Assessing Australia's Innovative Capacity: 2005 Update

Joshua Gans and Richard Hayes

Melbourne Business School and Intellectual Property Research Institute of Australia, University of Melbourne

Contact: **J.Gans@unimelb.edu.au**. The latest version of this paper will be available at **www.mbs.edu/jgans**.

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1 Background

Gans and Stern (2003) provided a new set of results and a focus on Australian innovation in their study of the drivers of national innovative performance. This is an update of Gans and Stern (2003); itself part of the National Innovative Capacity Project conducted by Michael E. Porter, Scott Stern and several co-authors over the past several years. The goal of these projects has been to understand the drivers of innovation across countries and use this to generate a measure of innovative performance. This update refines the empirical study further with more data, a greater coverage of years and an alternative model including the effects of specialisation. It gives us our clearest picture yet of the innovative state of the world.

This report follows our 2004 update (Gans and Hayes, 2004). Both updates complement Gans and Stern (2003). As such, we do not repeat their discussion outlining the national innovative capacity framework and its underlying history. Instead, we report only changes to some of the quantitative results and any changes in methodology and interpretation.

The report proceeds in three sections. Section 2 outlines the latest methodology used in this update while Section 3 provides the main results from this quantitative assessment. In general, despite data improvements and, a larger sample, the results of Gans and Stern (2003) are largely confirmed in both the original and the alternative model. A final section concludes reiterating the policy conclusions of Gans and Stern (2003).

2 Measuring National Innovative Capacity

The distinctive feature of the Porter-Stern approach is a clear distinction between innovation output (specifically, **international** patenting) and its drivers (infrastructure, clusters and linkages) as well as a careful determination of the 'weights' attached to each innovation capacity driver.[1] Each weight is derived from regression analysis relating the **development** of new-to-the-world technologies to drivers of national innovative capacity. This has the advantage of avoiding an 'ad hoc' weighting of potential drivers and instead using the actual relationship between innovative capacity and innovation to

[1] See the Appendix and Furman, Porter and Stern (2002) for a more thorough discussion of this methodology and prior research in this area.

provide those weights. Thus, measures which historically have been more important in determining high rates of innovative output across all countries are weighted more strongly than those which have a weaker (though still important) impact on innovative capacity. The end result is a measure of innovative capacity that is measured in per capita terms to allow for international comparisons as well as a set of weights that focuses attention on **relative** changes in resources and policies both over time and across countries.

2.1 Measuring Innovative Output

In order to obtain the weights for the Innovation Index, we must benchmark national innovative capacity in terms of an observable measure of innovative output. In this study, we use the number of "international" patents **granted** in a given year for each country in the sample, as captured by the number of patents granted to inventors of a given country by the United States Patent and Trademark Office. While no measure is ideal, as explained by Gans and Stern (2003), measures of international patenting provide a comparable and consistent measure of innovation across countries and across time.

This update continues the practice of Gans and Hayes (2004), using patents granted in a given year as the measure of innovative output. Gans and Stern (2003) used patents granted according to the date of the patent application, primarily to take into account some missing data issues. In contrast, these updates return to the use of patents granted in a given year, as in the original Furman Porter and Stern (2002) work.

Using this measure requires it to be lagged. This is because the innovation environment pertinent for the patent grant is that environment that prevailed at the time of application. This lag reflects the difference between innovative capacity (innovation inputs) and the innovation index (predicted innovation outputs). Recent advice from the USPTO indicates that the average lag between patent application and patent grant remains at 2 years, the lag used in the 2004 update. Accordingly, we have continued to use this lag, rather than the three years used by Furman, Porter and Stern (2002).

That said, patents granted measured by date of application and patents granted measured by date of grant are highly correlated, and the use of one or the other measure as the innovation output measure does not affect the core findings of this study.

2.2 Calculating the Index

The Index is calculated and evaluated in two stages. The first stage consists of creating the database of variables relating to national innovative capacity for our sample of 29 OECD countries from 1973 to 2004. These measures are described in Gans and Stern (2003). We have obtained additional UNESCO and World Bank data allowing us to extend the time series back to 1973, versus 1978 in last year's update. This database is used to perform a time series/cross sectional regression analysis determining the significant influences on international patenting and the weights associated with each influence on innovative capacity.

In the second stage of the analysis, the weights derived in the first stage are used to calculate a value for the Index for each country in each year given its actual recent resource and policy choices. It is in this sense that we refer to national innovative capacity: the extent of countries' current and accumulated resource and policy commitments. The Index calculation allows us to explore differences in this capacity across countries and in individual countries over time.[2]

In addition to extending the work by adding new data, we have also constructed an alternative specification that reincorporates a measure of innovation SPECIALISATION, reflecting the presence and strength of industrial innovation clusters.

Both specifications produce broadly similar patterns of innovative capacity over time and countries. The econometric appendix provides further details.

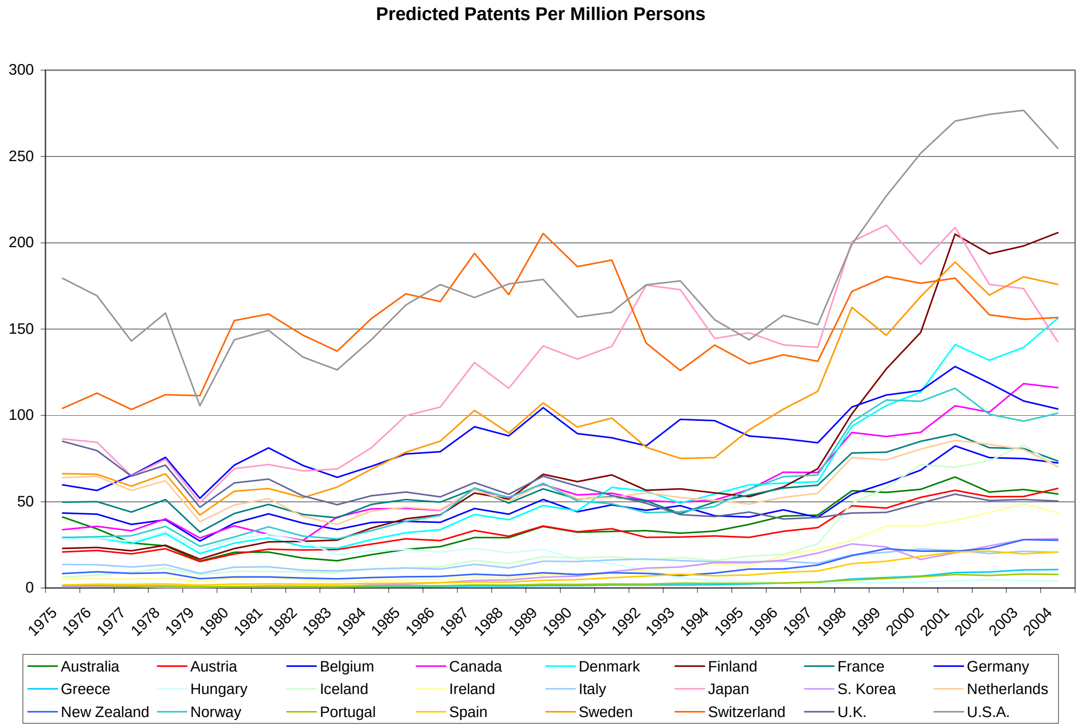
2.3 Findings on Innovative Capacity

Stern, Porter, and Furman (2002) and Gans and Stern (2003) found that there was a strong and consistent relationship between various measures of national innovative capacity and per capita international patenting. The appendix details these for the expanded dataset using the original model and the alternative model featuring specialisation and largely confirms the findings of previous studies. This indicates the general robustness of this approach to measuring the underpinnings of innovative performance. As such, we refer the reader to Gans and Stern (2003) for a comprehensive discussion of these findings.

