exports to imports in technology-based products. In terms of the indicators, Australia's position declined from 1978 through 1983, but this was not followed by a fall in 1984. The low R&D intensity of Australia's manufacturing exports highlights its poor past performance, relative to other products, in world trade in high-technology products (Table 3.9). Compared with the OECD countries, Australia has the lowest proportion of high R&D
Table 3.8
Payments and Receipts for Technical Know-How
by Business Enterprises: Australia

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Exports (a)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receipts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>8.8</td>
<td>19.5</td>
<td>23.3</td>
</tr>
<tr>
<td>All Industries (a)</td>
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<td>17.4</td>
<td>36.2</td>
</tr>
<tr>
<td>Payments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
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<td>107.1</td>
<td>144.7</td>
</tr>
<tr>
<td>All Industries (a)</td>
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<td>130.0</td>
<td>162.6</td>
</tr>
<tr>
<td><strong>B. Net (b)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receipts/Payments:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>11.1</td>
<td>10.7</td>
<td>16.5</td>
</tr>
<tr>
<td>All Industries (a)</td>
<td>14.2</td>
<td>13.8</td>
<td>23.3</td>
</tr>
<tr>
<td>Receipts/EBID</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>4.6</td>
<td>5.4</td>
</tr>
<tr>
<td>All Industries (a)</td>
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<td>4.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Payments/EBID</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>50.3</td>
<td>44.9</td>
<td>23.0</td>
</tr>
<tr>
<td>All Industries (a)</td>
<td>44.2</td>
<td>55.8</td>
<td>22.8</td>
</tr>
</tbody>
</table>

(a) Excludes enterprises in ASIC Division A (agriculture, etc.)
Source: ABS (Cat. No. 8108.0).

Table 3.9
Structure of Manufacturing Sector Exports by R&D Intensity of Industry

<table>
<thead>
<tr>
<th>Country</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Relative R&amp;D Intensity of Manufactured Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>22.3</td>
<td>46.9</td>
<td>30.7</td>
<td>1.23</td>
</tr>
<tr>
<td>Japan</td>
<td>20.6</td>
<td>45.2</td>
<td>34.2</td>
<td>1.15</td>
</tr>
<tr>
<td>EEC</td>
<td>13.5</td>
<td>44.2</td>
<td>44.2</td>
<td>1.15</td>
</tr>
<tr>
<td>Sweden</td>
<td>10.1</td>
<td>33.6</td>
<td>54.2</td>
<td>0.76</td>
</tr>
<tr>
<td>Canada</td>
<td>8.1</td>
<td>48.3</td>
<td>45.6</td>
<td>0.97</td>
</tr>
<tr>
<td>Australia</td>
<td>6.3</td>
<td>47.4</td>
<td>46.3</td>
<td>1.00</td>
</tr>
<tr>
<td>All countries</td>
<td>16.0</td>
<td>44.0</td>
<td>40.0</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Source: AITC (1985).

CHART 2
Trade per head of population in selected technology-based products 1984

Source: Department of Science (1986b)
intensity manufacturing exports (3.3 per cent compared with an average of 16.0 per cent), and the highest share of low R&D intensity exports (69.0 per cent compared with an average of 40.0 per cent).

Australia has not been participating in the fast growing world trade in high technology manufactures (19). This is highlighted by the fact that most other industrial countries have a higher proportion of high R&D exports than is accounted for by their manufacturing industry structure (as can be observed by comparing Tables 3.7 and 3.9). In contrast, the 3.3 per cent share of high R&D exports in Australia's manufactured exports is well below the 7.4 per cent share of high R&D industries in its manufacturing sector. Sweden has a similar structure to Australia in terms of the R&D intensity of its manufacturing sector, yet the structure of its manufactured exports is considerably more technology intensive. Canada has a less technology based structure compared to Australia, but has a more highly technology based structure in exports, with a considerably higher proportion of medium R&D intensity exports and a considerably lower proportion of low intensity exports. Undoubtedly, Canada's better performance can be explained partly by its proximity to the US market.

These weaknesses in technological effort and performance do not augur well for maintaining the pace of improvement in productivity which will be needed to maintain Australia's recently improved competitiveness, while avoiding a decline in the standard of living compared to OECD and NIC competitors. There is a clear and urgent need to do better.

3.2 THE NEED FOR BETTER PERFORMANCE

'Competitiveness in international trade is increasingly being determined less by comparative advantage based on relative endowments of physical resources (eg energy and raw materials) and more by created advantages based on technological superiority, management and workforce skills.'


The above quote contains an important part of the answer to those who would attempt either to excuse or to explain Australia's poor technological effort or total factor productivity performance.

Australia's natural resource endowments do not necessitate a weak innovative effort in the other sectors. Abundant natural resources will tend to create comparative disadvantage for certain segments of manufacturing and service sectors, through their indirect effects on labour costs and the real exchange rate. However, this should not mean that Australia's manufacturing sector has to be less productive than other countries with comparable or even higher wage costs. For example, the evidence cited by Lewis (1986) indicates that while Sweden's labour costs were higher than Australia (even before the recent depreciation of the A$), labour productivity was more than correspondingly higher. Through specialisation and innovation, Sweden has created important areas of comparative advantage in selected manufacturing activities: its approach to retaining competitiveness without the need to lower living standards is the capacity for innovation. As noted by Pavitt (1984):

'Technological innovation is a distinguishing feature of the products and industries where high wage countries compete successfully on world markets.'

The Nordic countries have also shown that a good natural resource base need not act as a barrier to structural change based on innovation and specialisation made possible by trade. Dalum and Fagerberg (1985) have commented on the trade-led transformation of the Nordic economies to become increasingly highly industrialised economies. In 1961, almost 80 per cent of exports from Nordic countries to the rest of the OECD was in natural resource based products, with only 15 per cent based on engineering. By 1970, resource-based exports were less than 60 per cent, while the share of engineering products had almost doubled to 29 per cent.

While differences in geography and institutions may prevent Australia from following such examples too closely, they suggest that performance can be improved through technological change, trade and industrial restructuring.
The need to do better is underlined by the factors described in Section 2.2. Not only do traditional exports have a less promising medium-term future, but Australia is also facing competition in a wider range of sectors from the NICs. The need for relatively high income countries to maintain competitiveness through an adequate pace of innovation has been summed up by Ergas (1984, p33) as follows:

'Two factors underline current concern about innovation performance. The first is the conviction that - in a context of persistently and unacceptably high unemployment - the development of new industries and, more controversially, of new firms, is essential to the creation of new jobs. Reinforcing this view is the rapid industrialisation of the developing world, which aggravates the competitive pressures bearing on mature labour-intensive industries in the advanced countries.

The second is the fear that ... in an integrated world economy, the Schumpeterian process of creative destruction may operate at the international level. Within the OECD region, the "winners" from this process would successfully respond to intensifying world competition, while the "losers" would be trapped between the NICs at one end and the innovation high-performers at the other.'

It is certainly not in Australia's interests to become one of the losers, by missing opportunities as has happened during the post-war period.

The prospects for improving Australia's productivity by fostering a faster pace of technological change can be enhanced by a clear understanding of the nature of technological change and the determinants of good performance. An appreciation of why some countries are better at innovating and applying new technology than others can help to assess the effectiveness (or otherwise) of the environment for innovation and technological change in Australian society. Such an analysis can then form the basis for the consistent development of a coherent policy framework to foster better future performance.

4. DETERMINANTS OF TECHNOLOGICAL CHANGE

4.1 THE NATURE OF TECHNOLOGICAL CHANGE

Perhaps most importantly, technological change should not be regarded as a phenomenon which is exogenous to the process of economic growth. There are a number of famous inventions which have opened up major new possibilities, such as the steam-engine followed by the internal combustion engine, the cathode ray tube, the transistor and, more recently, the silicon microchip. However, it should not be assumed that such discoveries arise by chance. There is an extensive body of literature suggesting that innovation of new products and the diffusion of new technologies do not depend solely on the driving force of new discoveries; the process is, simultaneously, closely linked to demand pressures.

The path-breaking analysis of Schmookler (1966) showed that demand, by influencing the size of the potential market, is a major determinant of inventive effort. A subsequent UK study (Langrish et al (1972)) revealed that successful innovation depends crucially on a close coupling of technological opportunities and market need. This evidence tends to be borne out by the relatively intensive and successful inventive effort in Australia in the traditional export sectors which have always been oriented towards a world-wide market, in contrast to the lack-lustre record of those sectors which have largely catered to a restricted and captive domestic market. It is also borne out by perhaps the only quantitative assessment of this issue for manufacturing industry in Australia by Gannicott (1984). On the basis of an econometric investigation using Australian Bureau of Statistics survey data for 1979, Gannicott concluded that the single most important influence on decisions concerning R&D is prospective demand, with the science orientation (or technology push) of the industry playing a subsidiary role.

