The Australian Pharmaceutical Industry and its Global Context

Working Paper No. 7

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Pharmaceutical Industry Project
Equity, Sustainability and Industry Development
Working Paper Series

September 2002

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Abstract

The knowledge content in OECD economies has intensified over the last two decades (OECD 2001). As a sector of strategic importance for social welfare, the pharmaceutical industry has attracted considerable research energy. However, there has been insufficient attention given to the industry in macroeconomics; only fragments of the big picture are recorded. Several studies also point to a trend towards concentration of business activity in the USA away from Europe. We seek to gain more comprehensive view of the industry. The evidence presented here highlights the diversity of OECD countries and the rise of a few centres of excellence in the 1990s. The paper also reviews the performance of the Australian industry and compares it with other OECD countries.

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1. Introduction

Our intuition of a modern economy has undergone a radical shift in the 1990s. Now, knowledge creation and innovation are seen as crucial indicators of economic vitality and social welfare. In fact, the knowledge content in OECD economies has intensified over the last two decades (OECD 2001). The high-technology sector plays a crucial role in the "knowledge economy". It contributes significantly to economic growth and is a major investor in knowledge.

Developments in the science/evolution literature reinforce the above shift in economic thinking. A new hypothesis has emerged. Summarised in the term "global brain", it emphasises "group selection" as the driving force of human evolution (Bloom 2000). In contrast to the neo Darwinian view of "individual selection", the new hypothesis re-emphasises the old view of humans as "social animals" and the imperative of group think, associations and networks as a superior "learning machine". Global brain is defined as:

> …a worldwide-webbed intelligence which telegraphs its knowledge more instantaneously than do we, a group brain without parallel in creativity, the microbial mesh which links quadrillions of individuals into its processing machinery. (p. 209)

Professor Bloom also refers to the pharmaceutical industry as a very active player at the frontier of global brain evolution. The recent genetic coding of the Human Genome and the "astonishing surge of medicines" seem consistent with the Landau, Achilladelis and Scriabine (1999) view that the pharmaceutical industry has revolutionised human health.

The pharmaceutical industry features prominently in the high-technology sector. It relies heavily on a workforce with high education and research skills. The general perception is that, over the last 15 years, the industry has become a significant manufacturing sector in terms of production, investment, innovation, international trade and employment. The industry has attracted considerable research energy in recent times. However, most of the studies are limited to the microeconomics of pharmaceuticals and health and only fragments of the big picture are recorded.[1] For such an important industry, it seems high priority to obtain an integrated, comprehensive, global view of the industry.

According to Gambardella et al. (2000), the birth of the pharmaceutical industry is almost synonymous with Europe but more recently there is a "diffused perception" that Europe has lost its competitiveness when compared with the USA. The authors confirm the view

[1] APMA (2000) and Jacobzone (2000) are important exceptions.

of Europe as a laggard but highlight the fact that Europe is not a homogenous group. In the light of this, we re-examine the most recent evidence.

Australia has a reputation as a nation with a highly educated population and a strong information and communication infrastructure. There has been some time since the pioneering work of AEA (1998) that outlined the profile of the Australian pharmaceutical industry. Although some of the empirical challenges in Australia remain, there have been important developments since 1998. First, it has now become more transparent that health care is a critical element of social welfare. This is particularly relevant in view of the fact that the Australian population is aging. Second, the industry has been identified as a major contributor to innovation and health improvements. Most recently, the Australian Government has been developing an Action Agenda in order to promote the sustainable development of the industry (DISR 2000, 2002). Third, new data have appeared.

In this paper, we seek to obtain a more comprehensive view of the industry. The paper is organised as follows. Part two takes a global view by examining OECD trends. Part three focuses further on the Australian industry. We seek to ascertain what Australia's contribution has been and how the industry evolved within the manufacturing sector. Finally, we summarise our findings and conclude.

2. OECD Trends: 1987-2000

Based on existing literature, we are interested in the following questions. How has business activity evolved in the long-term? How does the industry compare with other sectors? Which nations have contributed most to the development of the industry? Towards answers, we examine indicators such as value-added, international trade, business R&D expenditure (BERD), employment and earnings.

Production and Consumption

The rise of the global pharmaceutical industry is well documented.[2] Much of the literature has identified strong growth in sales and health expenditures in OECD countries. Table 1 indicates that *private* health expenditure has grown substantially during the 1990s with consumers in the USA, Korea and Greece placing a high budget priority in health-related consumption.[3] The UK records the lowest consumption share while growth in Australia has been below average. In nominal terms, much stronger growth in sales is evident that reflects the well-known growth in health expenditures by the public sector.

[2] For details, see DISR (2001), OECD (2001) and EFPIA (2002).
[3] These trends have been attributed to ageing populations and rising living standards (US Department of Commerce 2000).

Table 1. Real health consumption expenditure and sales (1991-1999) (%)

	Consumption	Average annual growth (1991-99)	
	Share (%)	Consumption[(a)]	Sales[(b)]
Australia	4.2	1.5	n.a.
Austria	3.5	3.7	n.a.
Belgium	3.7	n.a.	n.a.
Canada	3.6	n.a.	n.a.
Denmark	2.7	3.9	n.a.
Finland	3.5	1.9	8.4
France	3.6	2.2	n.a.
Germany	3.7	4.1	n.a.
Greece	5.8	4.7	15.1
Iceland	2.3	5.4	8.8
Ireland	2.6	2.0	n.a.
Italy	3.2	6.2	3.6
Japan	3.2	1.5	4.4
Korea	7.4	6.1	n.a.
Mexico	4.3	1.5	n.a.
Netherlands	4.0	n.a.	11.0
Poland	4.2	n.a.	n.a.
Spain	3.7	n.a.	n.a.
Sweden	2.0	n.a.	10.8
UK	1.2	2.3	n.a.
USA	16.2	2.9	n.a.

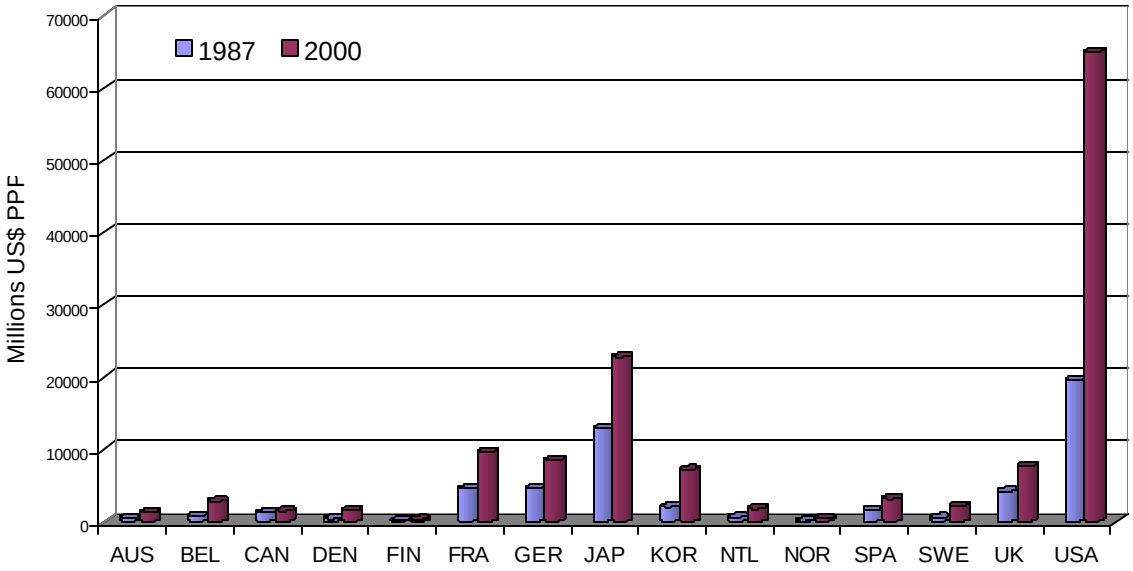
Notes: (a) constant dollars; (b) current, national currency.
Sources: OECD (2001*) National Accounts 1988-1999*; OECD *Health Data 2002*; ABS (cat. no. 5206).

OECD (2001) has identified high-technology sectors to be major contributors to economic growth, international trade and BERD. We are interested to know how the pharmaceutical industry has performed and whether some countries play a relatively more important role in the development of the industry. On prior information, we would expect the USA to have overtaken Europe as a leader.

We begin with value added as a key indicator. We focus on the 15 biggest players denoted as OECD-15.[4] Figure 1 clearly shows that the industry adds considerable value with the USA and Japan contributing most to the global economy. In growth terms, however, Figure 2 shows that several European countries made good progress; Norway, Denmark and Sweden recorded the highest growth rates. Given a high base level, growth in the USA seems remarkable.

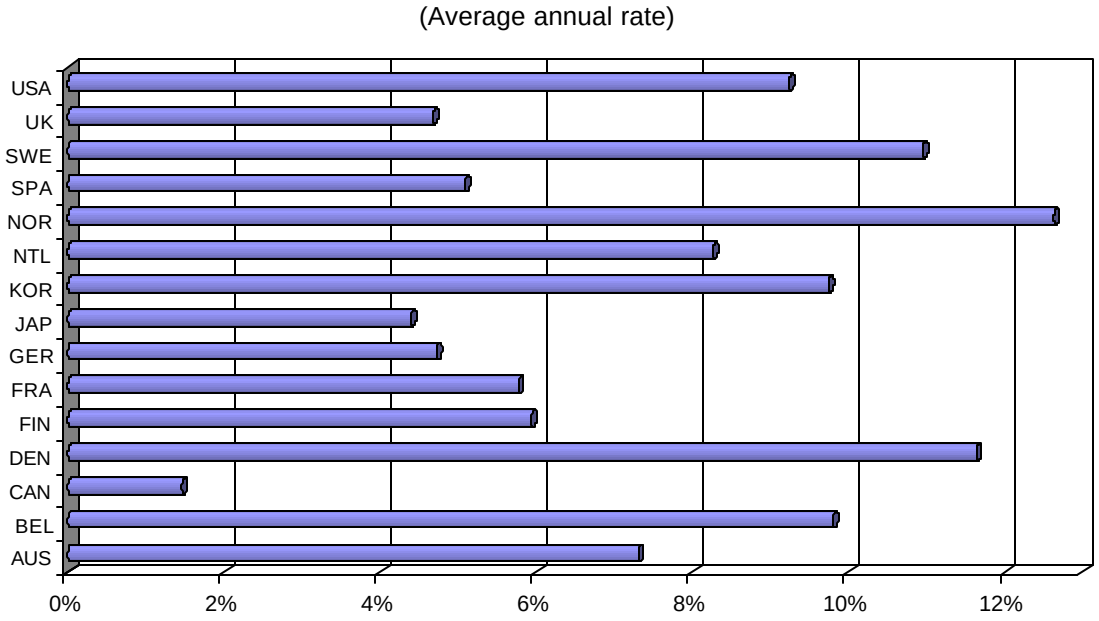
[4] The OECD-15 is: Australia, Belgium, Denmark, Canada, Finland, France, Germany, Korea, Japan, Netherlands, Norway, Spain, Sweden, the UK and the USA. See Appendix A for country codes and Appendix B for complete description of data sources.

