JOINT STANDING COMMITTEE ON FOREIGN AFFAIRS, DEFENCE AND TRADE

TRADE SUB-COMMITTEE

IS AUSTRALIA ENTERPRISING ?

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SUMMARY

- While Australia's research and development expenditure relative to that of other industrial countries is at a rather mediocre level this is almost entirely a consequence of the low level of expenditure on research and development by the manufacturing sector. When this low level of expenditure is taken into account Australia's performance in the combined government, higher education and the non-manufacturing sub-sector of the business sector is substantial. It is amongst the highest in the world.

- It is possible to demonstrate that the majority of researchers in the manufacturing sector are engineers.

- If Australia's manufacturing sector were wished to perform research and development in the manufacturing sector at a level commensurate with the median level of the industrial nations of the world it would be hard put to it to recruit sufficient numbers of engineers with the appropriate types of engineering qualifications to perform this work.

- Recognising the critical importance of an adequate supply of engineers for the performance of research and development as well as other technological functions, many foreign countries are producing, relative to population, many more engineers than Australia. In fact few industrial countries produce fewer engineers per million population than Australia.

- On present indications Australia's poor relative performance in regard to the education of engineers is likely to persist for at least the next four years.

- If it is proposed that Australia's manufacturing become internationally competitive it will therefore be necessary to take prompt action to attract many more persons into engineering courses.

INTRODUCTION

The pattern of Australia’s research and development effort differs substantially from that of many other industrial countries. Despite the repeated claims to the contrary by the partisans of Australian science the level of basic research in Australia continues to compare favourably with that achieved in many other countries. In addition the level of research and development expenditure in the so-called publicly-supported sectors (higher education and government laboratories) continues at a level that, while not quite so high as it has been in the past, exceeds that of many of the OECD-member nations. When one compares the detailed breakdown of research and development expenditure in Australia with that of other countries it becomes clear that the only sector of the economy in which there is an comparative serious shortfall is the manufacturing sector.

While Australia continues to downplay manufacturing and pursue policies that maintain the derivative nature of our technology, the relatively low rate of graduation of our engineers may not be very critical. However, if we seek to raise the level of research and development (R&D) in the manufacturing sector so that it is comparable with the level prevailing in countries such as Sweden, Finland, Korea or Taiwan it is likely that there will be insufficient young engineering researchers to enable this to be achieved. Therefore the problem that could face Australia is that of attracting adequate numbers of young people into professional engineering and in particular into mechanical and electronic engineering and their related specialities.

1. THE STRUCTURE OF AUSTRALIAN RESEARCH AND DEVELOPMENT

The distribution of Australia's research and development (R&D) effort between the sectors of the economy differs from that of many other countries. In view of this it is appropriate to give consideration to the detailed pattern of R&D expenditure between sectors as compared with other industrial countries.

Conventionally, for statistical purposes national R&D expenditure is divided between four sectors - government, higher education, the business enterprise sector and the private non-profit sector. The business enterprise sector is further sub-divided into the manufacturing and non-manufacturing sub-sectors. The standard abbreviations for the level of R&D expenditure in the main sectors of the economy are as follows :

- Government — GOVERD
- Higher education — HERD
- Business enterprise — BERD.

I will use the abbreviation MFGERD to refer to the level of R&D expenditure in the manufacturing sub-sector of the Business Enterprise Sector.

Australia's overall level of R&D expenditure relative to Gross Domestic Product (GDP) is at a middling level in comparison with other countries which are members of the OECD and certain other countries for which data are available. In contrast the level of R&D expenditure in this country's combined government and higher education is among the highest in the world (see Table 1). This combination of R&D sectors is frequently referred to as the publicly-supported sectors.