The influence of demand is likely to be even stronger in future. The increased specialisation of scientific endeavour and the equipment required for scientific research means that it is less likely that breakthroughs will be made in the absence of substantial investments of time and money. Such investments are likely to be directed towards perceived market opportunities of substantial size. These factors also suggest that large firms (or
Proximity to a large sophisticated market can also help guide the further development and successful commercial application of discoveries. Many commentators, including Freeman (1982), have stressed that feedback from users to suppliers plays an important role in the design and refinement of new high-technology products. As Vernon (1966) has argued, most relevantly for Australia, that if US firms spend more than their foreign counterparts on new product development, this may be due not to some obscure sociological drive for innovation but to more effective communication between the potential market and the potential suppliers of that market.

Demand factors are a necessary, but not sufficient condition for technical progress. There is extensive historical evidence that successful technical changes depend on the availability of complementary technologies. For example, Rosenberg (1982) explains how interaction between concurrent advances in new technologies for power generation, metallurgy, and transportation made possible the industrial revolution which began in the 18th century (22). More recently, the adoption of new short-stemmed, high-yielding varieties of wheat and rice has been termed the 'Green Revolution'. This revolution did not only result in effective demand for output; it also required the combination of control over water supplies, the availability of chemical fertilizers and pesticides and the strengthening of crop credit systems.

The interdependence of technologies for successful commercial application suggests that it is not sufficient to be innovative; it is also important to be aware of technological advances in many other fields in order to transform innovations to successful products.

Cultural and institutional factors are also crucial; technological progress can be thwarted even if demand is strong and proven technological combinations are available. The 'Green Revolution' technology was made available to all of the food deficit regions of South Asia about 20 years ago. Nevertheless, due to a perverse system of land ownership and tenancy, the politicisation of the credit system and the lack of co-operative arrangements for the exploitation of ground water, the coverage of new rice and wheat varieties in Bangladesh remains around 25 per cent. This contrasts with the almost complete adoption of new hybrids in the Punjab over the same period and even more markedly with the increase in the coverage of hybrid corn in Iowa from 10 to 90 per cent in just four years (23).

The importance of complementarities in technological change means that reducing institutional constraints (such as outdated work practices) on the use of either new machinery or better management techniques can help accelerate technological change in Australia.

The process of technological change requires many steps between a new idea and its optimal commercial application. Studies of many industries, such as the research on the petroleum refining industry by Enos (1958), indicate that the most substantial commercial benefits are often derived from its commercial application, adaptation and optimisation (24). More recent empirical work (for example, Georgiou, 1982 and 1983) strongly affirms this, asserting that success or failure in innovation is less about the conditions for innovation than about the ongoing performance of the firm, or its ability to provide a stream of post-innovation improvements.

There is scope for major gains by those who are able to adapt or improve on new discoveries or to find novel applications for them. This lesson seems to have been well absorbed by Japanese policy makers, as noted by Caves and Uekusa (1976):

'The level and pattern of research and development within Japan are closely related to the import of technology from abroad... A 1963 survey of Japanese manufacturers showed that on average one-third of respondents' expenditures on research and development went for research and development in an effort to improve the performance and versatility of a new product. The moderate level of diffusion, and applied character of Japan's research effort are consistent with a facility for securing new knowledge from abroad.' (25)

A relevant example of Japan's approach was the acquisition by Sony of the licence for the transistor, which it subsequently researched and modified for use in its successful transistor radios. Although neither the inventor of the transistor nor the first to develop it with the radio, Sony made substantial gains from the product. One of its scientists subsequently received a Nobel Prize for his further research work on the transistor (26).

The advantages to be gained from technological awareness and ability to adapt are potentially great in Australia, where 98 per cent of technology is obtained from external sources. The relative weakness in transforming domestic discoveries to commercial application is a major cause of lost opportunities.

Technological change is not a linear process which simply progresses in one direction from research to experimental development, followed by early commercial application, then a phase of improvement, adaptation and cost reduction as experience is gained with the new product or process. Such a simple linear 'technology-push' model is both equally simplistic, but more recent linear 'demand pull' model are both increasingly regarded as extremes of a more
generalised model (see Rothwell and Zegveld, 1985, p.49). There are important linkages in both directions.

Significant original research breakthroughs can be generated by knowledge gained from experimental development, or even from seemingly mundane efforts to improve a product or to reduce costs after initial commercial application. Rosenberg (1982) cites a number of such instances in the telephone industry where attempts to improve the quality of telephone transmission over long distances led to fundamental breakthroughs in astrophysics and information theory (27). He notes that:

'...the most successful research institutions in private industry have already demonstrated that it is possible to conduct both fundamental and interdisciplinary research in a commercial, mission-oriented context.' (p.291)

The high academic, as well as commercial, reputation of institutions such as Bell Laboratories suggests that the distinction between "basic" and "applied" research is artificial. An increasing emphasis on commercially oriented research in Australia need not be a serious impediment to important new scientific discoveries.

In some important fields technological application has sometimes run ahead of a fully understood scientific basis for extended periods. For example, the scientific basis of aerodynamics and metal fatigue are still not fully developed. This has contributed to the very high costs of commercial aircraft development due to the need for expensive experimentation, since the behaviour and durability of aircraft cannot be fully predicted from theory. Other examples of important technological improvements running ahead of theoretical foundations include metallurgy and petroleum refining. In these cases, as noted by Rosenberg:

'...technological progress identifies, in reasonably unambiguous ways, the directions of new scientific research offering a high potential payoff.' (p.148)

Steering research into such directions requires channels for feedback of information from industry to centres of research. Any substantial reorientation of research in practically desired directions can, in turn, require additional investment in the teaching of related disciplines (28). It is, therefore, important to maintain good lines of communication between industry and teaching institutions (29).

Two additional, and increasingly important, features of technological change are the accelerating pace of diffusion of new technical knowledge and the increasing costs of developing path-breaking new products such as successive generations of more powerful microchips. Since only a short time is available to exploit an expensively obtained technical lead, the risks of efforts to stay at the forefront of technology are, in many sectors, extremely high. Such efforts are more likely to be undertaken by large firms or government-backed institutions in areas where a breakthrough is likely to have an access to a large market. The capacity to engage in basic research and development can also depend crucially on the ability of firms or countries to co-operate in order to spread the risks of major research. By implication, a small country or small firm is more likely to succeed by specialising in the adaptation or improvement of discoveries by others. In view of the high risks of developing entirely new products and the potential gains from further improvement or adaptation of inventions, a 'fast-second' strategy based on rapid technological transfer and imaginative application can be an attractive option for a small country (30).

The scope for specialisation has been increased in recent years. Reduced transportation costs, especially for electronic equipment and other high-technology products, have made possible new divisions of labour and the segmentation of industries. For example, specialised high technology components for a new generation of aircraft can be dispersed among several countries which may have developed different areas of technological expertise. At the same time, the final assembly of aircraft has become a relatively low-technology process and could possibly be relocated in the NICs in coming years (31).

The ability to specialise and so take advantage of an accelerating pace of technical change will require flexibility. It will be increasingly important for successful economies to be willing and able to change their pattern of production. As the pace of technological change accelerates, the nature of capital investment will also need to change. There will be relatively less need for equipment designed for large-scale manufacturing of a single product, compared to more flexible equipment such as robots and numerically controlled machinery. Such flexibility will be needed to cope with the shorter life of products and processes before they are overtaken by new technology.

The shorter length of product life-cycles will also have a profound effect on the workforce. New technologies will be typically more skill-intensive and will require a constantly changing mix of skills. There is less and less likelihood of employees using the skills which were acquired before entering the workforce during the rest of their working life. Just as firms will need to adapt their patterns of production or be short-lived, employees will need to upgrade or expand their skill throughout their careers. In industrialised countries like Australia we will need to enhance institutional mechanisms that can reduce barriers to mobility (for example through increasing the coverage of portable occupational superannuation) and to improve the facilities and incentives for mid-career training.
In the absence of flexibility and the ability to upgrade skills, there is a danger that the process of technological change will be impeded by the resistance of those who are trapped in low-skilled occupations in industries in which high labour-cost countries can no longer hope to compete.

4.2 INGREDIENTS FOR SUCCESS

The preceding brief overview of the process of technological change suggests that the important features of economies, which are likely to determine the pace of innovation and technical improvements, could be summarised as:

- **Demand**, which provides the incentive to innovate: sectors of production catering for large, sophisticated markets are more likely to record a relatively rapid rate of technological change;
- **Technical capability**, which determines the ability to generate and/or take advantage of new innovations; such capability will depend on the standard of educational and research institutions and the effectiveness of interactions between them and industry;
- **Industrial structure**, which can determine the incentive and willingness to innovate. The strength of competitive pressure will determine, to a significant extent, the pressure on firms to apply new technology. The size of firms, or their ability to co-operate, can be important in determining their capacity to bear the costs of R&D efforts. The flexibility of the industrial structure and the workforce can enhance the ability of countries to take advantage of technological developments.