Figure 1. Value added in pharmaceuticals: 1987 and 2000



Source: OECD (2002) *STAN Database*.

Figure 2. Growth in value added, pharmaceuticals, OECD, 1987- 2000[5]

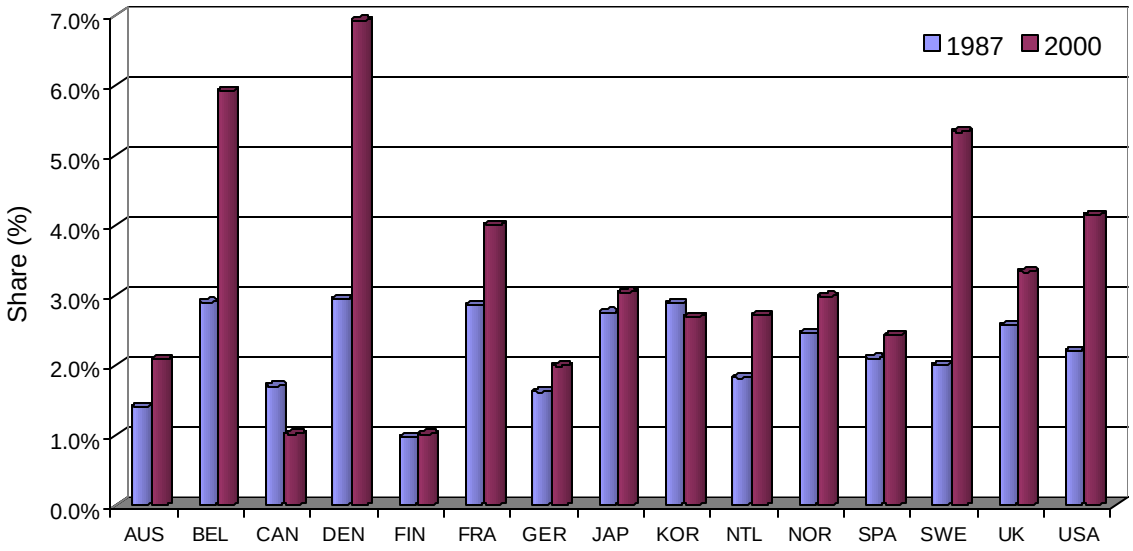


Source: OECD (2002) *STAN Database*. Figures are in 1995 US$ PPP.

Figure 3 compares the pharmaceutical industry with the manufacturing sector as a whole. The share of the former has increased substantially in Belgium, Denmark, Sweden and the USA by 3%, 4%, 3.3% and 1.9% respectively. This progress contrasts with the 1% change of Europe-10 and the relatively small shares in Canada, Germany and Japan.

[5] Growth rates are in logarithms throughout this paper.

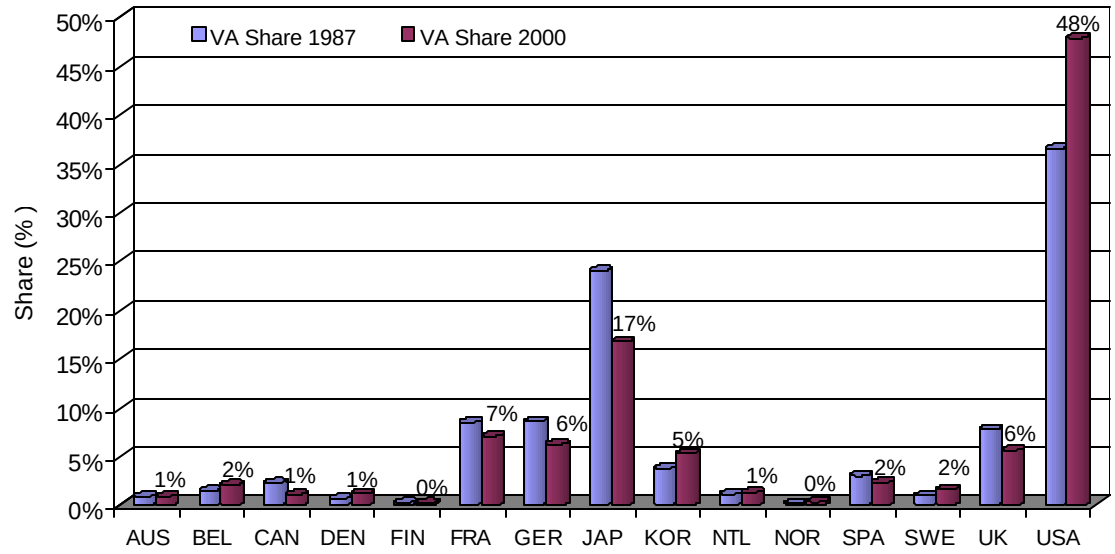
Figure 3. Value added, pharmaceuticals, 1987 and 2000 (as a % of manufacturing)



Source: OECD (2002) *STAN Database*. Figures are in US$ PPP prices.

In a global competitive environment, it is also important to assess a nation's relative performance. Figure 4 takes into account of OECD trends and focuses on the world (i.e., OECD) distribution of value added. It now becomes obvious that France, Japan and the UK performed relatively worse than the USA with the latter increasing its OECD share from 36.5% in 1987 to 48% in 2000. On the other hand, Europe-10 and Japan have both lost share to the USA with a loss of 4.5% and 7.2% points. Our earlier finding Europe as a heterogenous group is again confirmed: Belgium, Denmark, Sweden, Netherlands and Norway have all increased their share.

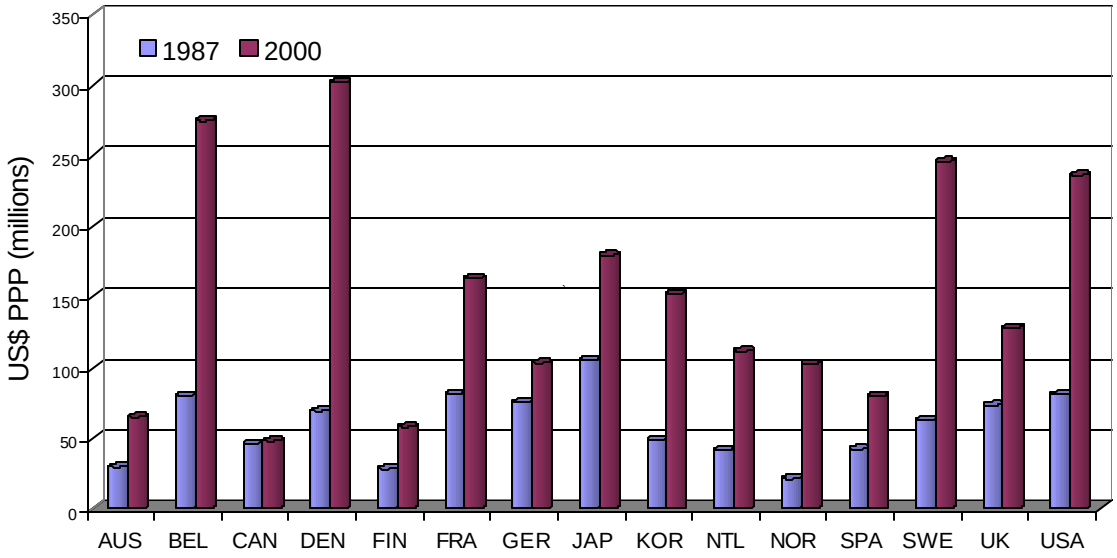
Figure 4. Valued added OECD share, pharmaceuticals, 1987 and 2000 (US$ PPP)



Source: OECD (2002) *STAN Database*.

Another useful indicator is labour productivity (value added per employee). Due to data limitations, we settle for per capital value added that shows how productive the average person has been in a particular country. Figure 5 adjusts for population differences and depicts the trend in *per capita* value added for the pharmaceutical industry. Here the re is a repeat of the pattern in figure 3 above. As well as in the USA, the average person in Denmark, and Sweden has substantially increased its value-added contribution to world GDP for the period 1987–2000. Note, Denmark has already been identified as 'extremely focused' on pharmaceuticals (European Commission 1997, p.273). It is interesting that the birthplace of pharmaceuticals accounted for only 32.5% of the total value added in OECD-15 in 1987. Moreover, Europe-10 has lagged further behind with a 4.5% reduction in its OECD-15 share, mainly due to a 2.3% and 2.1% loss by Germany and the UK respectively. We hasten to add, however, that both Canada and Japan have also seen their share diminish by 1.2% and 7.2% respectively.

Figure 5. Per capita value added, 1987 and 2000



Source: OECD (2002) *STAN Database*.

In summary, we have found the pharmaceutical industry one of the fastest growing sectors within manufacturing. The USA has further consolidated its world leadership in terms of its contribution to world value added in pharmaceuticals. As a group, Europe has lagged behind but so has Japan and Canada. In per capita terms, small north European countries have made extraordinary progress over the 1990s.

International Trade

Next, we examine the role of the industry in international trade. One would intuitively expect a knowledge-based industry such as pharmaceuticals to translate its high value added into better trade performance.

Table 2 looks at exports and imports in relation to production. The export ratio reflects an economy's capacity to satisfy world demand. The table illustrates a wide variation in export ratios with Denmark and Sweden surpassing all other countries. Note also, Australia came third last in 1998. Columns 3-4 present evidence on import penetration as an indicator of one's reliance on imports. Australia has recorded a ratio that is well above the OECD average.

Table 2. Export ratio and import penetration, OECD, 1990 and 1998, (%)

	Export ratio (a)		Import penetration (b)	
	1990	1998	1990	1998
Australia	14	22	37	45
Canada (c)	7	24	25	46
USA	8	11	7	14
Japan	4	6	8	9
Denmark	90	100	81	99
Finland	41	47	58	69
France	22	37	17	33
Germany (d)	40	57	29	45
Italy	16	50	25	53
Spain	11	25	17	38
Sweden	67	74	48	52
UK	43	56	30	47
Total OECD-11 (excl. Australia)	16	26	15	24

Notes: (a) Exports as % of production; (b) Imports as % of domestic demand;

(c) Medical, precision and optical instruments are excluded; (d) 1991 instead of 1990.

Sources: OECD, *STI Scoreboard 2001*, Tables C.2.2.1 & C.2.2.2; OECD (2002) *STAN Database*.

Table 3 further summarises the trade profile (also an indicator of openness) of various industries in OECD and Australia in the 1990s. OECD trade has grown particularly strong in aerospace, petrol products/nuclear fuel, and office/accounting/computing machinery. The pharmaceutical industry ranks fifth in terms of growth (3.1%) and its share in manufacturing. With the exception of shipping, the industry's trade share in manufacturing has grown faster than any other sector in Australia (i.e., 6.9%). Compared with total OECD, however, it appears that the industry is not as highly represented in Australian trade. In fact, this is consistent with Australia's lower than average OECD performance in high/ medium-high technology industries, defined in terms of high R&D intensity (i.e., R&D expenditure as a % of production or gross product). That said, column 2 of the same table indicates that Australia has seen strong export growth in medium-high technology sectors in the 1990s.

In summary, pharmaceutical products constitute a significant proportion of trade in manufacturing and that share has grown recently. The trade share of pharmaceuticals in Australia is almost half of the average OECD but there has been much progress in the 1990s. Despite the low representation of the high-technology sector in trade in Australia, the pharmaceutical industry stands out as the biggest sector in that industry group.