[2] Gans and Stern (2003) also used some extrapolations to forecast the Innovation Index five years in the future. We have decided not to do this exercise this year but may include it in future studies.

3 Australian Innovative Capacity

In this section, we provide updated results of the determinants of Australian Innovative Capacity. **Figure 3-1** depicts the value of the Innovation Index value for each country over time. The Index, interpreted literally, is *the expected number of international patent grants per million persons given a country's configuration of national policies and resource commitments 2 years before.*



As shown in **Figures 3-1 and 3-2**, the updated Index confirms our earlier finding of three groups of nations – first, second and third tier innovators. It also reconfirms the finding of Gans and Stern (2003) that during the 1980s, Australia moved from a classic imitator economy to a second-tier innovator.

Figure 3-2: Innovation Index Rankings

Country	1975 Rank	1975 Innovation Index
USA	1	179.4
Switzerland	2	104.1
Japan	3	86.3
UK	4	85.0
Sweden	5	66.2
Netherlands	6	64.0
Germany	7	59.8
France	8	49.8
Belgium	9	43.4
Australia	**10**	**41.2**
Canada	11	33.8
Denmark	12	29.4
Norway	13	29.3
Hungary	14	27.9
Finland	15	22.9
Austria	16	20.9
Italy	17	13.7
New Zealand	18	8.4
Iceland	19	6.4
Ireland	20	5.3
Mexico	21	2.0
Spain	22	1.8
Portugal	23	1.6
Greece	24	1.0
S Korea	25	0.7

Country	1980 Rank	1980 Innovation Index
Switzerland	1	155.0
USA	2	143.8
Germany	3	71.2
Japan	4	69.2
UK	5	60.9
Sweden	6	56.1
Netherlands	7	48.1
France	8	43.2
Belgium	9	37.7
Canada	10	36.1
Norway	11	29.6
Hungary	12	28.1
Denmark	13	26.1
Finland	14	22.9
Australia	**15**	**20.7**
Austria	16	19.7
Italy	17	12.1
Iceland	18	9.7
New Zealand	19	6.4
Ireland	20	5.6
Mexico	21	2.8
Spain	22	2.3
Portugal	23	0.9
Greece	24	0.8
S Korea	25	0.6

Country	1985 Rank	1985 Innovation Index
Switzerland	1	170.5
USA	2	163.9
Japan	3	99.9
Sweden	4	78.7
Germany	5	77.6
UK	6	55.6
France	7	51.3
Netherlands	8	46.8
Canada	9	46.1
Finland	10	40.2
Norway	11	38.7
Belgium	12	38.7
Denmark	13	32.0
Austria	14	28.5
Australia	**15**	**22.4**
Hungary	16	22.4
Italy	17	11.7
Iceland	18	11.5
New Zealand	19	6.6
Ireland	20	4.7
Mexico	21	3.0
Spain	22	2.8
S Korea	23	2.3
Portugal	24	1.4
Greece	25	0.7

Country	1990 Rank	1990 Innovation Index
Switzerland	1	186.2
USA	2	157.0
Japan	3	132.6
Sweden	4	93.2
Germany	5	89.4
Finland	6	61.6
UK	7	59.0
Canada	8	54.0
Netherlands	9	51.6
France	10	51.5
Norway	11	50.4
Denmark	12	44.7
Belgium	13	44.2
Austria	**14**	**32.5**
Australia	15	32.4
Iceland	16	17.4
Hungary	17	16.6
Italy	18	15.4
New Zealand	19	7.8
Ireland	20	7.1
S Korea	21	6.9
Spain	22	4.8
Portugal	23	2.0
Greece	24	1.5
Mexico	25	0.9

Country	1995 Rank	1995 Innovation Index
Japan	1	147.9
USA	2	143.8
Switzerland	3	129.9
Sweden	4	91.5
Germany	5	88.0
Denmark	6	59.8
Norway	7	57.3
Canada	8	57.1
France	9	53.8
Finland	10	52.9
Netherlands	11	48.6
UK	12	44.0
Belgium	13	41.2
Australia	**14**	**36.9**
Austria	15	29.4
Iceland	16	18.6
Italy	17	15.3
S Korea	18	14.6
Ireland	19	12.5
New Zealand	20	11.0
Spain	21	7.6
Hungary	22	4.0
Portugal	23	2.7
Greece	24	2.4
Poland	25	2.2
Turkey	26	0.4
Mexico	27	0.4

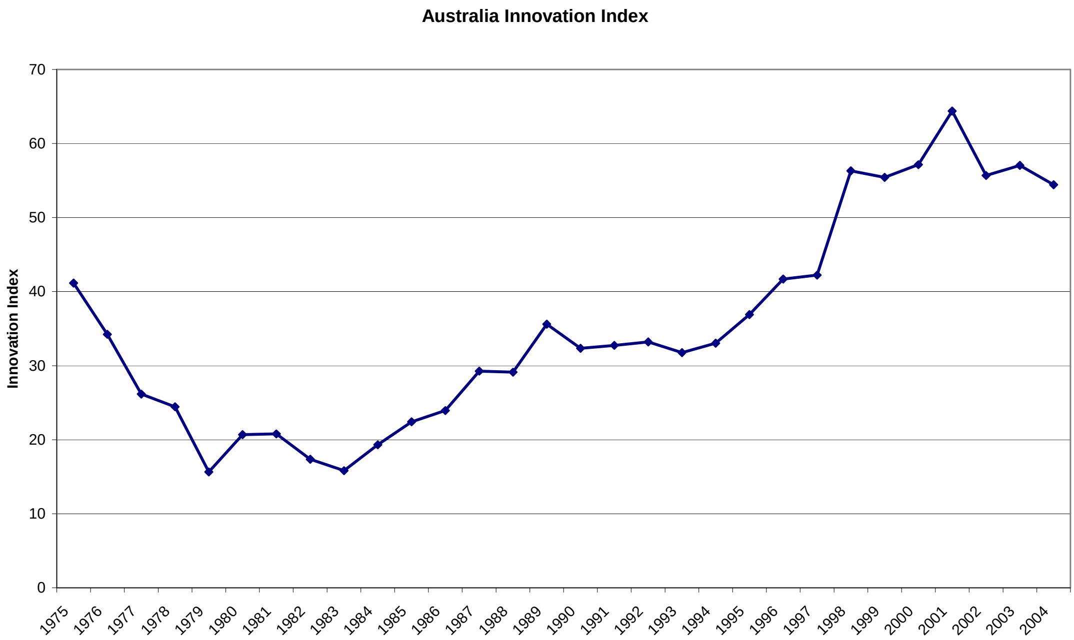
Country	2000 Rank	2000 Innovation Index
USA	1	251.8
Japan	2	187.6
Switzerland	3	176.6
Sweden	4	168.9
Finland	5	148.1
Germany	6	114.4
Denmark	7	113.6
Norway	8	108.1
Canada	9	90.2
France	10	85.0
Netherlands	11	80.5
Iceland	12	71.3
Belgium	13	68.3
Australia	**14**	**57.1**
Austria	15	52.5
UK	16	49.1
Ireland	17	35.9
Italy	18	22.6
New Zealand	19	21.4
Spain	20	18.3
S Korea	21	16.5
Greece	22	6.9
Portugal	23	6.5
Poland	24	3.6
Hungary	25	3.5
Turkey	26	0.7
Mexico	27	0.7