These important determinants of good technological performance were identified in a paper by Ergas (1984) and subsequently elaborated in a policy-oriented context by Rothwell and Zegveld (1985, p 258 ff). Ergas analysed seven major OECD countries and ranked them in terms of characteristics which indicate the strength of the above three determinants of technological performance as shown in Table 4.1.

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(1) Total potential weighting = 18
(2) But increasing

*** = weighting of 2
** = weighting of 1
* = all

Ergas notes that the ranking shown in Table 4.1 correlates well with most indicators of technological performance such as R&D expenditure; patent output; the balance of revenues from the sale of (or payments for) patents and know-how; production and world market share of high technology products; and the balance of trade in high technology products.

The nations with high rankings in Table 4.1 also seem to do well in terms of these indicators, as shown by the data analysed in Section 3.1. Ergas (1984) summarised the comparative data as follows.

1. The United States retains a dominant position in OECD innovation performance, though it has lost considerable ground to Japan.

2. On a number of indicators, the European position has improved over time, but much less so than that of Japan.

3. The European position differs substantially between industries, being particularly strong in fields related to biology and chemistry, substantially less strong in electronics and information processing, and relatively weak in aerospace.

4. There are very great disparities in innovation performance within Europe, particularly between the Federal Republic of Germany, the Scandinavian countries, Switzerland, and the Netherlands on the one hand, and the UK and France on the other.

The strength of this qualitative correlation of economic and institutional determinants with technological performance suggests that it would be worthwhile to examine the existence (or absence) of such determinants in Australia; such an examination could provide some insight into the reasons for our relatively poor technological performance during the post-war period (32).

5. THE ENVIRONMENT FOR INNOVATION IN AUSTRALIA

Drawing on the analysis of Section 4, this section seeks to identify the factors which could explain Australia's comparative lack of effort and results in terms of innovation and technological performance, whether such performance is measured by partial indicators (such as R&D expenditure or patent output) or by results (such as trends in total factor productivity).

Size and sophistication of markets: In view of Australia's small population and relative geographical isolation, the size and sophistication of the domestic markets are small when compared to most OECD countries, tending to reduce the demand for technical innovations. It is interesting to note, as discussed in Section 3, that innovative effort and performance has tended to be stronger in our primary exporting sectors which have catered to wider world markets. Nevertheless we appear to have an as yet unexploited potential to act as a springboard into the neighbouring, fast growing economies of the Pacific Rim.

Our performance stands in contrast to the manufacturing and service sectors, where a long legacy of policies has isolated the small domestic market from international influences (33). Their isolation has not only reduced the need to innovate, due to a lack of competitive pressure from outside but has also led to a lack of awareness of the evolution of world market patterns and tastes. There has been very little effort needed or invested in marketing. Slattery (1986) remarked that:

'It is not surprising that, by and large, Australian firms are not skilled in selling on foreign markets. Apart from resource-based firms, even most large firms with established international operations are not major exporters of Australian-made products.'

The lack of feedback from an increasingly sophisticated world market has also reduced the incentive to refine or adapt products. As Butlin (1986) noted:

'Shielding activity from external competition has been far less important in encouraging inefficiency than in making us insular, unaware of and unattuned to conditions of world demand and the nature of world tastes.'

For manufacturing, the effective market size has been further constrained by the large distances between concentrations of population, by varying State regulations and standards and, until recently, by State purchasing preferences which have fragmented an already small market.

Although the development of new technologies is tending to reduce the importance of economies of scale in production, the total Australian market is still extremely small in international terms. For most new products and processes,
access to a somewhat larger market is required to justify the high risks of research and development efforts.

**Industrial Structure:** Since the isolation of the domestic markets for manufacturing and service industries has reduced the need to innovate, it is not surprising that Australia's private sector R&D expenditure in these sectors compares very poorly with other industrialised countries. R&D efforts in these sectors have tended to be regarded as discretionary; they have been the outlays which were among the first (along with training efforts) to be cut back at times of temporary difficulties. The unfavourable attitude of management has been reflected in responses to recent surveys (34). While a majority of managers admitted that their products and process were not up-to-date with overseas technologies, an even larger majority expressed satisfaction with their R&D efforts.

The small size of the domestic market has also militated against the formation of large firms in the manufacturing sector, comparable to Volvo or LM Ericsson in Sweden, which have the financial strength to undertake significant research efforts. Subsidiaries of large multinationals in Australia were originally induced to locate here to "get behind the tariff wall" and tended to acquire new technology ready-made, with a lag, from their parent companies. The cost structure imposed on such firms by a combination of tariffs on some inputs, higher wages in comparison to neighbouring countries and the availability of alternative vehicle products in the Australian market meant that subsidiaries of multinationals had no incentive to use Australia as a base for exports to the region. While these factors have limited their incentive to contribute to the R&D efforts of their parent companies, Johnston et al (1986, pp 26-29) have shown that, for the period up to 1982, foreign-owned companies spent more on R&D as a percentage of sales than Australian firms. Subsidiaries tend to be concentrated in more technology intensive industries, such a result is not unexpected. However, their R&D outlays may not necessarily compare favourably with firms in similar industries in other countries.

Moreover, the availability of protection from competition by means of tariffs, quotas or regulations has gradually undermined the flexibility of the industrial structure. A general expectation was created, unchallenged until quite recently, that all sectors of production could expect government actions to guarantee their continued existence. Sectional interests have been permitted to become strong, entrenching resistance to change. Gruen (1986) quotes Hanour Olson's statement that the model of a society which has become increasingly rigid and prone to economic stagnation 'fits Australia like a glove' (35). Such tendencies are likely to frustrate efforts to implement processes which reflect the accelerating pace of technological change in world markets.

36

The education system and its links to industry: Although educational expenditures have risen rapidly in the post-war years, Australia is lagging behind other developed countries in terms of some key indicators. This evidence was presented in Office of EPAC (1986 #15). Some key points are:

- relatively low proportion of the 16-24 age group participating in education;
- lower emphasis on technology-related disciplines in higher education;
- lower percentage of the labour force qualified to first degree level. (36)

As noted in Office of EPAC (1986 #17) most of the increases in education expenditures are accounted for by increases in costs per student rather than by increased participation in secondary or higher education.

The lack of priority given to commercial, scientific or engineering training is a reflection of weak links between education and industry. Charles (1986a) commented that:

'For too long there has been an attitude that science and technology is something that is conducted in universities and publicly funded institutions remote from industry, while industry for its part tended to think that it could get by picking technology off the shelf. Australia has not been alone in this attitude which appears to be part of our Anglo-Saxon heritage'.

According to Ergas (1984), the weakness in the linkages between industries and universities is one factor underlying the weakness of United Kingdom's technological performance (37). The persistence of poor linkages in Australia, which has been confirmed by the recent Business Council of Australia survey of business attitudes to education, is likely to be equally damaging (39).

The present approach to the funding of institutions of higher education in Australia tends to shield these institutions from the need to respond to demand for changes in emphasis either from industry or from their students. Among some of the Australian academic community, suspicion persists that closer linkages with industry could divert the functions of universities too far from the pursuit of knowledge for its own sake. The validity of this concern is, however, somewhat undermined by examples cited in Section 4, which suggest that important scientific breakthroughs have flowed from concern with practical industrial problems.

**Skill formation:** The rapid evolution of technology means that those nations which want to stay close to the forefront of implementing new techniques of production and
management will need to have a flexible workforce; mid-career training to upgrade skills will become increasingly important.

Although the paucity of data prevents firm conclusions, there does not appear to be a great deal of mid-career or in-service training in Australia: it appears that Australia spends a lower proportion of GDP on skill formation than Japan, USA and West Germany and that the shortfall is particularly marked in the private sector (see Curtin et al (1986)). Moreover, the existing pattern of many occupational structures fails to provide adequate incentives to upgrade skills. At times, occupational structures can preclude the effective application of newly acquired broader skills (39).

6. EMERGING POLICY DIRECTIONS

Since 1983, a wide range of policy measures have been taken to improve incentives for research, application, innovation, and the widespread adoption of new technologies developed overseas. It has been recognized that just as there is far more to industry policy than the reduction of protection rates, there is far more to technology policy than direct financial support to R&D (40). This section reviews the progress made to improve the prospects of more rapid technological progress in Australia.

6.1 MACRO-ECONOMIC POLICIES, CAPITAL MARKETS AND INVESTMENT

Macro-economic management should not be considered to be divorced from technology policy. The application of new techniques requires either new investment in plant and equipment embodying new technology or changes in management or work practices to allow more effective use of investments. A combination of both is often required.

The shortfalls in Australian business investment during the past 15 years, discussed in Office of EPAC (1986 #10) and by Carmichael and Dew (1986) mean that the average age of Australian plant and equipment has increased relative to most of our trading partners. In particular, as shown by Dixon (1985), there was a persistent increase in the average age of equipment throughout the 1970s. This underlines the necessity of promoting a sustained high rate of investment in order to modernize Australia's capital stock. Such investment can only be expected in a macro-economic environment which can provide the prospect of stable and adequate rates of return for efficient investment.