Table 3. Manufacturing Trade, OECD, 1990-1999(a)

Industry (ISIC Rev. 3)	Code	Trade Balance (AUD millions)		Annual Growth		Share in Total Manufacturing (b)					
				Exports	Imports	Share				Annual Growth	
		1990	1999	1990-99		1990		1999		1990 - 99	
		Australia		Australia		OECD	Australia	OECD	Australia	OECD	Australia
High-technology		-9006	-19615	11.3%	9.2%	18.8%	19.0%	25.3%	22.5%	3.3%	1.9%
Aerospace	353	-2131	-2622	4.4%	2.7%	1.7%	4.5%	2.9%	2.9%	6.2%	-4.7%
Pharmaceuticals	2423	-790	-2423	17.1%	13.9%	5.0%	2.0%	6.6%	3.7%	3.1%	6.9%
Office, Account. & Computing Machin.	30	-2828	-5770	8.8%	8.1%	5.4%	5.8%	8.5%	6.1%	5.1%	0.5%
Electro. Equip.(Radio, TV & Commun.)	32	-1765	-6102	12.9%	13.7%	3.3%	3.4%	3.4%	5.7%	0.5%	5.8%
Instruments, Watches & Clocks	33	-1492	-2698	14.0%	8.7%	3.5%	3.3%	3.9%	4.1%	1.2%	2.1%
Medium-high-technology		-13794	-26764	10.5%	8.1%	38.7%	29.6%	39.1%	31.8%	0.1%	0.8%
Electrical Machinery	31	-1565	-2635	12.2%	7.3%	9.4%	3.2%	8.7%	3.4%	0.8%	0.4%
Motor Vehicles	34	-4023	-9414	11.7%	9.9%	11.9%	8.6%	10.5%	10.8%	1.3%	2.5%
Chemicals (less Pharmaceuticals)	24 - 2423	-2732	-4798	9.9%	7.4%	3.7%	6.8%	4.9%	6.9%	3.0%	0.2%
Other Transport nec	352 + 359	-216	-641	7.2%	11.6%	13.2%	0.4%	14.4%	0.5%	1.0%	3.5%
Machinery, nec	29	-5256	-9277	9.3%	6.9%	0.5%	10.6%	0.6%	10.2%	2.4%	-0.4%
Medium-low-technology		3301	3202	5.1%	7.0%	17.9%	25.0%	14.1%	21.2%	2.6%	-1.8%
Coke,Ref. Petrol. Prod. & Nucl. Fuel	23	-227	1159	7.0%	-2.8%	3.2%	3.8%	1.8%	2.4%	6.1%	-5.0%
Rubber & Plastic Products	25	-1469	-2652	10.5%	7.2%	2.8%	2.7%	2.9%	2.7%	0.6%	-0.1%
Non-Metallic Mineral Products	26	-730	-1022	9.4%	5.0%	1.8%	1.5%	1.5%	1.2%	1.9%	-2.0%
Ships	351	-144	-83	20.4%	14.6%	6.9%	0.7%	4.8%	1.6%	4.0%	9.3%
Basic Metals	27	6660	7441	3.8%	10.8%	2.7%	14.0%	2.6%	11.2%	0.4%	-2.5%
Fabricated Metal Products	28	-789	-1641	4.7%	7.1%	0.6%	2.3%	0.5%	2.1%	1.4%	-1.3%
Low-technology		-1511	-2467	7.0%	6.8%	24.3%	26.4%	21.3%	24.5%	1.4%	-0.8%
Wood, Paper, Printing, Publishing	20...22	-3487	-5702	8.1%	6.2%	3.3%	8.4%	3.4%	7.6%	0.4%	-1.1%
Food products, beverages and tobacco	15+16	3989	7056	6.9%	8.0%	4.3%	11.4%	3.5%	10.9%	-2.1%	-0.5%
Textiles, Fur & Leather	17...19	-2013	-3821	6.5%	6.9%	1.4%	6.6%	1.3%	6.1%	-0.5%	-1.0%
Total Manufacturing (c)	15...37	-21011	-45644	7.3%	7.9%	100.0%	100.0%	100.0%	100.0%		

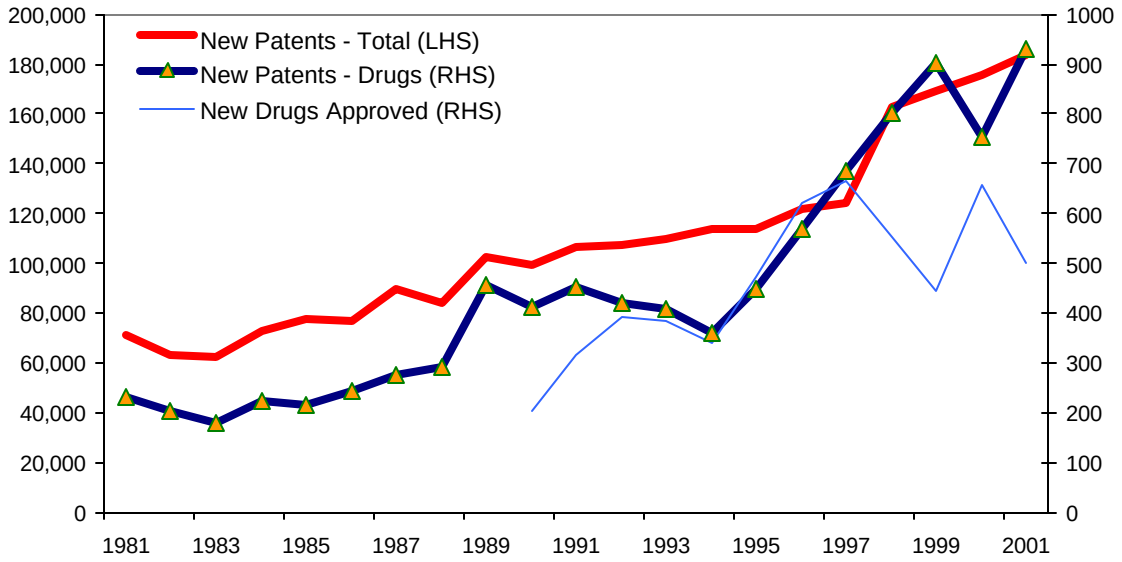
Notes: (a) Average value of exports and imports, (b) Total OECD excludes Korea, Czech Republic, Hungary, Poland and Slovakia.

Sources: OECD *STI Scoreboard 2001*, Table D.7.1; OECD (2002) *STAN Database*.

Business R&D Expenditure (BERD)

Much of the growth in the global pharmaceutical industry can be attributed to its capacity to innovate and thus add substantial value to a growing world market for improved health. This is an industry where innovation is closely associated with scientific breakthroughs and technological progress. Figure 6 is a time-series plot of new patents granted in USA for ethical drugs. The former clearly illustrates the fact that innovation output has accelerated in the pharmaceutical industry since 1994, has declined in 2000 but recovered in 2001. The 1990s trend compared favourably with the aggregate trend towards increased innovation in the USA. Since patent do not exactly translate into new products, we also consider a series of new drugs approved by the U.S. Food and Drug Administration since 1990.

Figure 6. Patents and new drugs approved, USA, 1981-2001



Sources: U.S. Food and Drug Administration, *Orange Book* (author's calculations); U.S. *Patent and Trademark Office* (classes 424 + 514; excludes duplicate patents and independent inventors).

Business R&D expenditure (BERD) is critical to innovation in pharmaceuticals. It is thus Not surprising that the industry invests heavily in R&D: ranked third in 2000 (table 4). Also, it is one of the most profitable in the world.

Table 4. Top 500 international companies by R&D investment, 2000

Industry	R&D (% of Total) 2000	R&D intensity (% Sales) 2000	Average annual R&D Growth 1996-2000 (%)	R&D per employee £000	Operating profit (% sales)
IT hardware	27.4	8.1	16.2	15.6	10.5
Automobiles & parts	17.6	4.0	11.4	7.7	5.9
Pharmaceuticals	15.5	12.8	19.0	25.5	22.6
Electronic & electrical	9.7	5.8	7.1	7.3	9.1
Chemicals	5.0	4.1	6.5	8.4	8.6
Software & IT services	4.3	14.3	35.0	23.8	32.1
Aerospace & defence	3.9	4.4	18.4	5.6	7.1
Engineering & machinery	2.8	2.8	5.8	3.9	6.3
Household goods	2.6	2.6	8.7	3.3	6.1
Telecommunications	2.2	1.8	2.3	3.2	12.3
Electricity	2.1	1.3	n.a.	4.3	15.3
Health	2.0	5.3	18.6	10.7	13.0
Construction & building	0.5	1.1	7.2	1.9	4.3
Total 500	95.7	4.2	13.5	8.2	11.1

Source: Department of Trade and Industry (2001) *R&D Scoreboard*, (http://www.innovation.gov.uk).

Table 5 further focuses on R&D intensity in order to compare the performance of the pharmaceutical industry with other industries for 13 major OECD countries.[6] Again the industry takes third place in the USA, Canada, Europe and Australia. In terms of the level of intensity, Australia ranks second last above Spain. In pharmaceuticals, note also that Sweden remains the absolute leader (i.e., see European Commission 1997, p.47) with the UK in second place.

Although tables 4-5 do not precisely depict *world* distribution of R&D expenditure, it is widely known that BERD is heavily concentrated in OECD. Only seven of OECD countries attract 87% of the total OECD funds and the USA accounts for 44% (NFS 2002, p. 4-43). Given the leadership of the USA, it is also interesting to observe the R&D flows from USA to the world. Details from an industry survey conducted by the manufacturers association (PhRMA 2002) clearly shows that of the total 2000 R&D spending abroad, 52.3% went to West Europe, 5.3% to Canada, 12.1% to Japan and 1.1% to both Australia and NZ. This compares sharply with their OECD population shares being 40%, 2.8%, 11.5% and 2.1% respectively.[7]

[6] Columns 1-14 are a reproduction of data in OECD *STI Scoreboard* 2001.
[7] OECD *Health Data 2002*, author calculations.