It is widely acknowledged that the Australian business enterprise sector's R&D effort compares badly with that of the other industrial nations. What does not appear to be so generally recognised is that the R&D expenditure of the non-manufacturing sub-sector of the business enterprise sector compares quite favourably with that of many other nations. It is the low level of manufacturing sub-sector R&D which results in the poor showing of the Australian business sector's R&D effort. This is clearly demonstrated in Table 2. Australia's MFGERD was 0.33 % of GDP in 1998-99. As I pointed out in a study that was published in 1991 that level is not much greater than the level that prevailed as long ago as 1968-69 and even then compared badly with that of many other countries (Rice M.R., 1991).

The median value of MFGERD for all countries in the tabulation is 0.88 % of GDP. Australia's level is less than 40 % of that median value. The only countries that we outperform are Iceland (barely), Hungary, Poland, New Zealand, Turkey, Portugal, Greece and Mexico. Since the data in the tabulation were collected it is likely in contrast with the future course of Australian manufacturing R&D the levels of such R&D in many other countries will have increased.

In a later section of this submission I will consider the human resource consequences of setting Australia's manufacturing R&D effort at a level commensurate with that of the median level indicated above. Attainment of such a level would still leave us trailing a number of small countries.

TABLE 1

GOVERD PLUS HERD
OECD MEMBER COUNTRIES

(Per Cent GDP)

Country	HERD plus GOVERD
Iceland	1.26
Israel	1.05
Sweden	0.97
Netherlands	0.95
Finland	0.95
France	0.84
New Zealand	0.80
Australia	**0.79**
Germany	0.76
Korea	0.76
Denmark	0.73
Taiwan	0.73
Norway	0.72
Switzerland	0.71
Singapore	0.69
Japan	0.67
Austria	0.65
United Kingdom	0.63
Canada	0.63
USA	0.61
Belgium	0.49
Italy	0.48
Czech Republic	0.46
Poland	0.45
Turkey	0.44
Spain	0.43
Portugal	0.42
Greece	0.40
Hungary	0.39
Ireland	0.38
Mexico	0.27

Notes : 1 Data for Austria are for 1993; data for Belgium are for 1994; data for Israel are for 1995; data for Switzerland are for 1996, data for Singapore are for 1999; data for Canada, Czech Republic, Finland, Germany, Hungary, Finland, Italy, Australia and Taiwan are for 1998. The data for all other countries are for 1997.

Sources : 1. “Basic Science and Technology Statistics - 1999” , OECD, Paris
2. “Indicators of Science and Technology, Republic of China, 1999”, National Science Council, Taiwan, 1999.
3. National Science and Technology Board, Singapore.
4. “Statistical Abstract of Israel”, Central Bureau of Statistics, Israel.

TABLE 2

R&D EXPENDITURE IN THE MANUFACTURING SECTOR (MFGERD)
IN OECD COUNTRIES AND TAIWAN
IN DESCENDING ORDER OF MAGNITUDE

(PER CENT OF GDP)

Country	MFGERD % GDP
Sweden (1997)	2.33
Japan (1997)	1.93
Korea (1997)	1.75
Switzerland (1996)	1.56
United States (1997)	1.55
Finland (1997)	1.54
Germany (1997)	1.45
Taiwan (1998)	1.21
France (1997)	1.19
United Kingdom (1998)	1.00
Singapore (1999)	0.95
Ireland (1997)	0.94
Belgium (1995)	0.93
Israel (1997)	0.90
Netherlands (1997)	0.88
Denmark (1998)	0.88
Canada (1998)	0.67
Czech Republic (1998)	0.64
Austria (1993)	0.63
Italy (1998)	0.47
Norway (1997)	0.41
Spain (1997)	0.34
Australia (1998)	**0.33**
Iceland (1997)	0.31
Hungary (1998)	0.22
Poland (1997)	0.22
New Zealand (1997)	0.19
Turkey (1997)	0.13
Portugal (1997)	0.10
Greece (1993)	0.08
Mexico (1997)	0.04

Source : 1. “Basic Science and Technology Statistics - 1999” , OECD, Paris
2. “Indicators of Science and Technology, Republic of China, 1999”, National Science Council, Taiwan, 1999.
3. National Science and Technology Board, Singapore.
4. “Statistical Abstract of Israel”, Central Bureau of Statistics, Israel.