Country	2003 Rank	2003 Innovation Index
USA	1	276.7
Finland	2	198.1
Sweden	3	180.3
Japan	4	173.6
Switzerland	5	155.7
Denmark	6	139.4
Canada	7	118.4
Germany	8	108.4
Norway	9	96.7
Iceland	10	82.9
France	11	80.8
Netherlands	12	80.3
Belgium	13	75.0
Australia	**14**	**57.0**
Austria	15	53.1
UK	16	51.2
Ireland	17	48.6
New Zealand	18	28.1
S Korea	19	28.0
Italy	20	21.2
Spain	21	19.8
Greece	22	10.5
Portugal	23	8.1
Hungary	24	4.3
Poland	25	3.7
Mexico	26	0.7
Turkey	27	0.7

Country	2004 Rank	2004 Innovation Index
USA	1	254.7
Finland	2	205.8
Sweden	3	175.9
Switzerland	4	156.6
Denmark	5	156.2
Japan	6	142.6
Canada	7	116.0
Germany	8	103.7
Norway	9	101.3
France	10	73.6
Belgium	11	72.5
Netherlands	12	70.3
Iceland	13	70.0
Austria	14	57.8
Australia	**15**	**54.4**
UK	16	50.4
Ireland	17	43.6
S Korea	18	28.6
New Zealand	19	27.7
Spain	20	20.9
Italy	21	20.7
Greece	22	10.8
Portugal	23	7.9
Hungary	24	4.0
Poland	25	3.2
Turkey	26	0.6
Mexico	27	0.6

Figure 3-3 shows Australia's innovation index rose slightly from 1998 and has in recent years fallen back. The 2 year lag between innovative capacity (innovation inputs) and the innovation index (predicted innovation outputs) means that there have been no gains in our innovative capacity since 1996.

Figure 3-3: Evolution of Australia's Innovation Index



To understand this, it is useful to look at the drivers of innovative capacity for Australia. **Figure 3-4** presents the changes over time in the key measures used in the benchmarking analysis. It will be seen that the reasons for recent declines have been (i) stagnating R&D expenditure; (ii) a decline in IP protection; and (iii) continuing decline in education funding.

2004 saw Australia's Innovation Index record a small decline. Together with Austria's improved index this decline saw Australia's OECD ranking fall from 14th in 2003 to 15th in 2004.

What explains this fall in the innovation index for 2004? The innovation index for 2004 reflects the innovation policies and resources of recent years. Examining recent drivers of innovation reveals that the answer is not in the most direct drivers of innovative capacity, R&D spending and R&D personnel. In these areas Australia's growth rate from 2001 to 2002 was slightly higher than the average growth rate for the OECD. Although these factors do not explain the 2004 dip they remain cause for concern. Looking back beyond the most recent year, Australia's R&D spending has stagnated since 1996 and Australia's employment of R&D personnel relative to the OECD average has declined.

Some more subtle drivers of innovation rates appear to be behind the 2004 decline in the Index. Australia's impressive strides in intellectual property protection are shown. However in 2001 and 2002 there was a notable decline in the perception of intellectual property protection, which in turn has contributed to the decline in the innovation index. If the IP protection value for 2001 had even remained constant into 2002 then Australia's overall Index value would have recorded a slight increase, all other thing being equal.

The reasons for the decline in perception of Australia's IP protection may be related to controversy surrounding copyright issues, music copying and more recently IP issues highlighted by the US-Australia free trade agreement. There has been a general decrease across the OECD in the perception of the strength of IP protection, no doubt fuelled by worldwide controversy over piracy, copyright and digital IP issues.

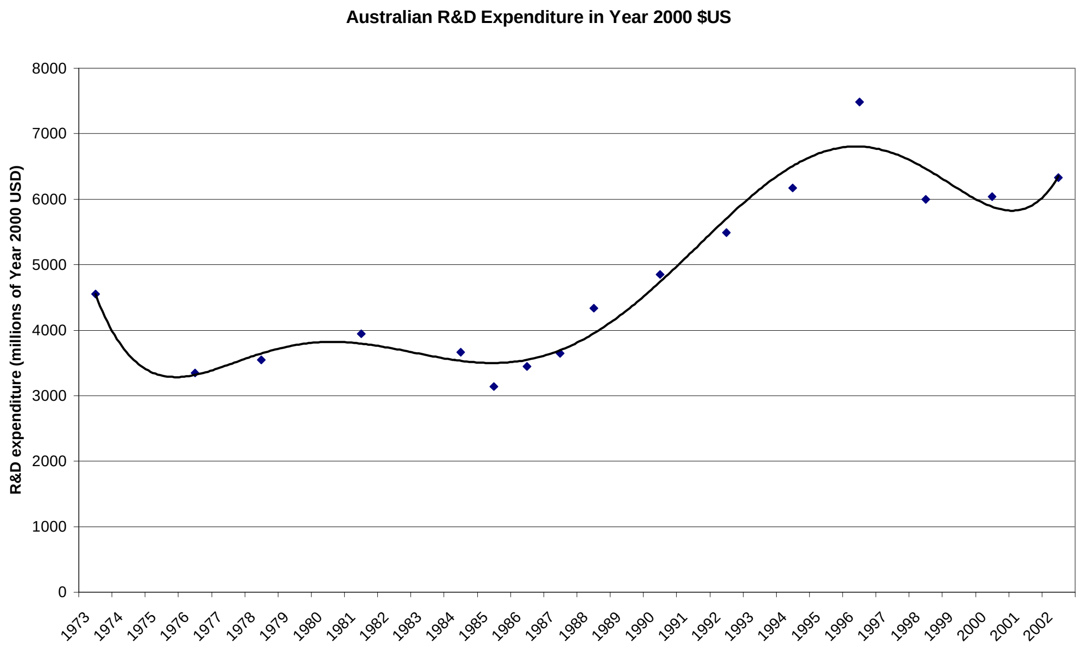
Although perceptions of IP protection also weakened across the OECD, Australia's decline was greater than the OECD average. More recent surveys indicate that this decline in perceived IP protection has continued, which will feed into future innovation index calculations.