Table 5. R&D Intensity in OECD, 1991-1997 (average)

Industry (ISIC Rev. 3)		Total	USA	Canada	Japan	Europe	Germany	France	Italy	UK	Spain	Sweden	Norway	Finland	Ireland	Australia
High-technology																
Aerospace	353	14.2	14.6	10.1	9.9	14.6	28.1	14.1	11.9	9.3	16	15.3	0.9	0.9	..	1.5
Pharmaceuticals	2423	11	12.4	7.4	9.6	10	8.4	8.7	6	18.6	3.1	21.5	11.8	14	5.2	5.1
Office, Account. & Computing Machin.	30	9.3	14.7	6.8	7.5	4.3	7.5	5.6	7.2	2	2.6	12	7.8	3.1	0.6	6.3
Electro. Equip.(Radio, TV & Commun.)	32	8	8.6	12.7	6	10.2	13	10.3	11.7	5.2	6.3	17.8	25.7	11.4	8.6	8.7
Instruments, Watches & Clocks	33	7.3	7.9	..	8.1	5.9	6.1	11.1	1	3.5	2.1	8.2	3.1	7	2	4.2
Medium-high-technology																
Electrical Machinery	31	3.9	4.1	0.9	6.8	2.4	2.4	2.6	1	4.8	0.9	2.6	2	4.5	1.7	1.9
Motor Vehicles	34	3.5	4.5	0.2	3.1	3.6	4.6	3.2	3.3	2.9	0.8	6.1	1.8	1.8	1.2	1.9
Chemicals (less Pharmaceuticals)	24 - 2423	3.1	3.1	0.8	4.7	2.5	4.4	2.4	0.8	2.5	0.6	2.2	2.2	2.8	0.4	1.0
Other Transport nec	352 + 359	2.4	..	0.2	2.6	2.6	5.5	2.6	1.2	1.5	1.2	2.5	0.8	9.4	0	3.9
Machinery, nec	29	1.9	1.8	1.2	2.2	1.8	2.3	2	0.5	2.1	1	4	2.6	2.4	1.1	1.5
Medium-low-technology																
Coke,Ref. Petrol. Prod. & Nucl. Fuel	23	1	1.3	0.6	0.7	0.9	0.3	0.9	0.3	2.9	0.4	0.4	0.8	0.8	..	0.2
Rubber & Plastic Products	25	0.9	1	0.4	..	0.8	0.9	1.6	0.5	0.4	0.5	1.5	0.7	1.7	0.8	0.7
Non-Metallic Mineral Products	26	0.9	0.8	0.2	2.2	0.5	0.7	0.8	0.1	0.5	0.2	0.9	0.5	1.4	0.9	0.5
Ships	351	0.9	..	0	0.8	0.9	1.4	0.4	1.2	0.7	1.5	2	0.5	0.7	1.2	4.0
Basic Metals	27	0.8	0.4	0.6	1.3	0.6	0.6	1.1	0.3	0.4	0.2	0.8	1.5	0.7	0.4	1.2
Fabricated Metal Products	28	0.6	0.7	0.4	0.8	0.4	0.5	0.5	0.2	0.4	0.2	0.8	0.5	1.1	0.9	0.7
Low-technology																
Wood, Paper, Printing, Publishing	20...22	0.3	0.5	0.2	0.4	0.2	0.1	0.1	0	0.1	0.1	0.7	0.3	0.5	0.2	0.6
Food, Beverages & Tobacco	15+16	0.3	0.3	0.2	0.7	0.2	0.2	0.3	0.1	0.4	0.1	0.4	0.3	0.6	0.4	0.4
Textiles, Fur & Leather	17...19	0.3	0.2	0.4	0.7	0.2	0.5	0.3	0	0.2	0.1	0.5	0.6	0.6	1	0.2
Total Manufacturing	15...37	2.5	3.1	1.2	2.8	1.9	2.5	2.4	0.8	2.1	0.6	3.7	1.4	1.9	1	1.1

Notes: R&D intensity BERD as a % of gross output; 1995 GDP PPPs are used.

Sources: OECD *STI Scoreboard 2001*, Annex 1.2; OECD (2001) *ANBERD Database*; OECD (2002) *STAN Database*.

Next we examine developments in the global industry over the period 1987-2000. The international standard for measuring R&D expenditure is set out by the *Frascati Manual* (see OECD 1994). Guided by the *Frascati Manual*, the OECD ANBERD database is a consistent source of data that applies the same definition throughout OECD. The *Manual* adheres to *performer-based* reporting and seeks to correctly identify the sums an organisation or sector has received from another unit. In order for these funds to be counted as BERD, the "transfer must be both intended and used for the performance of R&D" (OECD 1994, p.21).

We begin with table 6 that summarises R&D expenditure in pharmaceuticals over the period 1976-2000. Figure 7 depicts the OECD distribution of BERD for 1987 and 2000.

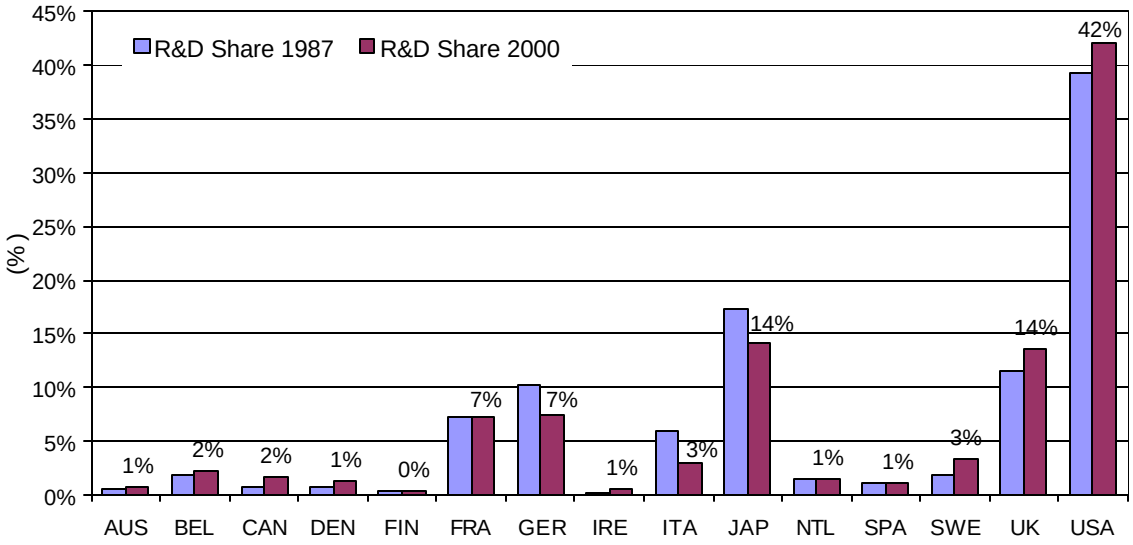
Table 6. BERD in pharmaceuticals, OECD, 1976-2000 (US$ PPP, millions)

	1976-80	1981-85	1986-90	1991-95	1996-2000
Australia	13	24	69	127	194
Belgium	66	133	208	292	573
Canada	24	49	119	278	469
Denmark	22	48	98	192	333
Finland	9	23	37	57	87
France	241	516	846	1680	2202
Germany	525	705	1136	1319	1953
Ireland	2	8	15	63	130
Italy	184	400	724	904	873
Japan	536	1225	2072	3435	4179
Netherlands	66	95	174	211	381
Spain	31	56	132	225	306
Sweden	53	120	246	482	876
UK	367	708	1441	2493	3552
USA	1362	2859	4952	8800	11997
OECD -15	3501	6970	12269	20559	28106

Source: OECD (2001) *ANBERD Database*, ISIC Rev 2 and Rev 3.

Here we observe the bulk of OECD BERD being increasingly absorbed by the USA whose share has risen by 2.9% points to 42%. Europe has seen a small decrease of its share (from 42.1% down to 41.4%) but the most adverse outcome was in Japan with a loss of 3.3% points. Italy and Germany have also seen a sharp decline. Except Spain, all other European countries have improved their performance, especially the UK and Sweden.

Figure 7. BERD OECD distribution, pharmaceuticals, 1987 and 2000 (US$ PPP)



Source: OECD (1998, 2001) *ANBERD Database*, ISIC Rev 2 and Rev 3.

Table 7 compares the R&D expenditure by the pharmaceutical industry to total BERD. We observe the industry expenditure to be a significant component of total BERD. Most discernible is the dramatic (relative) increase in Denmark, Sweden and the UK with the latter becoming the world leader in the 1990s.

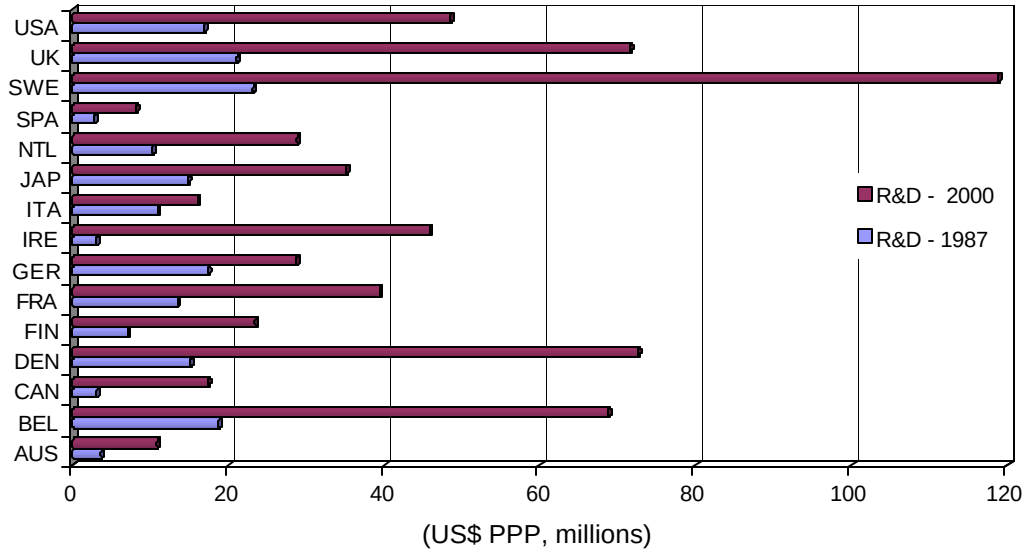
Table 7. BERD in pharmaceuticals as a share of total BERD (%)

	1976-80	1981-85	1986-90	1991-95	1996-2000
Australia	5	4	5	5	6
Belgium	n.a.	n.a.	13	12	17
Canada	3	2	3	5	6
Denmark	12	13	15	18	20
Finland	6	6	5	5	4
France	6	7	7	10	13
Germany	6	5	5	5	6
Ireland	6	10	9	14	14
Italy	12	12	13	12	10
Japan	6	6	6	7	6
Netherlands	7	6	7	7	9
Spain	9	8	8	10	10
Sweden	7	7	10	14	16
UK	7	9	12	18	22
USA	4	4	5	7	7
OECD -15	5	5	6	8	8

Source: OECD (2001) *ANBERD* Database, ISIC Rev 2 and Rev 3.

Figure 8 is a plot of per capita BERD in 1987 and 2000. Clearly, figure 8 reveals a vastly different pattern to that presented above. It illustrates the capacity of some small nations (in terms of population) to attract considerable R&D business funding. Ireland, Sweden, the UK, Denmark and Belgium stand out. More precisely, the average person in Ireland, Sweden and Denmark has made remarkable progress if we consider that these nations have increased their BERD by 270%, 164% and 156% respectively within a 13-year interval; Most interesting is the fact that, as a group, Europe-10 has raised its per capita BERD by 10% per annum; the corresponding rates for Japan, the USA and OECD-15 are 6.6%, 8.1% and 9.4% respectively.