Accordingly, high priority has been given to sound macro-economic management. The moderation in both real and nominal unit labour costs since 1983 has restored the share of profits and led to a significant increase in competitiveness, opening up a range of investment opportunities in export and import-competing areas.

Direct incentives for investment have included the accelerated depreciation provisions for plant and equipment, the allowance of depreciation of buildings and structures and the introduction of an imputation system for dividends. The deregulation of the financial system is expected to boost the availability of risk capital.

As discussed in detail in Office of EPAC (1987 #25), particular attention has been given to enhancing the availability of venture capital to assist the growth of small, potentially fast-growing high-technology companies. The capital base of the Australian Industrial Development Corporation (AIDC) has been strengthened. AIDC has been encouraged to increase its equity participation in innovative ventures and has already developed a substantial
venture capital equity portfolio. In line with the recommendations of the Esplee Report, the Management and Investment Company (MIC) program was set up in 1984. Investors in companies licensed under this program can claim a 10 per cent tax deduction on their subscription. By late 1986, the total approved capital for MICs had reached $161 million. At the end of September 1986, $157 million had been invested by the 11 MICs in 92 different businesses; the estimated cost to revenue in 1985/86 was $20 million. Financial market deregulation, in particular the establishment of second boards on all stock exchanges, is assisting the access of new and to local innovative companies to capital markets and providing an important exit mechanism for high risk investors. 167 companies are now listed on second boards with total capitalisation approaching $2 billion.

The Esplee Committee identified the lack of business and management skill among high technology entrepreneurs as a major barrier inhibiting investment and the growth of businesses using high technology. The MICs provide management support directly and have a demonstration effect to encourage other venture capitalists. According to a recent estimate by Ward-Ambler (1986), over 300 potential businesses have been evaluated by venture capitalists to date.

The MIC scheme was envisaged by Esplee to be a catalyst to the development of an active private sector venture capital market. Notwithstanding a slow start by the MICs and recent concern that the program may be facing a severe shortfall in capital (see Scitech (1986)), recent figures suggest that the venture capital market has become strongly established. Total funds to support entrepreneurial investment have increased from around $5 million in 1983 to reach $275 million by mid-1986.

6.2 TECHNOLOGY TRANSFER

As a small country, Australia cannot expect to generate all of the new technology of potential use to industry - it is realistic to expect that the proportion of new technology added from overseas will remain overwhelmingly large. Australia does not have more than a few large firms with the capacity for major research and development efforts in entirely new fields. Comparative advantage in innovation is more likely to be created by small firms which are quick to recognise and develop new uses for, or make imaginative improvements on discoveries made in other countries in other fields. Such a "second" strategy requires effective capacity for technology transfer, based on high level technological intelligence gathering to identify world trends in output and market potential, then direct limited domestic R&D capacity to adapt technologies to fill perceived market niches (see Green (1985)).

Overseas technologies can be transferred to Australia by purchases of new capital goods or by licensing arrangements. Both of these can be backed up by follow-up support from the vendor, but the effective application of the acquired technology will require domestic to expertise to adapt the new technology to local conditions, the awareness of new developments overseas as well as efficient capital markets and incentives for investment to facilitate the acquisition of know-how embodied in new capital goods.

As noted by Parry & McWilliam (1985) and by Office of EPAC (1986 #19), technology transfer cannot be considered separately from R&D; since new technologies cannot, in most cases, be simply transferred without some adaptation for use by domestic industry. Therefore, effective technology transfer also requires a research and development base within the country in order to foster the human skills to apply new technologies (41). As ASTEC (1986) has recently concluded, overseas technology and a domestic R&D capability are complementary: one does not substitute for the other. Perhaps the most important benefit which may arise from an enhanced R&D effort by Australian firms is the increased ability to take advantage of innovation occurring overseas.

Awareness of new technology is an essential prerequisite for effective technology transfer. However, survey-based evidence suggests that managers are not adequately aware of new technology. (ASTEC (1986, p14)). For example, in a survey of 500 executives from five countries in 1984, PA Technology found that 60 per cent of Australian executives consider that their overseas competitors make better use of advanced technology. However, Australian company managers were shown by survey to be "inexperienced and poorly informed in their attitudes towards identifying technological developments and harnessing them to their own competitive advantage" (42).

To help remedy these deficiencies, enhancing technological awareness has become a major objective of government programs. The Technology Transfer Council has established a network of Innovation Centres. Emphasis has been placed on promoting the adoption of modern management techniques which have evolved overseas. These include the concepts of Value Added Management, which is based on more effective means of inventory management (such as in the example, in a "Time system") and quality control. The TEAM (Towards Excellent Australian Manufacturing) project, set up by the Technology Transfer Council has held major exhibits to promote the use of such improved management methods.

During the past year, a co-ordinated National Industries Extension Service (NIES) has been developed by agreement between the Federal and State Governments, reducing the previously existing duplication of efforts. The NIES is focusing on the dissemination of technology through demonstration centres as well as innovation and product development assistance.
In its 1985 Science and Technology Policy Outlook, the OECD documented the pervasive trend towards the internationalisation of technology through multinational firms. It concluded that reconciling national policy and interests with the international activities of companies is a growing and formidable challenge which member governments have yet to address fully. ASTEC (1986) has recommended the Government should monitor these trends towards increased collaboration between competing companies as well as between countries in programs such as the US Space Defense Initiative and the European "Eureka" program, in order to ensure adequate access to the world technology market for Australian firms.

An increasing number of successful Australian firms are adopting strategies to internationalise their activities through niche marketing, attracting foreign equity, direct foreign investment, joint venturing, joining with large international companies and participating in international joint R&D programs (see Charles (1986b)). The Government has been taking an increasing role in these processes which can facilitate the integration of Australian companies into world markets (43). Important initiatives include:

- Establishment of the Australian Committee of Industrial and Technological Cooperation (AUSCITEC) under the auspices of the Australia-Japan Business Forum.
- The first stage of a scheme to assist joint ventures between firms in Australia and the US was launched in November 1986, based on the highly successful US INFACT (International Partnerships for Commercialisation of Technology) program.
- In November 1986, a Science and Technology Agreement was signed with the Commission of the European Communities which will give Australia access to scientific and technological information previously not available, by fostering practical collaborative projects.

Technology transfer will also be promoted by the revision of offsets policy, following a review headed by Sir Brian Inglis. The new policy is designed to bias the use of offsets towards promoting domestic industry involvement in high-technology components of major government contracts. The Business Migration Program is also designed to boost Australian entrepreneurial and technical capacity by encouraging migrants with such skills to establish new ventures in Australia (44).

As discussed in Section 4, the efficient transfer of both 'soft' technologies (such as an improved approach to inventory management, computer-aided manufacturing or numerically controlled machine tools) requires a willingness by the workforce to adapt to changes. Skill-intensive processes, requiring attention to precision and quality will be increasingly important; they can be conducted successfully only by a skilled and highly-motivated workforce which understands and accepts the benefits of technological advances over the longer term. Many high technology, skill intensive companies, particularly in Silicon Valley in the US, as well as in other countries such as UK and Sweden, have developed profit sharing, or employee share ownership schemes, which can assist in building the necessary motivation in the workforce.

In the Australian context, the recent recognition of the need for constructive reviews of work practices which could impede productivity is timely and welcome. It is generally accepted that adaptation of work practices needs to be negotiated and agreed at the enterprise level. The application of programs like Employee Involvement which has been successful at Ford Australia offers a potentially useful model.

6.3 RESEARCH AND DEVELOPMENT

Private Sector R&D

Recent policy directions are designed to promote private sector R&D efforts by providing direct incentives and by increasing the competitive pressure for more innovative behaviour.

From July 1985, a 150 per cent tax deduction for R&D outlays applies to all industries. Expenditure on plant and equipment which is wholly attributable to R&D attracts 150 per cent deduction in the year the expense is incurred. Expenditure on buildings wholly attributable to R&D is fully deductible over three years. An incentive which is provided by a tax expenditure is of benefit only to firms with sufficient profitability to take advantage of such a concession. Therefore, it has been complemented by the Grants for Industrial Research and Development (GIRD) scheme which is available to all firms, but is aimed primarily at small new and innovative ventures (45).

At the time of its introduction, the Chairman of ASTEC stated his belief that the R&D tax concession is the most important measure yet introduced by government to encourage technological innovation in Australia (46).

The principal advantage of the tax concession over the more traditional grant scheme for R&D which it replaced, namely, the Australian Industrial Research and Development Incentive Scheme (AIRDIS), is that it leaves the decision on which R&D projects are to be supported in the hands of those in industry who are best placed to make the judgement, rather than in the hands of public servants. On the other hand, the tax concession for R&D has been criticised because of its potential for promoting 'measurable' as against 'effective' R&D expenditures. The
generous tax deduction could lead to efforts to inflate R&D expenditures for accounting purposes. On the basis of overseas experience, some reclassification of current activities into the R&D category is likely to occur (47). Such diversion may, nevertheless, have an important beneficial side effect to the extent that companies and their boards may focus, for the first time in many cases, on the objectives and importance of their R&D expenditures.