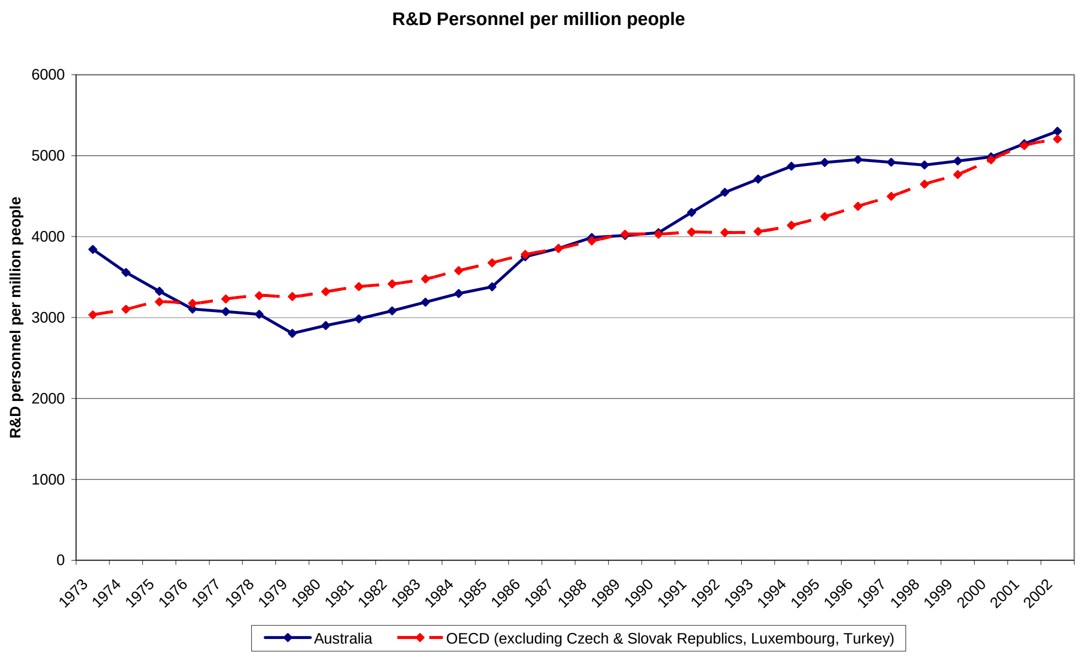
A further feature of the recent fall in the Australian Innovation Index is the continued decline in public spending on secondary and tertiary education as a proportion of GDP. This has been an area of long-term relative decline for Australia compared with the rest of the developed world. Although demographic shifts play some part in this decrease this is unlikely to explain the *relative* decline for Australia compared with the OECD average. Instead policy choices appear to have shifted public funding away from these sectors in Australia, comparing unfavourably with the persistent increases in public funding of education for the OECD as a whole.

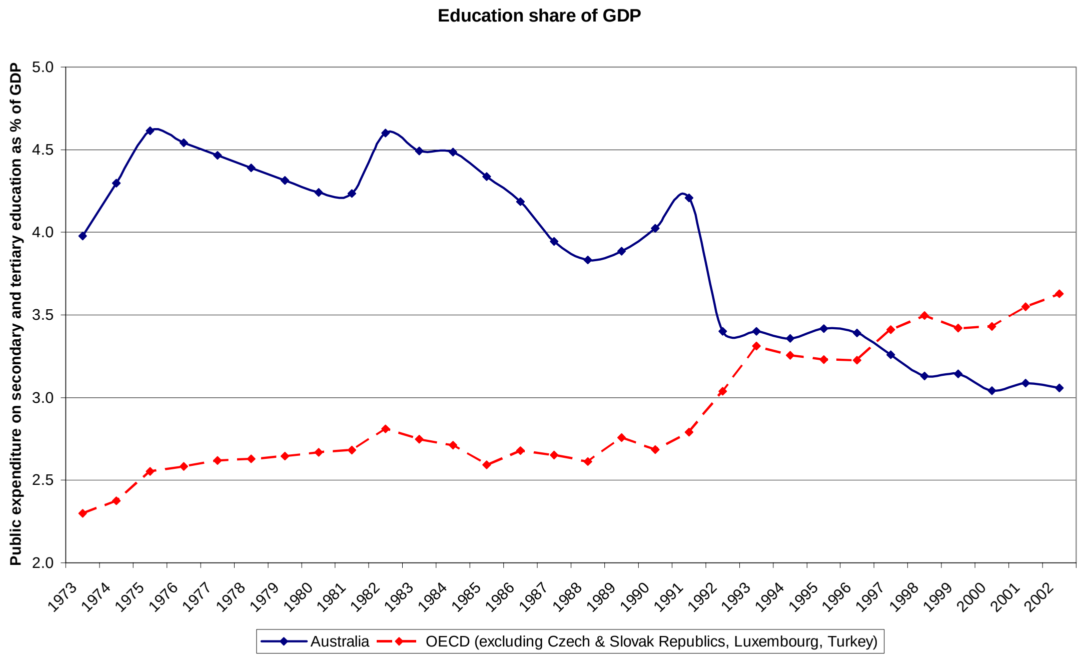
An important note is that the Index rose for only 8 of the OECD countries in 2004 despite generally increasing resource and policy commitments to innovation across the OECD. Part of the explanation for this lies in a "raising the bar" trend for new to the world technology, where increasing resource and policy commitments are needed merely to maintain innovation rates. Declines over time of the time dummy variables used in the regression support this explanation. (see Jones 1998 for further discussion of declining worldwide research productivity).

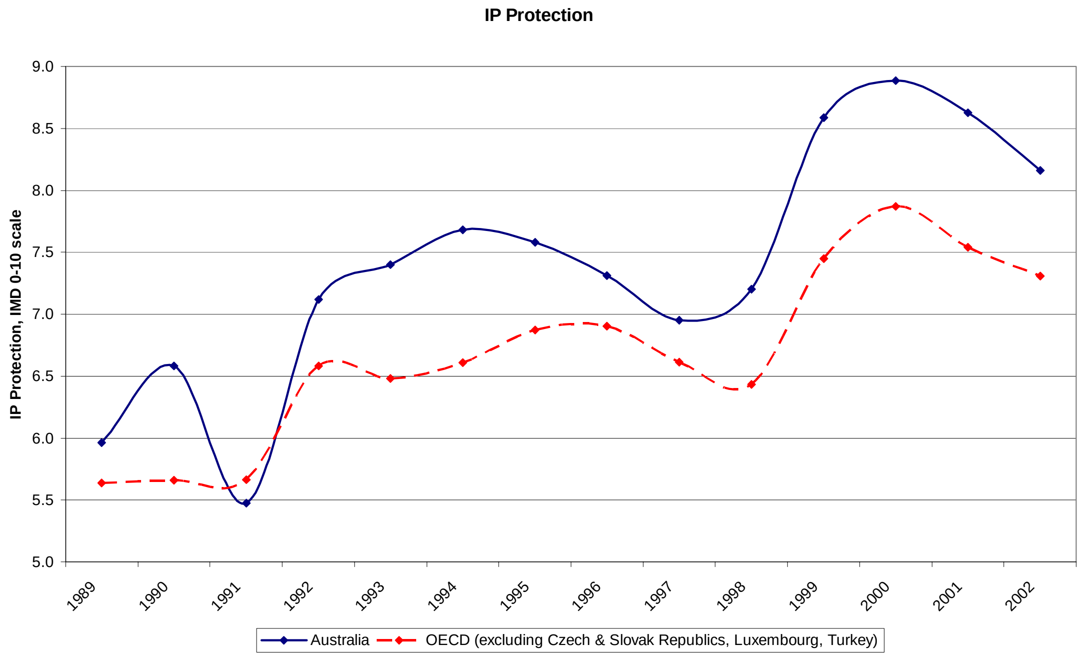
Figure 3-4: Drivers of Australia's Innovative Capacity