Figure 8. Per capita BERD, pharmaceuticals, 1987 and 2000



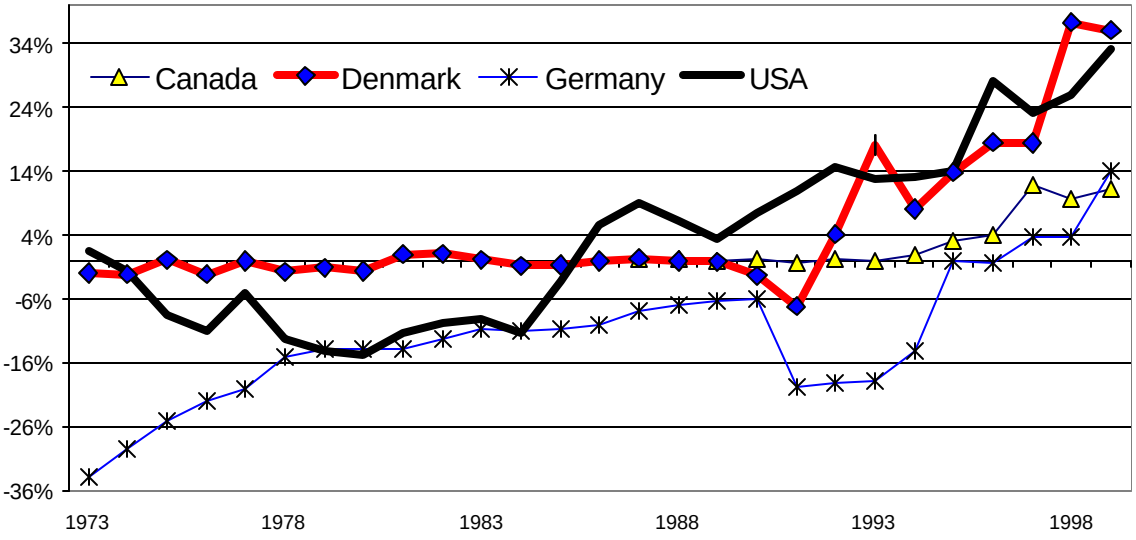
Source: OECD (1998, 2001) *ANBERD Database*.

We further advance our study of R&D practices by utilising an alternative data source for BERD. OECD Health Data 2002 provides access to industry data that is independent of ANBERD for Canada, Denmark, Germany and the USA. This database relies on industry surveys that measures R&D expenditure according to the source of funding devoted to R&D and contrasts with the ANBERD approach reporting on an R&D performer-basis. In contrast to ANBERD that strictly follows the *Frascati Manual*, the Health Data draws from industry sources. For the USA, the Health Data extracts its information from the *Annual Membership Survey* of Pharmaceutical Research and Manufacturers of America (PhRMA). PhRMA (2002) defines R&D expenditures as the "total cost incurred for all pharmaceutical R&D activity" which includes depreciation and "total outlays for all research and development work contracted to others (manufacturers, independent research laboratories, academic institutions, etc.)" (p. 94). Thus, one potentially major difference in the treatment of BERD between ANBERD and PhRMA is extramural expenditure that is excluded in the former but included in the latter.[8]

[8] NSF (2002, p. 4-57) also comments on the gap between 'performer-based' and 'source-based' and advices that ANBERD is the 'most reliable source' of international comparisons.

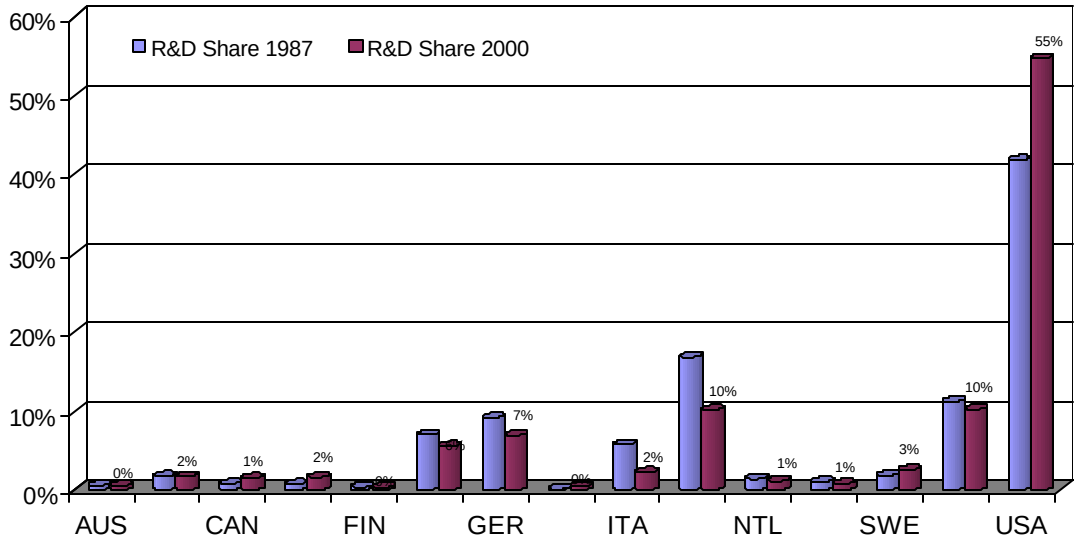
Figure 9 illustrates the reporting gap for the above four countries since 1973. We propose below that a major component of the gap relates to subcontracting. If that is valid, it appears the USA has taken an early lead and only to be overtaken by Denmark in the late 1990s. Also worth noting is that Germany has largely abstained from the practice of subcontracting. In fact, Germany has recorded a negative gap and we interpret that as a sign of heavy subsidisation of BERD by government and other sectors.

Figure 9. BERD reporting gap in pharmaceuticals, 1973-2000 (as a % of industry funds)



Source: OECD *Health Data 2002*; OECD (2001) *ANBERD Database*.

Figure 10. BERD distribution, pharmaceuticals, 1987 and 2000 (PPP)

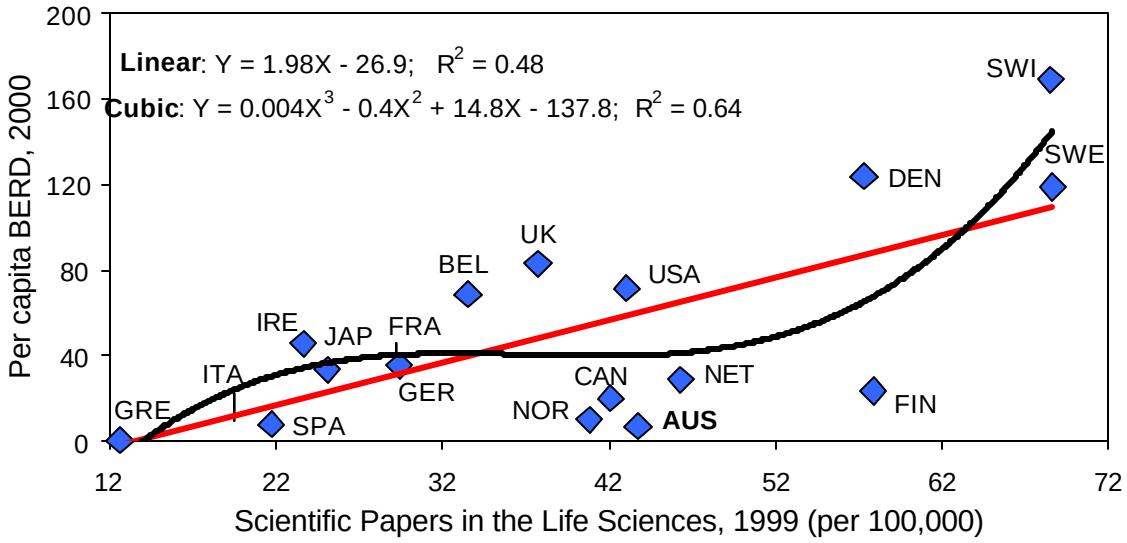


Source: OECD *Health Data 2002* (Canada, Denmark, Germany and USA), OECD (2001) *ANBERD* (other).

Figure 10 repeats the exercise in figure 1 but we replace ANBERD data with industry data for Canada, Denmark, Germany and the USA. Note that now the USA leadership seems more overwhelming than with ANBERD data. The USA is one of a few countries to have gained OECD market share in the 1990s: a gain of 12.9% points to raise its share to 55%. It is this extraordinary outcome that has raised serious concerns in Europe. EFPIA (2002), for instance, concludes that BERD is increasingly concentrated in the USA and Europe has lost its competitiveness. Against this trend, it is also interesting that Denmark, Ireland, Sweden have all managed to increase their OECD share. Of course, the disappointing result for Europe remains with a loss of market share from 40% down to 33%. Note also that Europe was not alone; Japan lost 6.7% points. Not reported here, however, the pattern in per capita figures remain similar to that in figure 8, except that a much better performance is recorded for Denmark and the USA.

The strong differential BERD performance amongst European countries warrants further analysis. We briefly explore higher education as a potential factor. Not reported here, we investigated the role of higher education enrolments as a lagged predictor of R&D and observed a low correlation. Next, we examine the hypothesis that business will seek to invest on R&D if returns are high. Obviously, a prerequisite for the latter is the capacity of a nation to contribute to world knowledge creation and innovation. As a proxy for that, we select per capita scientific publications in the fields of chemistry, biology, biomedical research and clinical medicine. The role of higher education as a potential driver of technological progress and innovation is a central proposition in modern economic growth theory (Wolf 2001).

Figure 11. BERD in pharmaceuticals and scientific output in life sciences



Note: BERD data are as in Figure 10.
Source: NSF (2002); EFPIA (2000) *The Pharmaceutical Industry in Figures*.

Figure 11 is a scatter plot of per capita scientific papers in Life Sciences in 1999 against per capita BERD in pharmaceuticals. In addition to OECD-15, we also include

Switzerland, given its strong profile in pharmaceuticals. Our regression estimation provides for alternative functional forms. Linear regression produces a statistically significant result with scientific papers correlating positively with per capita BERD in 2000. We experimented with various functional forms with the cubic producing the most significant outcome. We observe countries such as Switzerland, Sweden and Denmark to be leaders in scientific publications and that seems to influence business decisions with respect to R&D. According to either of the two functions, countries such as Australia, Canada and Spain under-perform in BERD while Denmark, the UK and Belgium seem to over-invest in R&D.