Recognising the potential for tax avoidance, the Australian legislation for the R&D concession incorporates a precise definition of R&D based on the OECD standard. To be eligible for the tax concession, companies are also required to register for the concession with the GIRD Board. Both the 150% tax scheme and the grant scheme will be subject to technical and cost effectiveness reviews.

The response to the R&D initiatives has been encouraging. Private sector R&D expenditure has increased from 0.23 per cent of GDP in 1981-82 to over 0.3 per cent of GDP by 1984-85 and a further increase is estimated to have taken place in 1985-86. It is expected that these two schemes could involve costs, plus revenue foregone, of more than $500 million over six years. Nevertheless, as noted in Section 3, the Australian private sector’s share of R&D outlays still remain far below the corresponding ratio of private sector R&D to GDP in other OECD countries and below the levels achieved in Australia in the late 1950’s. (48).

As well as boosting private R&D, policies to sustain public sector R&D and to improve its effectiveness will remain important. Due to the long lead times, high commercial risks and externalities associated with R&D, there are many types of R&D activities which are not likely to be aggressively pursued by the private sector (49).

Public Sector R&D

As noted in Section 3, Australia’s public sector R&D, expressed as a proportion of GDP, compares quite favourably with other OECD countries. Direct Commonwealth Government budget expenditure on R&D is projected to be just over $1 billion in 1986-87, rising to nearly $1.2 billion if other public sector (e.g. Telecom) outlays are included, and totalling nearly $1.8 billion if the general teaching and research expenditure in the higher education sector ($346m) and the cost of tax incentives ($120m) are also included.

In its general reference to ASTEC on Public Investment in R&D in Australia in May 1985, the Government sought advice on the most effective organisation of this substantial investment. ASTEC is addressing these terms of reference in four reports:

- Public investment in R&D (November 1985) which considers the rationale and objectives for government funding;

- Future directions for CSIRO (November 1985);

- Higher education research (due for completion in early 1987); and

- Private sector innovation and R&D (expected by mid 1987).

The first of these reports makes 15 broad recommendations to which the Government has yet to respond formally. The underlying theme of the report and its recommendations is the need to ensure that public sector research is relevant to the needs of industry and that there is close interaction with industry to ensure that the results are effectively transferred. ASTEC recommended that at least the present level of government support for R&D as a proportion of GDP be maintained.

The theme of interaction with industry is taken up explicitly, and in more detail, in the ASTEC report on CSIRO. The general approach recommended by that report has been adopted by the Government (see CSIRO Annual Report 1985/86, Chapter 1) and has been reflected in amendments to the Science and Industry Research Act.

ASTEC recommended that there should be a significant shift in the overall ethos of the organisation towards applications-oriented research, combined with a strengthened commitment to the effective transfer of research results to users. It also recommended a revised top management structure for the organisation and enhanced flexibility in financial and staff matters including the retention of earned income without reduction in appropriation funding.

Recent organisational innovations in the CSIRO that preceded the Government’s decisions on the ASTEC report but that are consistent with its theme include:

- Allowing Divisions to benefit from additional resources raised by their efforts;

- Changes in promotion criteria to increase the recognition of effective involvement with industry;

- Initiation of a Manufacturing Industry Collaborative Program to allocate additional resources to research areas identified as priorities by industry;

- The establishment of SIROTECH which focuses on the commercial application of CSIRO’s research.

- SIROTECH, in turn, is setting up joint ventures in research with private industry (for example a joint venture with ICI will seek to develop technology based on zirconium).
Similar themes are likely to emerge from government decisions to be taken during 1987 regarding the funding of research in institutions of higher education. The Commonwealth Tertiary Education Commission (CTEC) review of Efficiency and Effectiveness in Higher Education (September 1986) is to be followed up by ASTEC's review of higher education research. Decisions on these matters are likely to be taken in the budget context against the background of the CTEC proposals for funding the 1988-1990 triennium.

There have already been a number of encouraging moves to enhance the relevance of higher education research efforts to industry; more regular interaction and consultation is taking place as documented in the first joint report of the meeting between the Australian Vice Chancellors' Committee (AVCC) and the Business Council of Australia (BCA) (50). Most universities now have business liaison officers, support consulting companies and, in some cases, marketing and application efforts are being pursued by companies such as ANUTECH. Further cooperation can be encouraged through arrangements which promote staff interchange, joint staff appointments with industry and joint research programs.

The Government is keen to foster this interaction further. One objective of the 150% tax concession for R&D is to foster added interaction by more contracting of industrial R&D to universities. A Teaching Company Scheme has also been set up to contribute to the salary of graduates to work in a company under the supervision of a tertiary institution. Within the Education portfolio, the Commonwealth Tertiary Education Commission (CTEC) has established a Standing Committee on Tertiary Education/Industry Relationships (SCOTER); the Minister has established an Industry Reference Group and an associated Industry Liaison Unit within the department.

It has been recognised that the relevance of research by bodies such as CSIRO and tertiary institutions can be significantly increased by appropriate policies for the funding of research. Well-designed funding schemes can provide strong incentives for researchers to be responsive to the needs of industries, without underpinning a necessary degree of independence.

Both negative and positive approaches can be adopted for providing such incentives. A negative approach would 'freeze' funding from Government at present levels, requiring the institutions to attract all additional resources from industrial users of research. A positive approach would rely on devices like dollar-for-dollar contributions by Government to match additional resources obtained from industry sources. Another option is to allow individuals, or smaller units within large research organisations, to retain all or part of the financial gains from successful innovations. In practice, a combination of all of these approaches is evolving.

A further objective of current policies is to improve the coordination of R&D efforts to prevent duplication and to prevent an excessive dispersion of effort which may not yield good results on any front. It is not feasible to be at the forefront of all aspects of R&D - nor is it realistic to hope to pick specific 'winners' in advance. In order to build up Australia's capacity to acquire and apply technology in a number of broad fields which are expected to dominate the direction of technical advance during the next 10-15 years, it makes sense to channel R&D efforts. It would, therefore, be appropriate to focus on those new technologies (such as flexible manufacturing systems) which can facilitate small-scale decentralised production suitable to small economies (51).

The Government, through the Department of Industry, Technology and Commerce, has encouraged special efforts in a number of 'generic' technologies, including information technology, robotics, biotechnology and the development of new materials based on Australian natural resources such as zirconium. The development of a strong R&D base in these generic fields should also facilitate the rapid transfer of technology developed abroad and provide the scope for profitable and innovative adaptation of ideas generated world-wide.

The emerging awareness of the need for selectivity and priority setting is reflected in the CSIRO's recent strategic plan (52). Its objectives are to develop more systematic procedures for identifying growth areas and assessing the balance of research across economic sectors; to concentrate CSIRO's research efforts into fewer research programs; and to introduce more systematic evaluation of research. In its decisions on CSIRO, the Government has indicated that the Minister will issue periodic policy guidelines to the Board; the Board will issue three to five year strategic plans in accord with these guidelines and annual operating plans will be in accord with the strategic plan.

There is still scope for further development and application of the techniques of corporate planning, evaluation and resource allocation to the management of public sector research. Similar developments are likely to take place in the management of research in institutions of higher education, where there is concern that available resources are being spread too thinly.

6.4 INDUSTRY AND TRADE POLICIES

The industry policy directions of the past 10 years have given a gradually clearer signal to industry that it will need to be able to compete effectively on world markets. It will take some considerable time to transform attitudes. Butlin (1986) noted that the new policy directions aimed at reducing regulation and protection:
... confront attitudes, behaviour patterns and institutions that are deeply rooted in the traditions of the past century of our economic history.

Nonetheless, if recent policy directions are sustained, there will be an increasing recognition by Australian industry that they need to be innovative in order to retain a share of local markets and to participate effectively in world trade. Just as research institutions are becoming more responsive to industry, the business sector will gradually focus on what it needs in terms of new products and better management; thereby improving its ability to communicate its research needs and to select wisely the available scope for technology transfers.

The capacity of industry to respond to these new policy directions needs to be enhanced by a wide range of government policies. In fact, the wide range of complementary policies for boosting the pace of technological change are essentially the same as those which comprise the broad framework of policy in which has emerged since the preparation of the Crawford Report (1979). This is hardly surprising, since the key to future productivity and competitiveness is the promotion and adoption of innovative processes and products.

Marketing and Trade Policy: Although Australian unit labour costs have fallen sharply during the last few years, compared to other OECD countries, they are still well above those of our NIC competitors. It remains unlikely that Australia will have comparative advantage in mass-produced or low skill intensive products.

Australia is more likely to be successful in increasingly specialised intra-industry trade, with domestic industry providing specialized inputs or components to the needs of a broader internationally oriented sector of production. Examples include automotive and aircraft components for final world markets, as against finished final products. Final products exported from Australia are more likely to fill modest and often ephemeral 'niches' than to dominate sectors for long periods.