Common Innovation Infrastructure

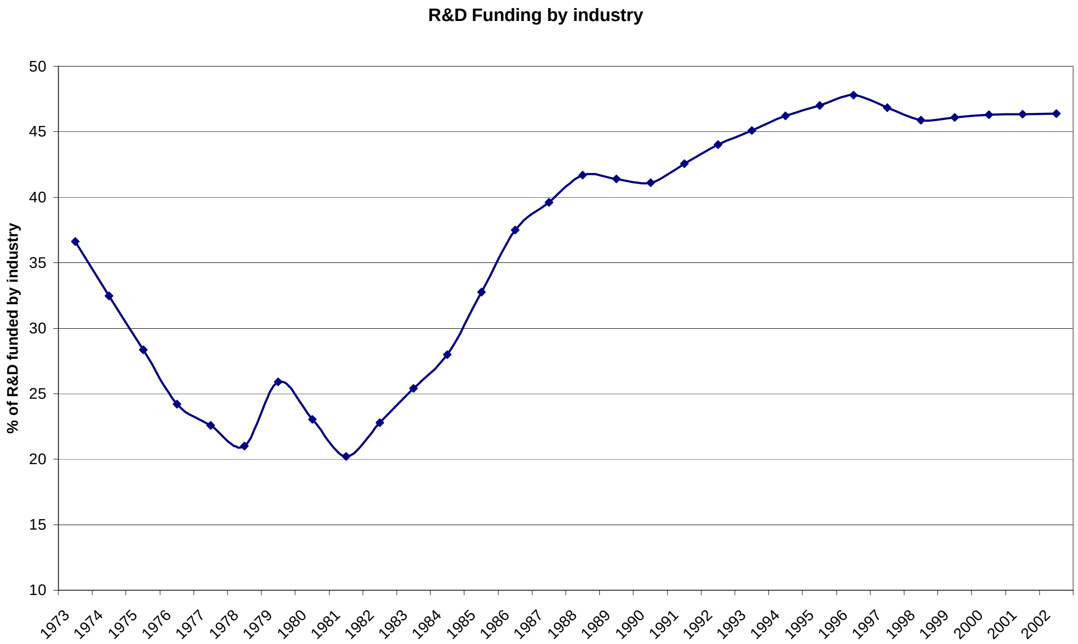




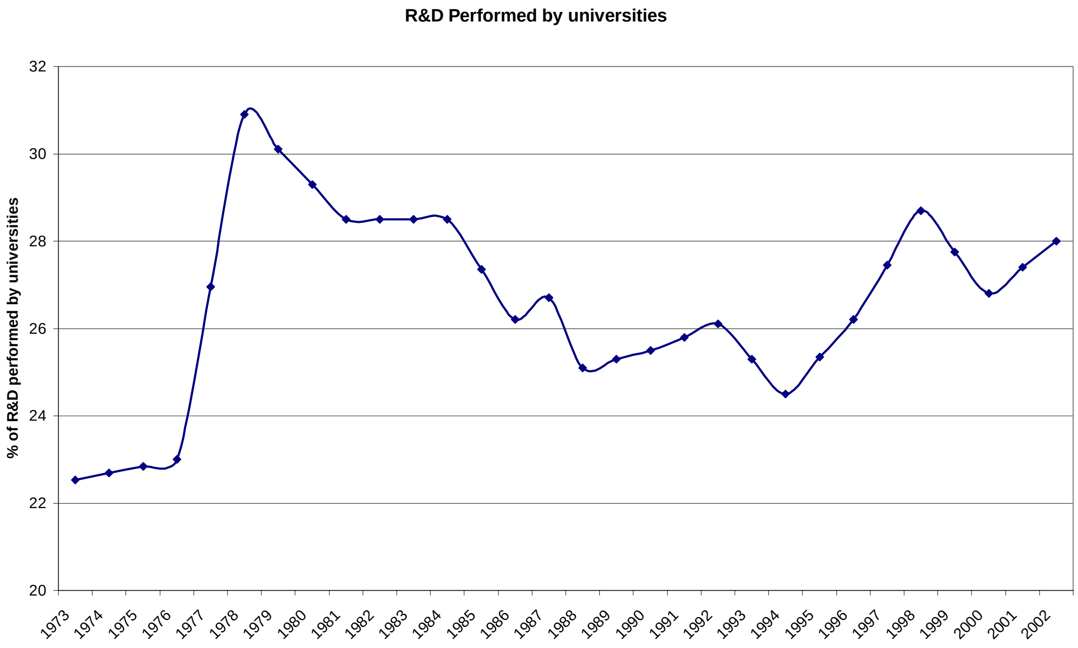

Education share of GDP
Public expenditure on secondary and tertiary education as % of GDP
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Australia
OECD (excluding Czech & Slovak Republics, Luxembourg, Turkey)


IP Protection
IP Protection, IMD 0-10 scale
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Australia
OECD (excluding Czech & Slovak Republics, Luxembourg, Turkey)

Cluster-Specific Environment



Quality of Linkages



4 Summary

Given the robustness of the conclusions of Gans and Stern (2003), it is appropriate to reiterate their policy recommendations for Australian innovation. Our expectation is that overtime, with changing policy directions, this general conclusion will change and evolve.

In a global economy, innovation-based competitiveness provides a more stable foundation for productivity growth than the traditional emphasis on low-cost production. Having secured a position as a leading user of global technology and creating an environment of political stability and regional leadership, Australia has an historic **opportunity** to pursue policies and investments to establish itself as a leading innovator nation. Australia must build upon a foundation of openness to international competition and the protection of intellectual property rights. However, Australia needs to focus upon the areas that appear to have become neglected over the past two decades. In particular, Australia should significantly increase its investment in order to:

- Ensure a world-class pool of trained innovators by maintaining a high level of university excellence and providing incentives for students to pursue science and engineering careers
- Provide incentives and opportunities for the deployment of risk capital
- Facilitate innovation as a cumulative step-by-step process
- Continue to open up Australia to international competition and investment and upgrading the effectiveness of intellectual property protection
- Maintain a vigorous yet sophisticated approach to antitrust enforcement
- Reduce barriers to entry and excessive regulation that hinder effective cluster development
- Build innovation-driven dynamic clusters based on unique strengths and capabilities
- Enhance the university system so that is responsive to the science and technology requirements of emerging cluster areas
- Encourage the establishment and growth of institutions for collaboration within and across industrial areas.

Australia's innovation policy must be cohesive in order to create a favourable environment for private sector innovation. Rather than micro-management of individual projects or short-term schemes that do not necessarily fit within the overall plan, innovation policy must be consistent and allow markets and investors to ultimately choose where to deploy resources and capital for global innovation. Indeed, in the Australian context, high-technology investments may not be in what are conventionally regarded as high-technology industries, as Australia's key strengths build on historical advantages in primary industries. Ultimately, policy should not be judged on whether a particular company or industry flourishes but on whether, taken as a whole, Australian firms are increasingly able to develop and commercialise innovation for global competitive advantage and as a source of prosperity for Australia going forward.