2. R&D PERSONNEL IN THE MANUFACTURING SECTOR

In considering the potential human resource consequences of increasing the level of Australia’s manufacturing R&D it is necessary to devote some discussion to the nature of the professional personnel employed in the performance of R&D in that sector.

Contrary to a widely held belief the great majority of researchers in the manufacturing sector are engineers rather than scientists. In a study published in 1994, I demonstrated that in such countries as the United States and Japan the majority of researchers in the manufacturing sector were engineers (Rice M.R., 1994). I estimated that it would be reasonable to conclude that about 80 % of such researchers were engineers. In view of the nature of R&D in the manufacturing sector very few of those engineers would have civil engineering qualifications. Following that time I obtained data relating to Taiwan. Analysis of those data supported the findings of the earlier study.

Many readers will find it difficult to accept that scientists perform a relatively minor role in industrial R&D but data relating to the occupational of the technological work force of specific industries make it clear that this is so. I will provide three examples.

The first of these relates to the computer and office equipment manufacturing sector in the United States. The most recent data available to me (National Science Foundation, 1995a) show that this sector employed 70,840 engineers in 1992 and 220 physical scientists (chemists and physicists). There were also 790 mathematical specialists and 10,320 computer specialists. In the same year the number of engineers engaged in R&D in that sector was 67,100 (National Science Foundation, 1995b).

The second of these relates to the electronic component and accessories manufacturing sector (microprocessors etc.) in the United States. The most recent data (National Science Foundation, 1995a) show that this sector employed 58,540 engineers in 1992 and 1,690 physical scientists (chemists and physicists). There were also 520 mathematical specialists and 5,110 computer specialists. In the same year the number of persons engaged in R&D in that sector was 28,400 (National Science Foundation, 1995b).

The third of these relates to the communications equipment manufacturing sector in the United States. The most recent data (National Science Foundation,1995a) show that this sector employed 35,720 engineers in 1992 and 230 physical scientists (chemists and physicists). There were also 110 mathematical specialists and 3,360 computer specialists. In the same year the number of persons engaged in R&D in that sector was 31,200 (National Science Foundation, 1995b).

It is clear from the above figures that even in the extremely unlikely situation that all scientists and information technology specialists in these industries were engaged solely in R&D, engineers would still be the predominant group of professionals in the ranks of researchers in those industries. For example, in the case of the American electronic component industry, if all scientists and computer specialists were engaged in the performance of R&D only 26 % of the researchers in that industry would have not been engineers.

3. THE HUMAN RESOURCE IMPLICATIONS OF INCREASED INDUSTRIAL R&D

The determination of the human resource requirement generated by increases in R&D expenditure are rarely considered by policy makers. However, it is a very informative exercise to examine the implications for human resources of an increase in R&D expenditure. In the case of the manufacturing sector there is a close relationship between the number of researchers and the level of expenditure on R&D. This is because R&D is a highly labour intensive activity.

In 1998/99 one researcher equated to $270,000 of R&D expenditure. This figure may be employed as an approximate means of determining the number of researchers implied by a given level of expenditure and I will use as the basis for the following calculation of personnel requirements.

Let us assume for example, that in 1988/99 Australia had set a target for manufacturing R&D expenditure at a level equivalent to the median value of MFGERD for the countries (excluding Australia) shown in Table 2, that is 0.89 % of GDP. The resulting level of expenditure in 1998/99 would have been $5.3 billion. Dividing this amount by $270,000 provides an estimate of the required number of researchers, that is, 19,600 researchers. That number is 12,250 greater than the actual number of researchers employed in the manufacturing sector in 1998/99.

Of these additional 12,250 researchers let us assume that 80 % would need to be engineers. This represents a need for an incremental increase of research engineers of 0.8 times 12,250 or 9,800 engineers and an incremental increase in the number of research scientists and I.T. specialists of 2,450. There would be some difficulty in recruiting 9,800 additional research engineers who were qualified in mechanical, electronic and other appropriate engineering disciplines. As mentioned in the foregoing there are very few civil engineers in the research work force of manufacturing industry.