Such a pattern of manufactures and services exports will not only require continuous, rapid innovation and product development, but will also depend on effective marketing. The reform of Australia's overseas trade representation, involving the establishment of the Australian Trade Commission (AUSTRADE) is designed to strengthen and co-ordinate market development, export finance and insurance efforts. Strengthening of marketing expertise is also being incorporated into industry plans such as the recent Heavy Engineering Plan.

Effective marketing will need to recognise that Australia will not be relying simply on price competitiveness in export markets. Price competitiveness becomes relatively

less important in skill-intensive high-technology products. Competitiveness will depend correspondingly more on designing or adapting a product to meet consumer needs in specific markets. Conversely, Australia's relatively small firms will need to be able to capture overseas markets in order to recoup their R&D investments in new products (53). Success in this regard will require sustained long-term commitment to developing an understanding of the tastes and market institutions of other countries, with a focus on the fast-growing markets of the Pacific Region; in many cases a physical presence in these markets will be needed (54).

While much more attention is being devoted to export markets, domestic markets are not being neglected. A National Preference Agreement has been concluded with State Governments, providing for an Australia-wide preference scheme, replacing the separate schemes which had previously fragmented an already small domestic market. An inquiry is also under way to investigate means of promoting the ability of domestic high-technology firms to supply Governments' purchasing requirements (55). Boosting the prospects of local firms to supply public sector demand need not rely on any new explicit or hidden forms of protection. It can be enhanced by providing better information on, and better planning of, public sector purchasing needs, as well as the removal of any bias against local firms in purchasing procedures (56).

Sectoral policies: Recent government policies have given priority to creating generally available incentives and pressure for innovative and competitive remains likely that Australia will have comparative advantage in mass-produced or low skill intensive products.

Eleven manufacturing sector Industry Councils have been set up with representatives from employees, employers as well as Government. These bodies are proving effective in terms of identifying sectoral issues and strategies to lift performance. They have been involved in the design of and implementation of industry plans for the steel, motor vehicle and heavy engineering industries; they could also provide the vehicle for sectoral reviews of technological capability which were recommended in a recent report by the OECD Examiners (57). A comprehensive overview of the policies required for future industrial development has been published recently by the umbrella organisation for these councils, the Australian Manufacturing Council (1986).

6.5 EDUCATION AND SKILL FORMATION

A well-trained work force is essential, not only to conduct research and be aware of technology transfer opportunities, but also to be able and willing to apply new technology. Effective investment in human capital will continue to be
required for successful pursuit of technological improvement. This has been recognised by all the successful nations in East Asia. The importance of education and skill formation was stressed by Office of EPAC (1986 #15) and also emphasised by Butlin (1986).

The skill-intensive nature of new products and processes, combined with the comparative advantage of developing countries in those sectors where unskilled labour remains important, means that there is an urgent need to upgrade the skill level of the Australian workforce. This upgrading is needed to overcome the problem of serious unemployment of the unskilled combined with quite widespread skill shortages. As noted in EPAC (1986 #21) this situation is already chronic and threatens to become entrenched, thereby strengthening the resistance to urgently needed structural reforms. The OECD (1986a) Examiners of Australia's science and technology notices concluded that:

"A system of training programs, which stimulated technical training and retraining within industrial enterprises would be among the most important contributions of the education and training system to national economic recovery" (p21).

Based on reviews of the education and training system by Karmel (1985) and Kirby (1985), a number of important policy initiatives have been taken, including:

- steps to increase participation rates in secondary education from 35 to 45 per cent in recent years;
- higher intakes to tertiary education, with increased emphasis on science, technology and business and management courses;
- increasing apprentice intakes from a low point of 35,000 in 1982-83 to 49,000 by 1984-85.

A common thread running through recent education and training policies (just as for research funding policies) is the forging of closer links between educational institutions and industry. Participants in industry, including Industry Councils, are being encouraged to assess their training needs regularly and systematically and to communicate their findings to education policy makers.

Future productivity and competitiveness in industry will also depend on the quality of post-school and adult training to cope with the need for skill upgrading throughout the work force. Employee-employer co-operation at the sector and firm level is needed to anticipate new needs for training and skill upgrading. The recent Heavy Engineering Plan also provides a good example of such co-operation.

In addition to increasing the opportunities for skill upgrading, adequate incentives must be provided to undertake such training. Employees need to be assured that their training will lead to recognised qualifications and to adequate financial rewards. Work practices and occupational structures will need to be examined critically to ensure these incentives can be provided - such reviews will be facilitated by recent initiatives to bring employers and employees together at the firm level to examine work practices with a view to raising productivity.

The effective utilisation of new skill and new technology will also require a high quality of management. Steps have also been taken to improve the quality and capacity of management training which lags behind that of comparable OECD countries. Once again, the relevance of such training can be greatly enhanced by close contacts between industry and the institutions providing management training. These links can be effectively strengthened if tertiary and institutions develop and market relevant non-award courses aimed at filling gaps in management skills on a commercial basis.

Policy co-ordination: The overlap and interaction of many of the policy areas discussed above serves to emphasise the need for a co-ordinated and balanced approach to the enhancement of technological progress in Australia. No matter how vigorous (or costly) efforts are made to raise research and development expenditures, a single-minded focus on things which are most directly concerned with generating innovation will not be sufficient to sustain rapid technological change. It is equally necessary to promote complementary efforts, such as the strengthening of the educational base and the gradual redirection of industry and trade policies. These long-term determinants of the demand for innovation, the supply of skills and market structures will have an overwhelming ultimate effect on the pace of technological change.
7. CONCLUSION

The need to promote a more rapid pace of technological change has been given high priority by Australian policy makers. At the same time, it has been recognised that past policies have not been conducive to innovation and the commercial application of new ideas and products. Australia’s domestic market is small and relatively unsophisticated in international terms and protectionist industry policies have not encouraged producers in the manufacturing and services sectors to enter overseas markets.

Nevertheless, there are signs that the new direction of industry and trade policies, the encouragement of R&D and of closer links between education and industry are beginning to have positive effects. As noted in Section 3, whilst indicators of technological effort, such as R&D outlays are still at disappointingly low levels, they are beginning to point upwards. While Australia lags well behind most OECD countries in these terms, there are some welcome signs of success. Some important footholds have been gained in potentially important high-technology segments of international markets.

As noted by Charles (1986a), there are a number of innovative Australian companies which spend a high proportion of their turnover on R&D and are strongly export oriented, relying on successful innovations to develop new markets. For example, NUCLEUS has specialised in medical technology, developing and marketing products such as pacemakers, hearing devices and bone growth stimulators. 90 per cent of output is exported and 8 per cent of sales are reinvested in R&D. NUCLEUS has found a niche in the fast-growing health care market which has the potential for rapid growth associated with increasingly wealthy and aging populations in the OECD countries.

VAPOCURE has developed a fast drying paint process which is now used in 20 production lines around the world. PACIFIC DUNLOP has been successful in penetrating international markets for rubber products on the basis of its successful research and development of lower cost, high quality processes. It has also developed what is considered by many to be the most advanced car battery in the world.

In many of these cases, marketing has relied on overseas investment to help obtain access to new markets. As discussed in Martin (1986), much direct foreign investment by Australian companies has had a strongly positive net impact on the Australian economy.

These successful examples still represent no more than a small fraction of Australia’s production and exports. High-technology products will not, by themselves, turn around our presently unacceptably adverse balance of trade in goods and services. Success in these terms will need improved export and import replacement performance across a broad range of industries, taking advantage of the massive improvement in competitiveness brought about by the depreciation of the Australian dollar and wage restraint during the past three years.

What these successes have shown, however, is that Australia’s natural resource endowments do not preclude the creation of new areas of comparative advantage which are built on knowledge and skill. The positive new policy directions of recent years have strengthened the prospect for creating further areas of comparative advantage.

While the task facing Australia is not impossible, the difficulties should not be underestimated. It will take time to reverse the inward-looking attitudes of the past. Moreover, Australia is competing with a large number of industrialised and newly-industrialising countries who are also seeking new technology-based markets. In an increasingly diversified and fast-evolving world market, their success need not mean our failure, or vice versa. It does mean that the technological effort in Australia will need to be vigorous and sustained and our pattern of production will need to become increasingly flexible and specialised to hold our own in international competition.
NOTES

(1) The extent of the improvement in Australia's balance of trade in goods and services which is needed to stabilise net external debt as a share of GDP over five years is described in External Balance and Economic Growth, Office of EPAC (1986 #22).

(2) Recent trends in the profit share and the incentive to invest (the Tobin q-ratio) are set out in Business Investment and the Capital Stock, Office of EPAC (1986 #10).

(3) Some of the literature on technological change has sought to distinguish between product innovation and process innovation. This would seek to separate the invention of new products from improvements in the processes by which existing products are made. This distinction may be becoming less relevant over time. There is considerable evidence that the distinction between manufacturing and service industries is becoming increasingly blurred. Correspondingly, it may become increasingly difficult to distinguish between products and processes. Rosenberg (1982, p288) comments:

'Consider, for example, the dissolution of the boundary line that could once be drawn between the telecommunications and computer industries. The microchip revolution and the growing information-processing needs of business are converting computers into forms that increasingly resemble telecommunications networks, whereas the old telephone system has already become, in a very meaningful sense, a gigantic computer.'