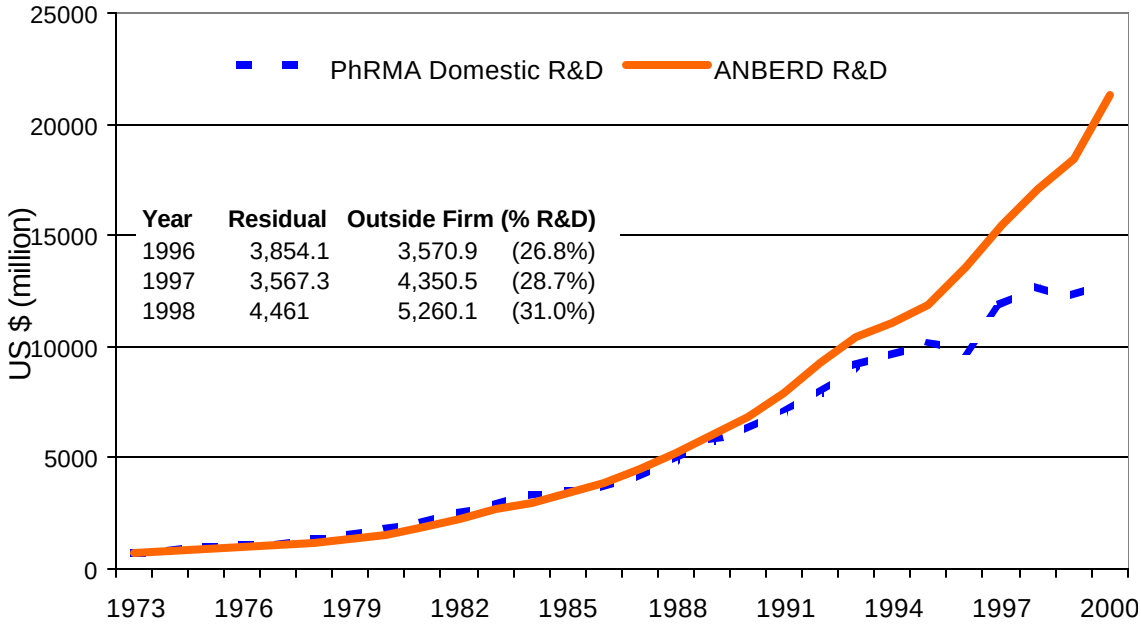
We now return to the issue of sub-contracting to further understand business R&D practices. Apparently, there is a blurring of the distinction between intramural and extramural R&D expenditures. Young (2001) speculates that most of 'extramural' (i.e., R&D activities funded by a pharmaceutical firm but conducted outside the firm) relate to clinical evaluation in phases I to III. These are integral to the R&D and innovation process. She, however, acknowledges that insufficient reporting does not allow us to identify the nature of the activity or the performer when R&D is contracted out. For example, PhRMA (2000) advises that R&D expenditures 'outside firm' include funds "contracted or granted" to other companies or "other research-performing organisations". Such a broad definition makes it difficult to reconcile industry figures with *Frascati.*

Figure 12 confirms the view that the reporting R&D gap for the USA can be attributed to extramural or 'outside firm' expenditures. Outsourcing and sub-contracting has become an important business practice in the USA in recent times. We expect the pharmaceutical industry to reflect that trend.

We utilise NSF electronic data to further explore this possibility. Figure 13 plots the BERD gap against estimates of contracted R&D expenditure in the "drugs and medicines" industry in the *Survey of Industrial Research and Development* conducted by the U.S. Bureau of Census (i.e., original source of ANBERD).

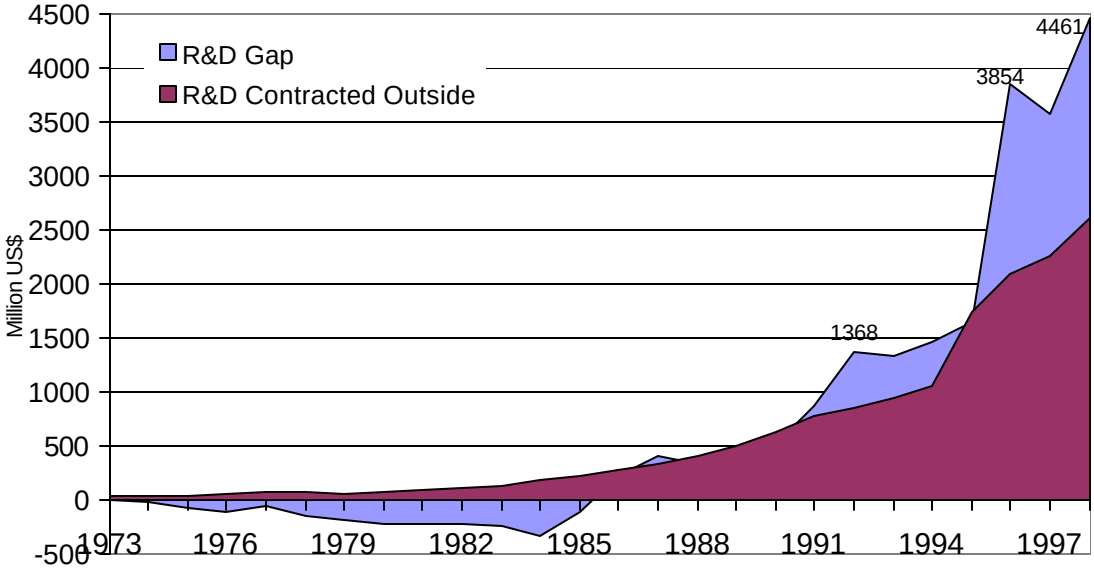
Obviously, contracted R&D expenditure constitutes a large share of the gap. Yet, 41% of the gap in 1996-98 was associated with practices other than contracted R&D, such as grants and scholarships. Nevertheless, subcontracting has become part of the landscape and it is not confined to the pharmaceutical industry (figure 13). The figure also depicts contracted R&D in pharmaceuticals as a share of total contracted R&D in the economy. This series clearly indicates an acceleration of contracted BERD in pharmaceuticals since 1987 well beyond the general upward trend. More precisely, while BERD in the industry accounted for an average of 13.6% over the period 1961-1986, it has steadily risen to 41.4% of the total contracted BERD in 1998.

Figure 12. R&D expenditures in the USA (1973-2000): Two tails



Source: PhRMA (2002); PhRMA *Industry Profile 2000*, p.116.

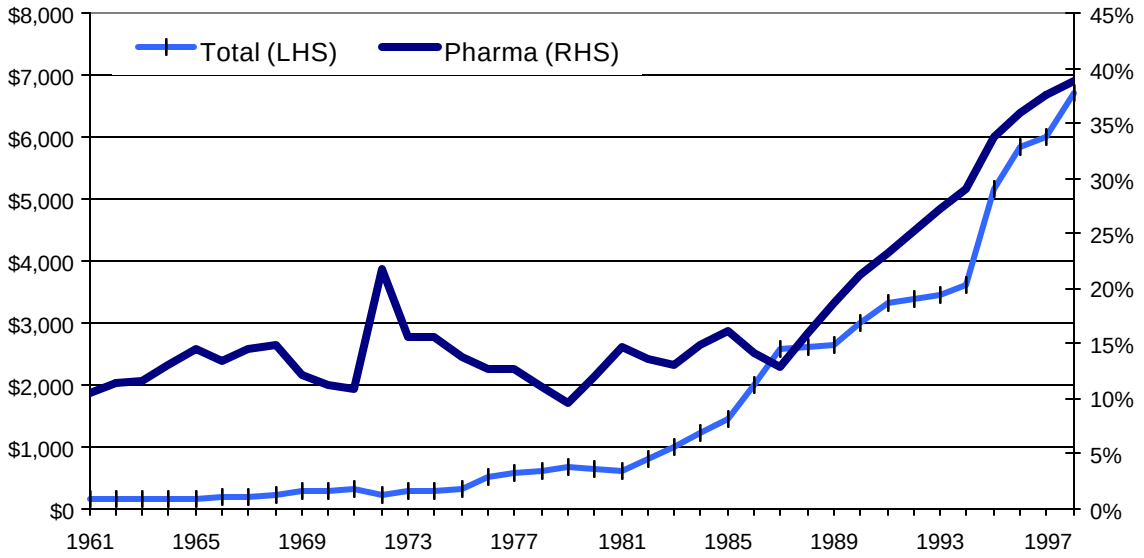
Figure 13. BERD gap and contracted R&D: Drugs and medicines, 1973-2000[9]



Source: PhRMA (2002); NSF *IRIS database* (http://www.nsf.gov).

[9] For the period 1978-1992, the NSF publication only reports contracted R&D data for every consecutive year. The gaps were filled by linear interpolation.

Figure 14. Contracted BERD in the USA, total and pharmaceuticals (as a share of total)



We summarise the evidence in this sub-section. We find the industry to be strong in patents and R&D intensive. The USA has become the undisputable leader in as far as absolute expenditure on R&D is concerned. Overall, the pharmaceutical industry has seen its R&D expenditure to grow stronger than total BERD. While Japan and Germany have witnessed a substantial decline, several European countries have devoted considerable funds for R&D. We propose that a strong science base is a key determinant of superior performance in per capita BERD. Last but not least, we observe a new strong trend towards subcontracting of R&D activities in the USA and Denmark.

Employment and Labour Compensation

R&D statistics may provide an incomplete assessment of the industry's contribution to innovation and/or social welfare. One reason for that is the fact that R&D expenditure constitutes only one input to innovation. Gambardella *et al.* (2000) have observed that the industry in Europe is weak in BERD but seems more labour intensive than in North America. Thus, it is of interest to examine labour statistics. Table 8 compares six OECD countries in terms of employment and earnings growth.

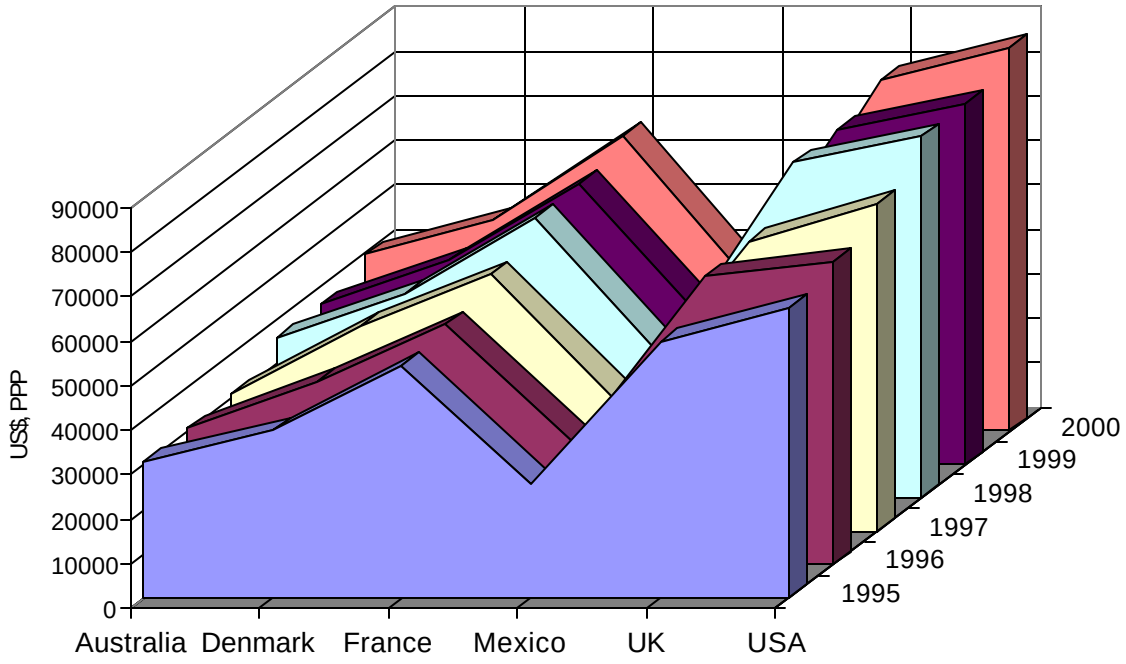
Table 8. Employment and earnings growth (%)

	Growth (1995 -2000)	
	Employment	Earnings
Australia	4.1	9.0
Denmark	1.6	6.1
France	-0.9	3.8
Mexico	3.7	9.0
UK	-5.2	1.1
USA	1.2	6.8

Sources: DISR (2001, p.9); OECD *Health Data 2002*.

Australia has seen the strongest growth in job creation and earnings.[10] Figure 15 presents an indicator of quality jobs by adjusting for differences in the labour force. It indicates average earnings[11] over the period 1995-2000. Australia now takes a second-last position with average earnings at $39,185 (US PPP), just above Mexico's $33,169. The earnings gap between Australia and France ($66,138), the UK (479,015) or the USA ($85,925) now seems substantial.