Appendix: Econometric Methodology

This Appendix provides a brief, more technical review of the procedures underlying the calculation of the updated Index and includes the results from our regression analysis. We proceed by reviewing the procedures associated with each of the three stages of the analysis.

Stage I: Developing a Statistical Model of National Innovative Capacity

The first stage consists of creating the database of variables relating to national innovative capacity for our sample of 29 OECD countries from 1973 to 2004. This database is used to perform a time series/cross sectional regression analysis determining the significant influences on per capita international patenting and the weights associated with each influence. Variables, definitions, and sources are listed in Table A-1. Table A-2 lists the 29 countries in the primary sample. Finally, Table A-3 provides some summary statistics.

Data choices are discussed in Furman et.al. (2002). Importantly, the data draws on several public sources, including the most recently available data from the OECD *Main Science and Technology Indicators,* the World Bank, and the National Science Foundation (NSF) *Science & Engineering Indicators*. Where appropriate, we interpolated missing values for individual variables by constructing trends between the data points available. For example, several countries only report R&D expenditure every other year; for missing years, our analysis employs the average of the years just preceding and following.

The primary measure of innovative output employed in the Index is international patent output. The data are provided by the United States Patent & Trademark Office. For all countries except the United States, the number of patents is defined as the number of patents granted in the United States. Since nearly all U.S.-filed patents by foreign companies are also patented in the country of origin, we believe that international patents provide a useful metric of a country's commercially significant international patenting activity. For the United States, we use the number of patents granted to establishments (non-individuals) in the United States. To account for the fact that U.S. patenting may follow a different pattern than foreign patenting in the United States, we include a dummy variable for the United

States in the regression analysis.[3] It is crucial to recall that patenting rates are used only to calculate and assign weights to the variables in the Index. The Index itself is based on the weighted sum of the actual components of national innovative capacity described.

We have used R&D expenditure in Year 2000 US dollars where previously we used R&D expenditure in current year US dollars. This does not affect the fundamental nature of the model due to the inclusion of year dummies.

Alternative model development – SPECIALISATION

The importance of clusters to the innovation process has strong support (see Porter (1990) for an influential account). Stern, Porter and Furman (2002) and Gans and Stern (2003) used measures of specialisation based on relative concentrations of patents across broad technological areas – chemical, mechanical and electrical. Our 2004 update and the Gans and Stern (2003) regressions did not find this variable to be statistically significant, at least partly due to irregular publishing of the underlying data.

In this update we have calculated a new SPECIALISATION measure. As innovative clusters will be associated with technologies from particular technological areas, we use the relative concentration of innovative output in individual USPTO patent classes to proxy for innovative concentration. We exclude the US because patent class information for US government and companies is not readily available from the USPTO and to avoid US raw patent numbers from dominating the specialisation calculation.

The use of 400 patent classes as the base for this measure of specialisation is considerably finer than the broad chemical, mechanical and electrical split used previously. As a result it is likely to be more reflective of genuine clusters and can also allow the identification of the clusters. The possibility of amalgamating some of these classes according to their perceived technological similarity is an option we may explore in future work.

We calculate relative concentration using the Ellison –Glaeser index used in Furman, Porter and Stern (2002), see there for a detailed explanation of the index. When a country has a lower rate of patenting it is easier to overstate its degree of specialisation. The Ellison-Glaeser index provides a correction for this effect.

[3] The coefficient is statistically insignificant. The variable should capture any systematic effect of the asymmetry in the patent measure used, some variables being measured in US dollar terms and the calculation pf specialisation excluding the US. It remains an area for future development.

Model fitting including the specialisation variable suggested dropping the GDPbase variable, a baseline variable. This variable interacted with GDP/POP to effectively capture the effect of it being harder for bigger economies to grow their innovation rate per million people faster. It appears that the specialisation variable is instead reflecting this. Accordingly GDPbase has been dropped from the alternate specification and GDP/POP remains as an indicator of customer sophistication and the overall accumulated level of domestic technological knowledge.

In any event this measure does potentially capture the consequences of cluster dynamics and the relative specialisation of national economies in a particular area. The variable is positive and significant at the 10% level but tends to have a low net weighting on the overall index, with the slight decrease in specialisation recorded for Australia making only a very small quantitative difference to the Index for 2004. This driver of innovative capacity remains an area for future development.

Table A-1: Variables & Definitions

VARIABLE	FULL NAME	DEFINITION	MAIN SOURCE[4]
INNOVATION OUTPUT			
$PATENTS_{j,t+2}$	International Patents Granted, by Year of Grant	For non US countries, patents granted by the USPTO. For the US, patents granted by the USPTO to corporations or governments. To ensure this asymmetry does not affect the results we use a US dummy variable in the regressions.	USPTO patent database
QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE			
FTE R&D $PERS_{j,t}$	Aggregate Personnel Employed in R&D	Full time equivalent R&D personnel in all sectors	OECD Science & Technology Indicators, UNESCO Statistical Yearbook
R&D $\$_{j,t}$	Aggregate Expenditure on R&D	Total R&D expenditures in millions of Year 2000 US$	OECD Science & Technology Indicators, UNESCO Statistical Yearbook
$IP_{j,t}$	Protection for Intellectual Property	Average survey response by executives on a 1-10 scale	IMD World Competitiveness Report
ED $SHARE_{j,t}$	% of GDP spent on secondary and tertiary education	Public spending on secondary and tertiary education divided by GDP	World Bank, OECD Education
$OPEN_{j,t}$	Openness to international trade and investment	Exports plus imports, divided by GDP, Year 2000 US$	World Bank
$GDP/POP_{j,t}$	GDP Per Capita	Gross Domestic Product per capita, 2000 US$	World Bank
$GDPBASE_{j,t}$	GDP in 1973	1973 Gross Domestic Product, billions of 2000 US$	World Bank
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT			
PRIV R&D $FUND_{j,t}$	% of R&D Funded by Private Industry	R&D expenditures funded by industry divided by total R&D expenditures	OECD Science & Technology Indicators, UNESCO Statistical Yearbook
$SPEC_{j,t+2}$	E-G concentration index	Relative concentration of innovative output across USPTO patent classes, excluding the US	Computed from USPTO data
QUALITY OF LINKAGES			
UNI R&D $PERF_{j,t}$	% of R&D Performed by Universities	R&D expenditures performed by universities divided by total R&D expenditures	OECD Science & Technology Indicators, UNESCO Statistical Yearbook

[4] Minor sources include US National Science Board,, Eurostat, RICYT

Table A-2: Sample Countries

REGRESSION DATA FROM 1973-2002 INDEX CALCULATIONS FROM 1975-2004				
Australia	Finland	Ireland	Norway	Sweden
Austria	France	Italy	Poland*	Switzerland
Belgium	Germany#	Japan	Portugal*	Turkey*
Canada	Greece*	Mexico	Slovak Republic**	United Kingdom
Czech Republic**	Hungary	Netherlands	South Korea	United States
Denmark	Iceland	New Zealand	Spain	