(4) The key findings, including quantitative analysis of trends in TFP may be found in IAC (1982), Appendix 2.3, "Sources of Economic Growth", pp155-161. It should be noted that differences in the share of growth attributable to improvements in total factor productivity (TFP) between Australia and other OECD countries cannot be explained simply by differences in the sectoral pattern of output. International comparisons of TFP in manufacturing are presented in Section 3.1.

(5) See Duncan and Fogarty (1984), pages 122 to 135.

(6) The relative decline in the use of raw materials as a proportion of world GDP, at about 1 per cent per year, is discussed by Sapsford (1985) as well as by FitzGerald and Urban (1986).


(8) For the purpose of international comparisons, the OECD's definition of business enterprises includes enterprises in both the private and public sectors.

(9) See OECD (1986a), Table 5. The share of total R&D funded by the private sector has been between 16 and 17 per cent over most of the last decade, while the share carried out by the public sector has been slightly higher at between 18 and 19 per cent. More recently, there has been a large increase in these shares to about 25 per cent in 1984-85, but this is still below the proportion recorded for 1973-74 (32 per cent).

(10) Such arguments have been set out in AITC (1985).

(11) The figures relate to government R&D funding; see Department of Science (1986), Table 13. Agricultural R&D in Australia is carried out predominantly in specialised research institutes.

(12) The substantial increase in R&D expenditure by business enterprises recorded in 1984-85 may have increased private sector R&D intensity in manufacturing to around 1.2 per cent in that year. Nevertheless, there has clearly been a declining long-term trend.

(13) High R&D intensity industries include aerospace, office machines and computers, telecommunications and pharmaceuticals among others. The automobile and chemical industries are part of the medium R&D intensity group while the low intensity group includes food, beverages and tobacco, textiles, footwear and leather, and paper and printing. A more detailed discussion can be found in OECD (1986b), Part II, Chapter II.

(14) Dwyer and Alchin (1986) note that for the Australian economy as a whole, GERD as a proportion of gross fixed capital expenditure has declined since 1975-76 and in 1981 amounted to 4 per cent compared with an average of 10 per cent for the major OECD countries. The proportion for Australia was less than most other countries, including Denmark, Norway, Finland and New Zealand.


(16) Problems with the data include some doubt about the extent of activity that is identified by the Australian Bureau of Statistics survey and the amount of technology transfer occurring between subsidiaries and parent companies overseas; see Johnston and Hartley (1986).

(17) Figures for OECD countries are as reported by Dwyer and Alchin (1986).
(18) OECD (1986b). Tables 2.8 and 2.9.

(19) OECD studies have shown that, between 1975 and 1980, high R&D intensity manufactured exports of industrial countries grew in real terms at a faster rate than low-to-medium R&D intensity exports. Between 1980 and 1983, exports of low-to-medium intensity manufactures declined while high intensity manufactured exports continued to increase, albeit at a diminished rate.

(20) See Rosenberg (1982), particularly Chapters 1 and 7.

(21) The influence of demand pressures on the direction of inventions is discussed by Schmookler (1965). The influence of potential profitability on the pace of diffusion of new technologies has been noted by Griliches (1960) and by Mansfield (1968).

(22) Rosenberg (1982, p. 246), describes the complementarities of the major industrial revolution technologies as follows:

‘Often, one innovation could not be extensively exploited in the absence of others or the introduction of one innovation made others more effective. Metallurgical improvements, for example, were absolutely indispensable to the construction of more efficient steam engines. The steam engine, in turn, was utilised for introducing a hot blast of air into the blast furnace. The hot blast, by improving the efficiency of the combustion process, lowered fuel requirements and thereby reduced the price of iron. Thus, cheaper metal meant cheaper power, and cheaper power was translated into even cheaper metal. Similarly, the availability of cheap iron was essential to the construction of railroads. Once in place, however, the railroads reduced the cost of making iron. But cheaper iron, in turn, meant cheaper rails, this involved a further lowering of transportation costs, which again decreased the cost of producing iron. Thus, part of the secret of the vast productivity improvements associated with the new industrial technology was that the separate innovations were often interrelated and mutually reinforcing’.

(23) See Griliches (1960).

(24) Findings similar to those of Enos (1958) on the oil refining industry were found by Holander (1965), who studied the evolution of the rayon industry. In his study of the sources of increased efficiency in Du Pont’s rayon plants, he found that the cumulative effects of minor technical changes on cost reductions were greater than the effects of major technical changes.

(25) See Caves and Uekusa (1976), p. 126. Ergas (1984) describes the system of 195 regional laboratories in Japan which provide a link between central government laboratories conducting sophisticated R&D and the industrial base of their regions. These laboratories’ primary function is the diffusion of late technology. Ergas notes that:

‘...the staff of the prefectural laboratories are systematically retrained by the central government to keep them abreast of the latest developments in science and technology.’

(26) Sony, under its earlier name, Tokyo Tsushin Kogyo, licensed the Bell Labs transistor from Western Electric. An American company, Regency, supported by Texas instruments beat Sony to the market with the transistor radio, but they withdrew the product. This story is told in Morita (1986, p. 36f), who describes Sony’s research effort on the transistor:

“We had to raise the power of the transistor — otherwise, it could not be used in a radio. It was very complicated work and our project team went through a long period of painstaking trial and error, using new, or at least different materials to get the increased frequency we needed. They had to reevaluate and virtually reinvent the transistor’ (p. 67).

(27) On pages 147 to 155, Rosenberg (1982) describes a number of fundamental scientific breakthroughs made at Bell Laboratories in USA which resulted from research to solve practical problems connected with the commercial application of earlier inventions. In addition to the examples cited in the text, Rosenberg notes that the decision by Bell Laboratories to undertake a basic research program in solid state physics, which culminated in the development of the transistor, was prompted by the desire to improve the reliability of vacuum tubes.

(28) An interesting example of a backward linkage from industry to tertiary education is noted by Rosenberg (1982). Before the advent of the transistor, solid state physics (which is now the largest subdiscipline of physics) was hardly taught at universities. He recounts that one of the scientists at Bell

‘...ran a six-day course at Bell Labs in June 1952 for professors from some thirty universities as part of an attempt to encourage the establishment of courses in transistor physics. Clearly, the main flow of scientific knowledge during this period was from industry to the university.’ (p. 155)
(29) Ergas (1984) summed up the importance of industry-university linkages for the quality of industrial R&D as follows:

"...the closer these links are:
- the more likely it is that applied science research in the universities will concentrate on the real technical challenges facing industry;
- the lower the investment firms will have to make in the more fundamental - and hence non-appropriable - aspects of research; and
- the quicker the transmission between firms of new technical results."

(30) The attractiveness of a 'fast-second' strategy based on rapid imitation is discussed by Rosenberg (1982, p 286). He also stresses opportunities available to those who can devise new uses for previous discoveries; an interesting set of examples may be found on pages 185-186.


(32) The correlation of these factors to total factor productivity growth is less strong. The comparisons by Denison (1967) and others, cited in Section 2, indicate that the contribution of TPP to US economic growth has been lower than in North-West Europe or Japan. The discrepancy between a lead in technological performance indicators used by Ergas (1984) and TPP performance could be explained by:
- TPP improvements can stem from many factors (e.g., better inventory control and other management techniques) which are not captured by the high-technology related indices used by Ergas (1984).
- The ability of other countries to exploit, perhaps more effectively at times, technological advances originated in the US.

(33) Charles (1986a) summed up this contrast as follows:

"The experience of manufacturing industry in this regard stands in a sharp distinction to that of our primary and mining industries. They achieved their competitive position in world markets not just through the richness of our resource endowment but also because of the contribution of Australian science and technology. One has only to think of the work done on seed types and soils for the agricultural industries and the work done on processing relatively low grade ores to realise the truth of this statement. These industries were always selling in world markets and therefore had to be internationally competitive right from the start. Effective means were found to harness our science and technology base to the needs of these industries. Unfortunately the same pressures were not evident in the area of manufacturing industry and the traded services. The linkages are accordingly much weaker."

(34) See for example a survey of companies which applied for the 150 per cent tax concession for R&D by FA Technology, as reported in The Australian, 14 October 1986.


(36) Further details may be found in Office of EPAC (1986 #15) Section 4, pp 10-12.

(37) See Table 4.1 and Ergas (1984), p 23.

(38) See BCA (1986).

(39) ASTEC (1985c) discusses industrial relations, skill formation and training issues in the context of computer related technologies in the metal trades industry (pp 95-112).