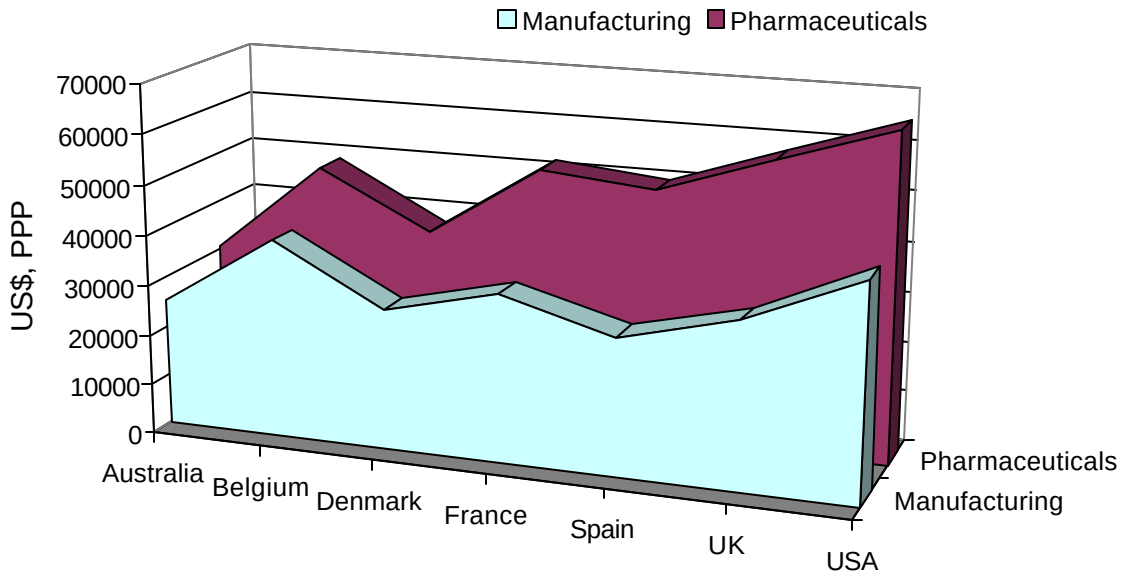
Figure 15. Average labour compensation, pharmaceuticals, 1995-2000



Next, we investigate whether the earnings gap is due to differences in the wage structure and manufacturing in general. Figure 16 compares the pharmaceutical industry to total manufacturing in 1995. Due to data restrictions, Figure 16 excludes Mexico but includes Belgium and Spain. Again, the lowest average earnings appear in Australia and the highest in the USA. More importantly, earnings differences between countries can partly be attributed to overall differences in manufacturing. However, the ratio between earnings in pharmaceuticals and in (average) earnings in manufacturing seems to vary considerably: 1.21 for Australia, 1.23 for Belgium, 1.35 for Denmark, 1.57 for France, 1.84 for Spain, 1.76 for the UK and 1.52 for the USA.

[10] Australian DISR (2001) figures were converted to US$ PPP prices.
[11] Both employment and earnings data include self-employed persons.

Figure 16. Average earnings: pharmaceuticals versus manufacturing, 1995[12]



In summary, the evidence in this sub-section suggests that the global pharmaceutical industry provides higher value jobs than other sectors but this is less so in Australia than in countries such as the UK and the USA.

3. Australia: 1970- 2000

Discussion in the previous sections focused on global trends and OECD data. With respect to the latter, AEA (1998) makes it clear that the Australian Bureau of Statistics (ABS) approach to measurement of R&D expenditure and production differs from that adopted by OECD. ABS data on R&D is classified according to production while OECD emphasises product fields. Furthermore, ABS R&D collection data has management as the unit of measurement. Towards consistency, ABS has recently revised its *Manufacturing Survey* to move away from an establishments-based data and adopt the management-unit approach. This change will now allow for the differentiation between medicinal pharmaceutical products (ANZIC code 2543) and pesticides (2544) that was not previously possible. This makes joint analysis of R&D and production data more compatible but it has the disadvantage that it provides only one observation (2000/01).

This section places the pharmaceutical industry within the context of Australian manufacturing and look at the historical development of the industry since 1970. We begin with Australian data as documented in official ABS publications. First we examine value-added data. For comparison purposes, we draw on ABS (8221) based on establishments units. Table 9 summarises the evidence. Value added in the

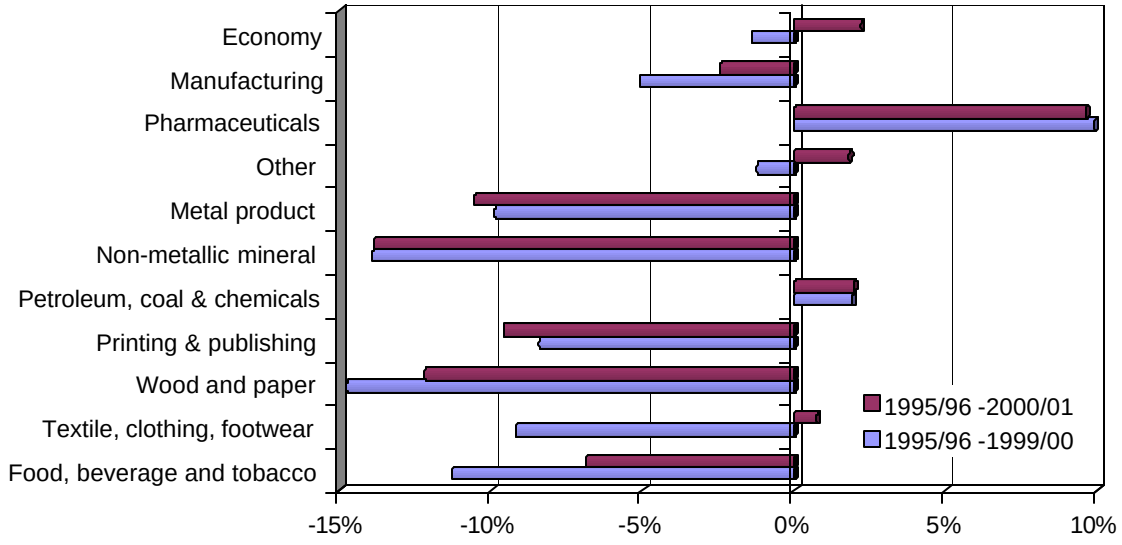
[12] Pharmaceuticals data are from OECD Health Data 2002 while manufacturing data are from the OECD (2002) *STAN Database*.

pharmaceutical industry is relatively small but its growth rate has been much greater than the average for manufacturing in the late 1990s. Next we look at the BERD track record for various Australian industries for the period 1995/96 to 2000/01. Given that total BERD in Australia is known to have consistently declined until 1999/00 and recovered in 2000/01, we look at BERD growth rates for two separate periods.

Table 9. Value added in australian manufacturing, 1997/8-1999/00

	Manufacturing share (1999/2000)	Annual growth (1997/98-1999/00)
	%	%
Food, beverage and tobacco	20.8	1.3
Textile, clothing, footwear and leather	4.4	-4.2
Wood and paper product	6.8	7.8
Printing, publishing and recorded media	10.5	5.3
Petroleum, coal, chemical and ass.	14.3	-0.6
Non-metallic mineral product	5.4	11.3
Metal product	15.5	-6.6
Machinery and equipment	19.1	-4.8
Other manufacturing	3.2	0.1
Medicinal and Pharmaceutical	**2.4**	**2.2**
Total Manufacturing	100.0	-0.5

Figure 17. BERD growth by industry, Australia, 1995/96-2000/01

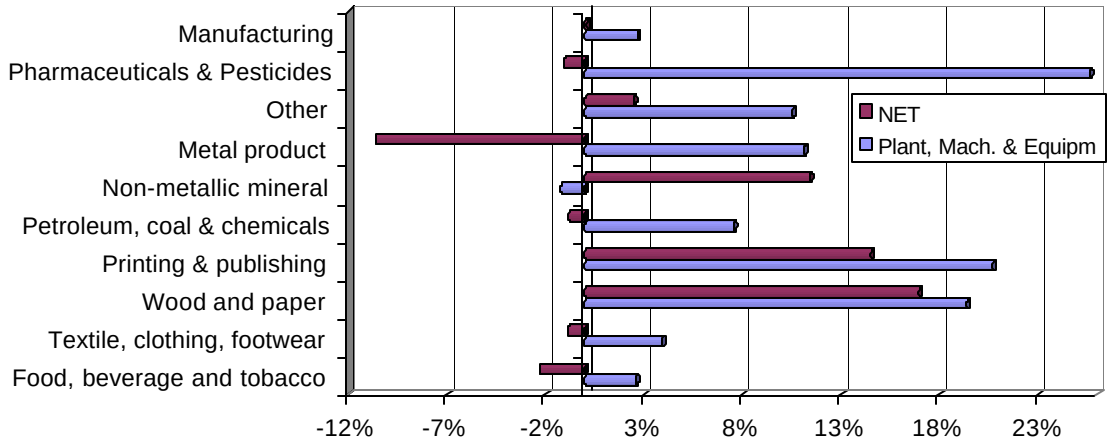


Source: ABS (various) *Research & Experimental Development, Business* (cat. no. 8104); ABS unpublished data.

Figure 17 shows that BERD has declined in absolute terms over the period 1995/96 – 1999/00. The decline was particularly acute for manufacturing with a growth rate of –5.1%. The sectors most responsible for this decline are food/beverage/tobacco, wood/paper, metals and non-metallic minerals. Despite this adverse trend, the manufacturing industry stands out with the highest growth rate of 9.9%. The pattern is almost identical in the full period to 2000/01.

Next, we explore ABS investment data. An important component of gross investment is capital expenditure on plant, machinery and equipment. Figure 18 depicts growth rates for real private capital expenditure for the period 1995/96–1999/01 using management unit data.[13] Again gross investment on plant, machinery and equipment in the pharmaceutical industry has grown faster than all *broad* manufacturing sectors. In terms of net investment, however, there has been a minor contribution by the industry. This is mainly attributed to a 78% decline in *intangible* assets expenditure in 1998/99 (i.e., computer software, patents and licences).

Figure 18. Investment growth by industry, Australia, 1995/96-1999/00



Finally, we seek to gain a long-term perspective on the development of the industry by comparing it with the Australian manufacturing as a whole and other OECD over the period 1970-2000. In order to extend the sample period back to 1970, we rely heavily on OECD data sources. We utilise OECD STAN database and ABS unpublished data.[14]

[13] GFCE figures were adjusted by their corresponding implicit price deflators.
[14] A value-added data gap in 1993-97 was filled by interpolation on the assumption of a linear trend in the value added-production ratio.