Currently, about 4,500 Australians graduate in engineering (other than civil engineering) each year. The provision of an additional 9,800 research engineers for the manufacturing sector would, in the absence of other demands for the services of engineers require two years' graduations in engineering. However, the professional engineering work force engaged in other activities than industrial R&D is itself growing at an annual rate of at least 3 %. In addition to providing the numbers for this continued growth there are replacement needs arising from emigration, retirements and deaths. Bearing in mind the fact that there is reasonably full employment in the engineering profession the difficulty of providing the numbers for even the relatively modest level of R&D represented by 0.89 % of GDP is not difficult to imagine.

In contrast, the estimated incremental need of 2,450 scientists and I.T. specialists represents only a fraction of one years' output of graduates in these fields. Currently, about 17,000 Australians graduate in these fields of study each year. Prima facie, there should not be any great difficulty in filling 2,450 new R&D positions relating to the sciences.

In considering the implications of the foregoing certain other factors need to be kept in mind. The above calculation of requirements related to 1998/99. Australia's GDP is now somewhat greater and the estimated incremental need for researchers would be correspondingly greater; even the maintenance of R&D expenditure at a given level of GDP requires an ever increasing commitment of human resources. The other factor is that, historically a high proportion of the countries listed in Table 2 have been steadily increasing the proportion of their GDP that is devoted to R&D in the manufacturing sector. Thus, it is likely that the median level of R&D expenditure will contain to increase. In that sense a target of the type discussed in the foregoing is a moving target.

I have examined the longer term prospects for the balance of the supply of and demand for in an earlier report (Rice M.R.,1993) and concluded that the availability of suitably qualified engineers for the performance of an increased level of manufacturing R&D would continue to be a limiting factor.

4. THE SUPPLY OF ENGINEERS

Currently, there are over 147,000 engineers in Australia under the age of 65 (Rice, M.R., 2001). The number of engineers has increased steadily for the last 130 years and since the Second World War the growth of the engineering profession has paralleled the growth in Australia's GDP. A similar situation has applied in the United States. If one postulates a continued growth in our GDP of 3 % per annum over the period 2001-2010 it would be reasonable to assume that the need for professional engineers would increase commensurately. On present indications it is not likely that such a rate of growth in the number of professional engineers will occur. The foregoing comments relate to engineers engaged in other functions than R&D. These issues are discussed in a forthcoming book (Lloyd et al., 2001).

As indicated above, if Australia's manufacturing sector's expenditure on R&D were to be increased to the average level of expenditure that prevails in the OECD there could be difficulty in providing the human resources to undertake that level of activity. Assuming that it was intended that catch up were to take place by 2010 there would then be too few engineers in the appropriate age group and with the appropriate education and skills to support the required level of expenditure (Rice, M.R.,1993). This is a factor that is usually ignored by policy makers and there advisors. It is assumed that there is a limitless supply of skills in the community whereas there are clear limits on the future availability of engineers in general and specialist engineers in particular. R&D is a labour intensive activity predominantly undertaken by electronic, communication, electrical and mechanical engineers in the earlier stages of their professional careers. In this regard it is significant that the median age of the respondents to surveys of the engineering profession who indicated that they were engaged in the performance of R&D was 31 years of age. Only 20 per cent of these respondents was over the age of 38.

An argument that might be used to assume away human resource problems is that immigration of engineers to Australia might continue at a relatively high level. However, the fact that the median age of immigrant engineers is 33 and the fact that many of these engineers would take a year or two to adapt to Australian engineering practice and culture implies that this source of new engineers might not be of much assistance in overcoming any human resource deficit of research engineers.