* These countries are not included in the base regression but are included in index calculations

** Czech and Slovak Republic Indexes are not calculable for base specification due to absence of GDPBASE data

Prior to 1990, figures are for West Germany only; after 1990 results include all Federal states

Table A-3: Regression Means & Standard Deviations

VARIABLE	Observations	Mean	Standard Deviation
INNOVATION OUTPUT			
PATENTS	647	3731	10006
QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE			
FTE R&D PERS	647	196022	394527
R&D $	647	18572	40272
IP	647	6.47	1.18
ED SHARE	647	3.15	1.18
OPENNESS	647	56.4	31.0
GDP/POP	647	18529	7439
GDPBASE	647	512	963
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT			
PRIVATE R&D FUNDING	647	50.2	14.5
SPECIALISATION	647	0.0132	0.0373
QUALITY OF LINKAGES			
UNIV R&D PERF	647	21.8	6.9

The statistical models draw heavily on a rich and long empirical literature in economics and technology policy (Dosi, Pavitt, and Soette, 1990; Romer, 1990; Jones, 1998). Consistent with that literature, we choose a functional form that emphasizes the interaction among elements of national innovative capacity, namely a log-log specification between international patent production and the elements of national innovative capacity:

Table A-4: Innovation Index Regression Models

Dependent variable = L $PATENTS_{t+2}$

Coefficient (Std Error)

	Base model	Alternate model – SPECIALISATION
QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE		
L FTE R&D PERS	1.218 (0.077)	1.058 (0.043)
L R&D $	0.113 (0.044)	0.097 (0.043)
IP	0.108 (0.027)	0.122 (0.026)
ED SHARE	0.100 (0.014)	0.109 (0.014)
L GDP/POP	0.775 (0.064)	0.738 (0.062)
L GDPBASE	-0.183 (0.075)	
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT		
PRIVATE R&D FUNDING	0.0162 (0.0018)	0.0169 (0.0018)
SPECIALISATION		0.643 (0.352)
QUALITY OF LINKAGES		
UNIV R&D PERF	0.0158 (0.0041)	0.0115 (0.0039)
CONTROL VARIABLES		
US DUMMY	0.0342 (0.0454)	0.0411 (0.0417)
YEAR EFFECTS	Significant	Significant
REGRESSION STATISTICS		
R SQUARED	0.997	0.997
NUMBER OF OBSERVATIONS	647	647

$$LPATENTS_{j,t+2} = \beta_t YEAR_t + \beta_{USA} USDUMMY_j + \beta_{FTE} LFTER\&DPERS_{j,t} + \beta_{R\&D\$} LR\&D\$_{j,t} + \beta_{IP} IP_{j,t} + \beta_{EDSHARE} EDSHARE_{j,t} + \beta_{GDP/POP} L(GDP/POP)_{j,t} + \beta_{GDPBASE} LGDPBASE_j + \beta_{OPEN} OPENNESS_{j,t} + \beta_{PRIVATER\&D} PRIVATER\&D_{j,t} + \beta_{UNIVR\&D} UNIVR\&D_{j,t} + \beta_{SPEC} SPEC_{j,t+2} + \varepsilon_{j,t}$$

This specification is inspired by 4.4 of Furman et.al. (2002). It has several desirable features. First, most of the variables are in log form, allowing for natural interpretation of the estimates in terms of elasticities. This reduces the sensitivity of the results to outliers and ensures consistency with nearly all earlier empirical research (see Jones, 1998, for a simple explanation of the advantages of this framework). Note that the variables expressed as ratios are included as levels, also consistent with an elasticity interpretation. Second, under such a functional form, different elements of national innovative capacity are assumed to be complementary with one another. For example, under this specification and assuming that the coefficients on each of the coefficients is positive, the marginal productivity of increasing R&D funding will be increasing in the share of GDP devoted to higher education.

Table A-4 reports the results from the principal regressions. The US dummy is insignificant in both models. For the base model other coefficients on the variables are significant at the 5% level with the exception of OPENNESS, which is significant at the 10% level. For the alternate model other coefficients on the variables are significant at the 5% level with the exception of OPENNESS and SPECIALISATION, which are significant at the 10% level. Consistent with prior research, the time dummies largely decline over time, suggesting a substantial "raising the bar" effect over the past 30 years (see Jones, 1998, for a discussion of declining worldwide research productivity).

Stage II: Calculating the Index

In Stage II, the Innovation Index was calculated using the results of the regression analysis in Stage I. The Index for a given country in a given year is derived from the predicted value for that country based on its regressors. This predicted value is then exponentiated (since the regression is log-log) and divided by the population of the country:

$$Innovation\ Index_{j,t} = \frac{\exp\left(X'_{j,t-2}\beta\right)}{POP_{j,t}}$$

To make our results comparable across countries, we included the U.S. DUMMY coefficient in the calculation. The issue of its inclusion or exclusion remains an area for closer examination in the future.

Table A-5 provides the Index value for each country for each year. The Index, interpreted literally, is the *expected number of international patents per million persons given a country's configuration of national policies and resource commitments 2 years before*. However it is important not to interpret the Innovation Index as a tool to predict the exact number of international patents that will be granted to a country in any particular year. Instead, the Index provides an indication of the relative capability of the economy to produce innovative outputs based on the historical relationship between the elements of national innovative capacity present in a country and the outputs of the innovative process.

Table A-5: Historical Innovation Index 1975-2004

Year	Australia	Austria	Belgium	Canada	Denmark
1975	41.2	20.9	43.4	33.8	29.4
1976	34.2	21.7	42.8	35.7	29.0
1977	26.1	19.8	36.8	33.2	25.8
1978	24.5	22.7	39.6	40.1	31.7
1979	15.6	15.3	27.2	29.0	20.0
1980	20.7	19.7	37.7	36.1	26.1
1981	20.8	22.5	42.9	31.1	29.0
1982	17.4	22.1	37.7	27.6	24.1
1983	15.8	22.2	33.9	41.1	23.0
1984	19.3	25.5	38.0	45.9	28.0
1985	22.4	28.5	38.7	46.1	32.0
1986	23.9	27.5	38.0	45.0	33.8
1987	29.3	33.4	46.0	57.1	42.6
1988	29.1	30.0	42.8	52.6	39.5
1989	35.6	36.0	51.4	60.0	47.8
1990	32.4	32.5	44.2	54.0	44.7
1991	32.7	34.4	48.1	54.9	58.3
1992	33.2	29.4	45.0	50.7	56.1
1993	31.8	29.5	47.7	49.6	49.2
1994	33.0	30.2	41.8	51.0	54.5
1995	36.9	29.4	41.2	57.1	59.8
1996	41.7	32.9	45.3	67.1	60.8
1997	42.2	35.0	40.9	66.9	61.6
1998	56.3	47.5	54.4	90.1	93.7
1999	55.4	46.4	61.0	87.8	105.6
2000	57.1	52.5	68.3	90.2	113.6
2001	64.4	56.6	82.3	105.6	141.1
2002	55.7	52.9	75.5	101.9	131.9
2003	57.0	53.1	75.0	118.4	139.4
2004	54.4	57.8	72.5	116.0	156.2