Figure 19. Australian pharmaceutical industry (as a share of manufacturing)

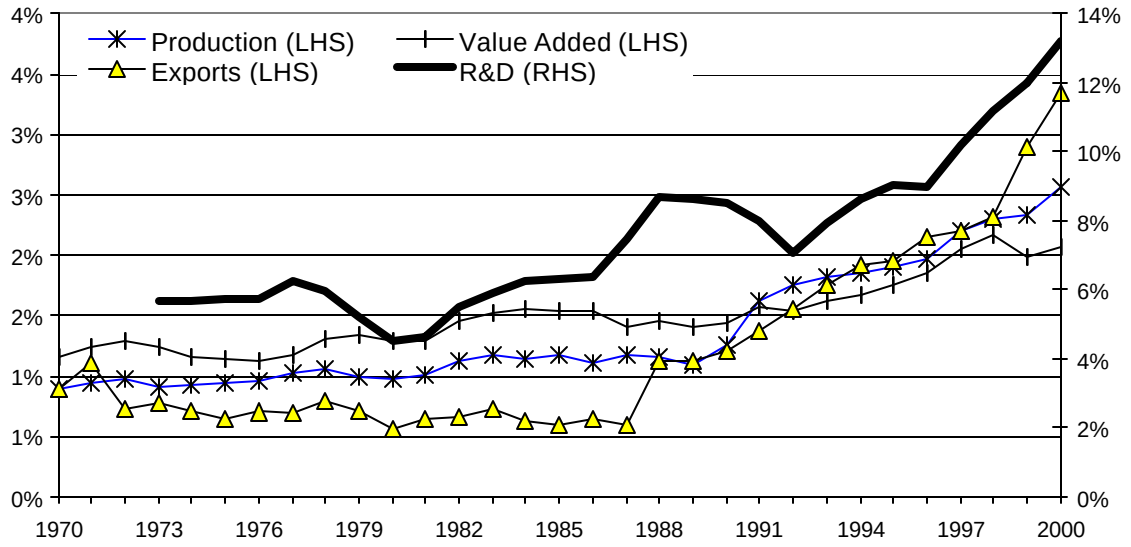


Figure 19 confirms the view that the pharmaceutical industry has steadily strengthened its position within manufacturing; the upward trend in BERD, production and export shares mainly begins in the late 1980s and is particularly strong in the late 1990s. As noted earlier, the latter also reflects the sharp decline in manufacturing. Worth mentioning is the fact that the industry's BERD share has been much higher than its production/value added share that suggests that Australia's innovation output and/or commercialisation capacity are below potential.

Last, we compare Australia with OECD. [15] Figure 20-21 depict Australia's share in OECD pharmaceuticals based on R&D, production, added value and exports. Figure 20 points to three distinct periods: (a) a low BERD, high value added era with the latter in a negative trend in the 1980s, a declining value-added share against a rising R&D share in the late 1980s, and a convergence of the two series in the 1990s. Note also, the strong BERD performance of the industry within Australia is not comparable to that witnessed within the context OECD in the late 1990s. On the other hand, Australia's improved exports performance observed above is also apparent within OECD: a 1.7% share in 2000 from 0.6% in 1980 (figure 21). Finally, at the expense of the UK and the USA, France and Germany have both strengthened their position in international trade. Finally, the share of all five of the above countries has declined overtime with only Denmark and Sweden increasing their combined share to 16% in 2000, compared to 8.4% in 1980.

In summary, the Australian industry is small relatively to other OECD countries but it has recorded strong growth in BERD, value added and exports. We have also identified a pattern in the development of the industry: a high (low) but declining value-added (BERD) share in the 1970s and early 1980s and a convergence in the 1990s.

[15] R&D data exclude Korea and Belgium but include Irelands and Italy.

Figure 20. Australian pharmaceutical industry (as a % of OECD-15)

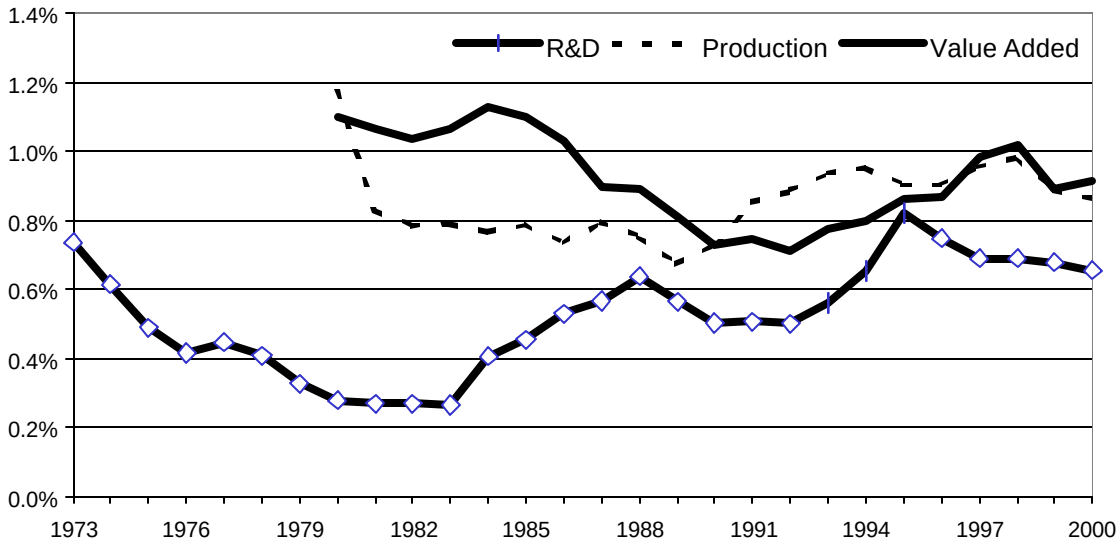
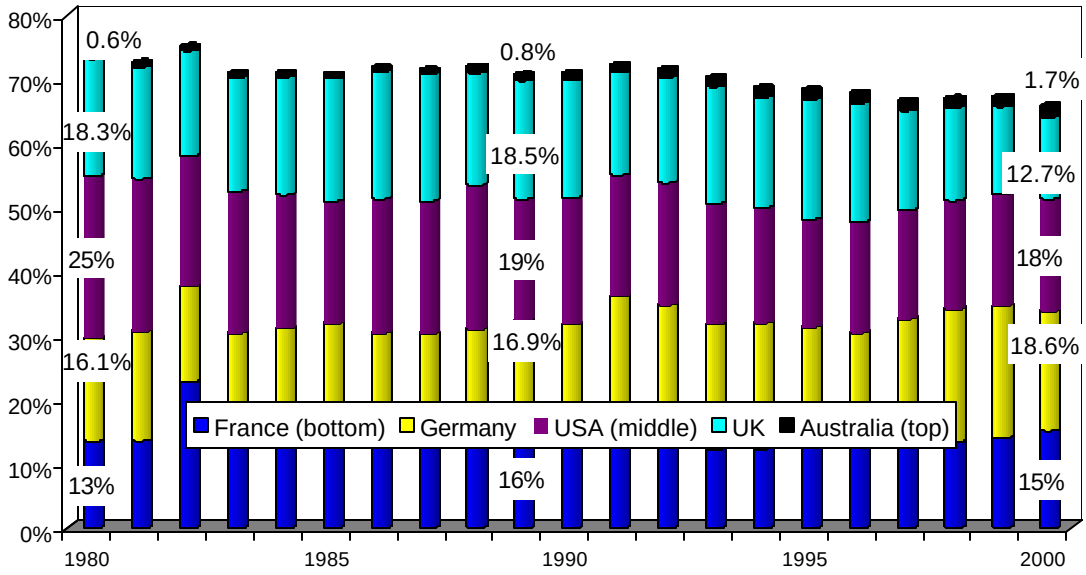


Figure 21. Exports in pharmaceuticals, 1980-2000 (as a % of OECD-15)



4. Conclusion

This paper has examined recent trends in the global pharmaceutical industry with emphasis on production, international trade and R&D expenditure. Our focus has been on international comparisons and the distribution of business activity within OECD.

The evidence here makes it clear that the pharmaceutical industry has evolved into a highly dynamic sector within the global economy. The industry has witnessed fast growth, has been a leader in BERD, offers quality jobs and is highly profitable. However,

the evidence provided here is not fully consistent with the view that R&D and production in pharmaceuticals is increasingly concentrated in the USA. More accurately, we find that BERD and production are increasingly concentrated in a few centres of excellence and this confirms recent OECD evidence by Reger (1998).

The pharmaceutical industry in Australia has also made substantial progress. It has seen substantial growth in capital expenditure and has raised its R&D profile. Further, it offers the most highly paid jobs in Australian manufacturing and the fastest employment growth in the OECD. It also faces some challenges. In terms of valued-added and job creation, the industry has made little progress in the last five years of the 20th century. When compared to other OECD countries, Australia's performance is found to be below average. Although it has grown rapidly, its R&D intensity hardly compares with that of other OECD countries.

In conclusion, it seems Australia ought to improve its performance in high technology sectors, if it is to remain an important player in the global innovation game. The pharmaceutical industry has become one of the most innovative industries in the world. Thus, Australia has a lot to gain in placing a higher priority on the development of the industry.

Appendix A: Country Abbreviations

AUS	BEL	CAN	DEN	FIN	FRA	GER	JAP
Australia	Belgium	Canada	Denmark	Finland	France	Germany	Japan
KOR	NTL	NOR	SPA	SWE	UK	USA	SWI
Korea	Netherlands	Norway	Spain	Sweden	United Kingdom	United States	Switzerland

Appendix B: Data Sources

R&D Expenditure

In general, ANBERD 2001 is the source for most OECD-15 countries. A change of classification from *ISIC Rev. 2* (code 3522) to *ISIC Rev 3* (code 2423) in ANBERD 2001 apparently maintains compatibility for pharmaceuticals. *Rev 2* of ANBERD 2001 is the primary source for the period 1973-1986 and *Rev 3* for the period since. Due to data limitations, there are some exceptions. We draw more extensively from ANBERD 2001 *Rev 2* for Germany (1973-94) and Italy (1973-98). For the period 1973-86, Belgium data are from OECD *Health Data 2002* that draws from ANBERD. OECD ANBERD 1998 (*Rev.* 2) is the source for Australia, 1970-1995.

For Germany, there is a break in the series due to the unification of Germany. We used 1991-99 data for "UDEU" (ANBERD code) in order to arrive at an additively spliced series with 1991 as the base year. Thus, "Germany" stands for Unified Germany. Data for Norway are from Health Data 2002. The 1997 figure for Switzerland is from EFPIA, *The pharmaceutical industry in figures: key data 1999 update* (p. 13) (Euro million) and was converted to Swiss Franc according to Eurostat (2000) and then to US$ PPP.

Production/Value-added/Exports

OECD STAN 2002 was used for most countries. For Australia, OECD STAN 1995 and 1998 (ISIC *Rev 2*) provide data for production and exports for the period 1970-79. Value added data come from the same source for 1973-92 but we draw on unpublished ABS data for 1998-2000. The gap in the data was filled on the assumption that there is a linear convergence in the (value added-production) ratio from 1992 to 1998. The production series for Germany was spliced as above while value added and exports come exclusively from STAN 1998. We note also that data for Belgium, France and Spain was converted to national currency (initially in 1999 Euro) using Eurostat (2000). The exchange rates were 40.62, 6.601 and 167.2 respectively.

Extrapolated Data

For countries with data gaps, all of the above series are linearly extrapolated on the assumption of a rate of change equal to the average over the last 3 years.

Population & US$ PPP Prices

Population estimates come from OECD *Health Data 2002*. OECD ANBERD *Rev 3* is used for US$ PPP prices.

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