(40) The difficulties which need to be faced in devising and implementing effective policies for technology have been well summarised by Stubbins (1981) as follows:

"While, in general, technology enlarges the economic cake, specific technological change tends to enrich some people at the expense of others, and therefore raises profound questions of economic welfare and dynamic, disequilibrium economics which are extremely difficult for the economist to resolve. Thus, while dispassionate countries find in favour of technology and its encouragement, their general approach is seldom able to resolve the conflict that arises where different parties are their interests at risk" (p 224).

These remarks are particularly appropriate in the case of the Myers report (Committee of Inquiry into Technological Change in Australia, 1980) which Stubbins concludes "is now widely viewed as a damp squib" (p230) and the ill-fated National Technology Strategy, 1984 and 1985.

(41) A review of the AIRDIS scheme by Price-Waterhouse, commissioned by DITAC indicated a close relationship between firms' involvement with R&D and their innovation activities. From a sample of 1640 respondent firms, only 1 in 6 firms with no internal
R&D had introduced a new or improved product since 1976; see Parry and McWilliam (1986).


(43) Strategies and experiences of international co-operation for R&D are discussed by Walsh (1986), Section 7 (d), paragraphs 127 to 130.

(44) Moyal (1986) demonstrates the historically wide multi-cultural input into invention and innovation in Australia. These migrants, most of them from backgrounds of strong technical education and expertise, also brought vigorous attitudes to manufacturing enterprises.

(45) A more detailed description of the 150 per cent R&D deduction and the GIRD scheme may be found in Dwyer and Alchin (1986).


(49) These issues are examined in ASTEC's (1985a) report on public investment in R&D, particularly Appendix A "The economic basis for public investment in research and development", pages 60-104.

(50) Joint Working Party on University/Business Cooperation, Report to the Business Council of Australia (BCA) and the Australian Vice Chancellors' Committee (AVCC), November 1985.

(51) The 1985 National Technology Strategy has proposed concentration on technologies that are:
- fundamental to the next generation of technological developments;
- applicable across a range of industrial and economic sectors;
- able to reinforce and extend areas of comparative advantage;
- able to contribute to the development of high value added products, processes and services for export markets;
- able to offer prospects of establishing new job generating industries based on new products, processes and services.
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The Australian record with respect to technological change is covered in Section 3 of the paper. Several indicators are used to show that, based on international comparisons, Australian manufacturing productivity was weak during the 1960s and early 1970s. The authors argue that low TFP performance may be due to relatively low innovation performance. International comparisons are cited to support the contention that Australia has a low level of innovation. The authors conclude by pointing out that Australia has not been participating in the fast growing world trade in high technology manufactures. What high technology products Australia produces tend to be domestically consumed.

Section 4 discusses the nature of the processes of technological change. Three basic determining factors are identified: demand (i.e. the incentive to innovate), supply (i.e. the ability/technological capability to innovate) and industry structure.

Elek and Camilleri make the interesting - and for Australia, highly relevant - point that institutional constraints such as inappropriate work practices can limit the potential beneficial effects of improved technology. This need for flexibility in order to take advantage of new technology is discussed at some length.

Section 5 looks at the factors which might explain Australia's mediocre performance with respect to innovation and technological performance. Factors discussed include the small, relatively unsophisticated, domestic market; industrial policies; the weak links between the education system and the demands of industry; and Australia's relatively low incidence of skill upgrading.

Section 6 outlines many recently-implemented policies designed to promote more rapid technological innovation. Some of the areas addressed are investment policies, technology transfer, R&D and industry and trade policies. The authors appear to fully endorse the policy measures introduced to date, and comment that because of overlap/interaction, there is a need for a coordinated and balanced approach to technological change in Australia. The "gradual redirection of industry policy" is seen as a complementary effort. The authors conclude that we are on the right path in respect of technological innovation, however, given our mediocre performance to date, it will be a long haul to match the progress of some of our competitors.
Industry structure is an important part of the story and is central to the development of an appropriate policy response.

The authors do not appear to view industry structure as central to Australia’s technological performance. In comparing Australia with the performance of other countries over the period 1973-1980 the authors conclude that "evidence for the manufacturing sector does not support the view that Australia’s relatively poor overall TFP performance is due to differences in economic structure". In my view the fact that we have a significant amount of Australian resources tied up in some textiles, footwear and clothing activities represents a major constraint to productivity.

If their conclusion from Section 3 of the paper was taken seriously (and I am not sure that the authors do) then we would be rather more concerned with how goods and services were produced not what was produced.

The problem is that Government policy cannot do very much about how goods are produced. However Government policy certainly influences the product mix in Australia. The structure of manufacturing protection in Australia is characterised by wide disparities in assistance levels provided to activities involving extremely simple production processes and where there is little scope for technological improvement.

In these circumstances most economists would argue that the thrust of Government policy should be directed towards encouraging a more appropriate product mix by lowering assistance provided to those activities which currently receive relatively high levels of assistance. Most economists agree that if Australia could achieve a lower and more policy neutral structure of assistance it would be possible to make better use of available resources.

I am rather more pessimistic than the authors about the effectiveness of Government policies directed towards changing how we produce goods rather than changing the product mix. Policies such as AIDC equity participation in “innovative ventures” and the MIC program to assist high technology companies to obtain funds fall into this category.
Government policy should be directed towards the consumption rather than the production of technology.

If, as the authors suggest in the introduction to their paper, the objective is to produce a more internationally competitive industry structure then Government policy should be directed towards encouraging the consumption rather than the production of technology. The major concern of Government should be to ensure that industry has access to the most appropriate technology so that production costs can be minimised. While there are technology transfer arguments for a modest offsets policy it should be recognised that this type of policy which provides an incentive for domestic production of technology can have the side effect of increasing the price which users must pay in order to have access to technology. In this way these policies can be an impediment to firms attempting to become more internationally competitive.

Where are the big gains in productivity to be achieved?

Finally I would like to raise a problem for which I have no solution. I agree with Eick and Camilleri that sustained improvements in productivity are needed. But I do not agree with the idea that it is the new high technology fields which are the key to productivity improvements.

I suspect that the key to greater productivity is to look at the institutions we have set up to produce goods and services and the way they are organised. What is the secret that Japanese firms seem to have and we do not?

There has been a major study which has been widely reported where the cost of producing a Ford Escort at various plants is compared. At the time of the study it was found that the Japanese could build the Escort for about $2500 less than if it was built in the US. About 40 per cent of this differential was due to the greater employment of white collar workers by US firms when compared to the Japanese.

This is a problem which repeatedly occurs in Australia. Recently I have been looking at productivity in ports in Australia. Port productivity is fairly easily measurable in terms of tonne equivalent units per man. Productivity between ports varies considerably. The differences cannot

be explained in terms of either capital equipment or size. In fact one of the largest ports, Port Botany, which has more capital equipment per man than most ports, has one of the lowest productivity levels. The major factor explaining the differences is that at Port Botany only about half of the labour engaged is actually handling cargo whereas in "high" productivity - at least by Australian standards - the figure is more like 60 to 65 per cent of labour actually handling cargo. Port Botany has one supervisor for every 33 men actually moving cargo.

Lester Thurow has been drawing attention to these problems for some time. He argues that the institutions set up in developed Western economies to produce goods and services reward people in accordance with the number of people that they supervise and that when institutions are forced to rationalise the decision makers lay off people who are least like themselves: they lay off people on the assembly line, not middle management.

I think that the secret of obtaining significant productivity improvements is to recognise that in most activities we tend to over manage and that we have institutions which provide incentives for this tendency to be maintained. While it is easy to identify these problems there are no easy solutions. Economists do not have theories which adequately address these problems. Governments are not well suited to develop policies which might help in solving these problems. As I said at the outset I have no solution but I do think this is one of the most important aspects which needs to be considered if we are to achieve significant increases in productivity.
COMMENTS OF SECOND DISCUSSANT:
Kenneth W. Clements*
University of Western Australia

I would like to start on a personal note regarding Fred Gruen in whose honor this conference has been organized. Fred has been a close colleague and friend of mine. He has made a remarkable contribution to Australian economics with his research and other activities at the CEPR. The conferences that Fred's Centre have organized over the years have been extremely valuable in bringing academics and policy makers together and have made a noticeable contribution to policy discussion in Australia.

I was very pleased that Fred was able to deliver the 1985 Shannon Memorial Lecture, our annual public lecture at UWA in economics. The lecture, "How Bad is Australia's Economic Performance and Why?" (Economic Record 61, June 1986, pp. 180-93), was an excellent contribution and I am happy that it acted as the stimulus to the subject matter of this conference.

The paper by Elek and Camilleri argues that Australia's performance regarding technological change has been less than satisfactory. It sets out reasons for this poor performance and concludes that, with some luck, recent policy initiatives should facilitate the introduction of new technology.

1. Australia's Major Problems

To focus my comments, I wish to start by arguing that there are three fundamental causes of Australia's current economic problems:

(i) The growth of government.

(ii) Highly protected and regulated markets for goods and labour.

(iii) The collapse of international markets for many of our primary products.

* I would like to acknowledge helpful discussions with my UWA colleagues Robin Ghoosh, Abu Siddique and Alfred Wong. They, however, do not necessarily share my views.