Essentially, the only reliable means by which an adequate supply of engineers could become available would be to increase the number of engineering graduates. A number of foreign countries have done just that and have focused a significant proportion of their educational resources on so doing. Furthermore they tend to be increasing the number of engineering gadgets. As an example Korea has increased the annual number of engineering graduates from 11,492 in 1980 to 41,309 in 1997(National Science Foundation, 1993 and National Science Board, 2000). In contrast the number of graduates in the physical and biological sciences increased from 3,800 in 1980 to 11,447 in 1995 (National Science Foundation, 1993 and UNESCO, 1997).

5. ENGINEERING EDUCATION OVERSEAS

The rapid increase in the annual number of persons graduating in engineering in Australia might lead one to optimistic conclusion that the annual rate of graduation of engineers in Australia would compare favourably with the situation prevailing in other countries. Nothing could be further from the truth as a perusal of the following table would indicate. This table compares the annual number of graduates with first degrees in engineering relative to population for a number of countries. The countries are listed in descending order of magnitude.

The data relate to a period five years ago, except in one or two cases as noted in the table. These are the most recently available data. There is no reason to believe that the passage of time since the mid-1990s has resulted in a change in the relative standing of the countries in the table although the magnitudes of the rates of graduation of some of the countries may have increased. Singapore is one such country.

As discussed below, recent data regarding enrolments in professional engineering courses in Singapore suggest that within the next few years annual graduations of engineers will achieve a level equivalent to 1,000 per million population — the highest in the world. As indicated in an earlier chapter, it is likely that the number of Australian engineering graduates per million population will decline.

It is readily apparent that Australia graduates fewer engineers relative to population than many other industrial countries. This situation has prevailed for many years. Comparative data were first published in a study undertaken on behalf of the then Association of Professional Engineers, Australia (Rice, M.R., 1969). Later studies confirmed that Australia’s comparatively low rate of graduation of engineers had continued (Rice, M.R., 1983, 1987, and 1993). If it had not been the very large number of foreign engineers settling in Australia the size of the Australian Professional Engineer Labour force (PELF) would compare even more unfavourably with the professional engineering work forces of other industrial countries than it does. Currently, engineers whose professional qualifications were obtained overseas represent 24.1 per cent of Australia’s PELF.

In the case of Singapore the data on enrolments indicate that the already high level of commencements in engineering will result in a continued increase in the number of engineering graduations (Singapore Department of Statistics, 2000). It is likely that Singapore will graduate over 3,500 engineers annually within three to four years. That number of graduates would represent about 75 per cent of the number of graduations in Australia. The population of Singapore is less than one-sixth of that of Australia.

It is evident that a comparison of Australia's rate of graduation of engineers with the rates prevailing in the Pacific-rim countries is particularly unfavourable to Australia. The relativities indicated by the data in the table are likely to persist. This is because the number of engineers graduating in those countries continues to increase while the recent number of commencements in Australia indicate that graduations in Australia are not likely to increase substantially for at least five years.

TABLE 3

NUMBER OF FIRST DEGREE LEVEL ENGINEERING GRADUATES RELATIVE TO POPULATION

Country	Year	Number of graduations in engineering relative to population (per million)
Korea	1997	898
Singapore	1998	837
Japan	1997	816
Finland	1996	768
Denmark	1993	650
Taiwan	1997	601
Norway	1994	502
Germany	1997	486
Belgium	1993	450
Ireland	1993	435
Switzerland	1996	435
Netherlands	1997	430
Sweden	1996	410
France	1996	391
United Kingdom	1997	383
Israel	1996	311
Australia	1998	**294**
Austria	1997	202
Italy	1996	189

Sources : Derived from data published in :-

1. National Science Board, "Science and Engineering Indicators 1998",Arlington, VA: National Science Foundation, 1998 (NSB 98-1).
2. National Science Board, "Science and Engineering Indicators — 2000" Arlington, VA: National Science Foundation, 2000 (NSB 00-1).
2. "Yearbook of Statistics, 2000", Department of Statistics, Singapore, 2000.
3. Department of Education, Training and Youth Affairs, Canberra, personal communication.

It may be worth pointing out that in the last decade Singapore has embarked on the education of engineers to post-graduate level to a staggering extent. The number of Singaporeans completing higher degrees in engineering has increased from 126 in 1993 to 891 in 1999. The latter figure does not fall far short of the current number of completion of higher degrees in engineering in Australia. Enrolment data indicate that the rate of graduation of Singaporean engineers with higher degrees will continue to increase. Currently, higher degree enrolments in engineering represent 44 per cent of all higher degree enrolments in Singapore. In contrast, higher degree enrolments in natural, physical and mathematical sciences are less than 7 per cent of total enrolments.

That the "Asian tigers" are concentrating on the expansion of their professional engineering work forces is unquestionable. The same cannot be said of their attitude to the supply of natural scientists. In Singapore's case, the total number of undergraduate enrolments in the natural sciences is only one-fifth of the number of undergraduate enrolments in engineering. Despite this the number of enrolments in the former has increased only 16 per cent in the period 1993 to 1999. In the same period the number of undergraduate enrolments in engineering has increased by nearly 90 per cent. A somewhat similar pattern prevails in post-graduate education in that country. The following table provides a powerful demonstration of the emphasis on engineering education that exists in many countries other than Australia. It is noteworthy that the dynamic Asian economies are to the forefront of these comparisons. It is also noteworthy that Australia's relative standing places it in last place in both comparisons. Not only does Australia take last place but it lags badly behind most of the countries in the tabulation.

TABLE 4

ENGINEERING GRADUATES AS A PROPORTION OF ALL GRADUATES
(Bachelor Degree)

Country	Engineering graduates as a	Male engineering graduates

	proportion of all graduates (%)	as a proportion of all male graduates (%)
Singapore	28.4	48.1
Finland	25.1	42.6
Belgium	22.0	33.0
Germany	20.6	30.1
Japan	19.7	27.3
France	18.7	26.8
Switzerland	17.9	n.a.
Taiwan	17.7	24.3
Netherlands	16.7	22.5
Korea	16.2	30.5
Sweden	15.9	27.7
Denmark	15.2	29.6
Norway	11.5	30.1
Ireland	11.3	20.4
Austria	10.3	16.4
United Kingdom	9.3	22.3
Italy	8.7	16.9
Australia	**6.2**	**12.1**
United States	5.3	5.9

Note : The data for all countries relate to 1994 except for the following countries which are listed together with the year to which the data for each country relates.
Australia - 1998; United States and the United Kingdom - 1996; Japan, South Korea, Republic of China (Taiwan), Austria and Switzerland - 1995; Belgium, Denmark, Ireland and the Netherlands - 1993; Singapore - 1999.

Sources : Derived from data published in :-

1. National Science Board “Science and Engineering Indicators — 1998”, Arlington, VA: National Science Foundation, 1998 (NSB 98-1).
2. “Yearbook of Statistics, 2000”, Department of Statistics, Singapore, 2000.
3. Department of Education, Training and Youth Affairs, Canberra, personal communication.
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6. CONCLUSIONS

The level of R&D expenditure in Australia’s manufacturing sector is abysmally low. It is lower than the level that prevails in many of the countries, small and large, with which we might wish to compete. Most of these countries are expanding their manufacturing R&D and are seeking to provide the personnel with which to support such expansion. This is why they concentrate on engineering education and in most cases give less support to science education both at undergraduate and post-graduate levels.

It is evident that any substantial increase in the level of R&D in the Australian manufacturing sector will be constrained by the limited availability of appropriately qualified engineers in the earlier stages of their careers. The lead time from the point at which a decision is made to study the enabling subjects appropriate to engineering studies in the final years of secondary education to the time of completion of an engineering degree (seven or more years) is relatively long. Therefore any solution by means of a substantial increase in the number of engineering graduates should be implemented as promptly as possible. This is a far more urgent matter than increasing the level of R&D in academic institutions.

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