Year	Finland	France	Germany	Greece	Hungary	Iceland
1975	22.9	49.8	59.8	1.0	27.9	6.4
1976	23.5	50.1	56.5	1.0	29.1	7.6
1977	21.6	44.0	65.2	1.0	27.1	9.2
1978	24.8	51.2	75.8	1.2	32.7	11.6
1979	16.7	32.5	52.0	0.7	22.2	7.8
1980	22.9	43.2	71.2	0.8	28.1	9.7
1981	26.8	48.5	81.2	0.7	31.4	9.7
1982	27.0	42.7	70.9	0.7	26.9	9.2
1983	27.8	40.7	64.1	0.6	19.4	9.0
1984	34.7	48.5	70.5	0.7	21.3	11.1
1985	40.2	51.3	77.6	0.7	22.4	11.5
1986	42.4	49.7	79.0	0.9	20.9	12.4
1987	55.1	57.5	93.4	1.2	23.0	15.9
1988	51.6	49.1	88.2	1.2	20.3	14.2
1989	65.9	57.4	104.5	1.5	22.4	18.1
1990	61.6	51.5	89.4	1.5	16.6	17.4
1991	65.6	52.9	87.0	1.8	14.1	18.1
1992	56.7	50.6	82.4	1.8	10.1	16.3
1993	57.4	43.1	97.7	1.8	5.9	17.6
1994	55.2	49.9	97.0	2.0	4.0	16.0
1995	52.9	53.8	88.0	2.4	4.0	18.6
1996	58.6	57.8	86.5	3.0	3.1	19.4
1997	69.2	59.6	84.2	3.4	2.5	25.7
1998	100.8	78.3	104.9	5.2	3.1	49.1
1999	127.0	78.7	111.8	6.1	3.3	58.0
2000	148.1	85.0	114.4	6.9	3.5	71.3
2001	205.0	89.2	128.3	8.9	4.0	70.0
2002	193.6	81.2	118.6	9.3	4.8	73.7
2003	198.1	80.8	108.4	10.5	4.3	82.9
2004	205.8	73.6	103.7	10.8	4.0	70.1

* For 1975-1989, the index value is for West Germany only.

Year	Ireland	Italy	Japan	Mexico	Netherlands	New Zealand
1975	5.3	13.7	86.3	2.0	64.0	8.4
1976	5.3	13.4	84.4	2.3	64.7	9.4
1977	5.2	12.2	65.0	2.4	56.5	8.5
1978	5.8	13.6	74.6	2.9	62.1	8.8
1979	4.0	8.5	49.4	2.0	38.4	5.4
1980	5.6	12.1	69.2	2.8	48.1	6.4
1981	6.2	12.4	71.5	3.3	51.7	6.5
1982	4.7	10.3	67.8	3.0	41.5	5.8
1983	3.8	9.9	69.0	3.1	36.8	5.3
1984	4.1	11.0	81.3	3.4	44.5	6.1
1985	4.7	11.7	99.9	3.0	46.8	6.6
1986	4.9	11.0	104.9	2.2	45.4	6.7
1987	6.4	13.7	130.7	2.2	56.9	8.0
1988	6.0	11.7	115.7	1.5	50.2	7.2
1989	7.9	15.5	140.3	1.3	60.6	8.8
1990	7.1	15.4	132.6	0.9	51.6	7.8
1991	8.7	16.3	140.1	0.8	52.4	8.8
1992	10.5	16.8	175.4	1.0	55.2	8.4
1993	12.5	16.0	172.9	1..3	52.5	7.2
1994	14.0	15.2	144.6	0.8	50.8	8.7
1995	12.5	15.3	147.9	0.4	48.6	11.0
1996	18.9	15.4	140.8	0.6	52.5	11.1
1997	22.5	14.4	139.5	0.5	54.8	13.3
1998	27.6	19.2	200.6	0.6	75.5	18.7
1999	35.9	20.7	210.2	0.6	74.3	22.8
2000	35.9	22.6	187.6	0.7	80.5	21.4
2001	39.1	21.8	208.9	0.6	85.5	21.4
2002	43.8	20.1	175.9	0.7	83.2	23.0
2003	48.6	21.2	173.6	0.7	80.3	28.1
2004	43.6	20.7	142.6	0.6	70.3	27.7

Year	Norway	Poland	Portugal	South Korea	Spain
1975	29.3		1.6	0.7	1.8
1976	29.7		1.5	0.8	2.1
1977	30.3		1.1	0.8	2.0
1978	35.8		1.2	0.3	2.4
1979	24.2		0.7	0.3	1.7
1980	29.6		0.9	0.6	2.3
1981	35.5		1.1	0.6	2.3
1982	30.1		1.0	0.6	2.2
1983	28.4		1.0	0.7	2.2
1984	33.2		1.2	1.7	2.6
1985	38.7		1.4	2.3	2.8
1986	42.1		1.4	3.1	3.1
1987	58.0		1.8	4.4	3.5
1988	52.2		1.7	4.6	3.5
1989	60.7		2.1	6.3	4.5
1990	50.4		2.0	6.9	4.8
1991	48.8		2.3	9.3	6.0
1992	43.6	4.7	2.3	11.5	6.9
1993	44.2	3.5	2.8	12.2	8.1
1994	47.2	2.4	2.7	14.7	7.1
1995	57.3	2.2	2.7	14.6	7.6
1996	64.6	2.1	2.9	16.2	9.2
1997	65.6	2.2	3.5	20.2	9.9
1998	96.2	3.8	4.7	25.6	14.1
1999	109.0	3.7	5.5	23.8	15.4
2000	108.1	3.6	6.5	16.5	18.3
2001	115.8	4.0	7.7	20.5	20.9
2002	100.8	3.6	7.3	24.4	21.3
2003	96.7	3.7	8.1	28.0	19.8
2004	101.3	3.2	7.9	28.6	20.9

Year	Sweden	Switzerland	Turkey	United Kingdom	United States
1975	66.2	104.1		85.0	179.4
1976	65.9	112.9		79.5	169.3
1977	59.0	103.4		64.8	143.2
1978	66.2	112.0		71.2	159.3
1979	42.3	111.4		46.8	105.6
1980	56.1	155.0		60.9	143.8
1981	57.7	158.7		63.1	149.3
1982	52.3	146.4		53.4	133.8
1983	58.4	137.2		48.3	126.3
1984	68.8	156.1		53.4	143.9
1985	78.7	170.5		55.6	163.9
1986	85.2	166.0		52.8	175.7
1987	102.8	193.8		61.0	168.3
1988	89.9	170.0		54.3	176.2
1989	107.3	205.4		64.8	178.8
1990	93.2	186.2		59.0	157.0
1991	98.4	190.0		53.7	159.8
1992	81.6	141.9	0.5	49.0	175.6
1993	75.0	126.0	0.6	42.6	177.9
1994	75.5	140.7	0.5	41.4	155.5
1995	91.5	129.9	0.4	44.0	143.8
1996	103.7	135.1	0.4	40.0	158.0
1997	113.9	131.4	0.4	40.8	152.5
1998	162.5	171.8	0.7	43.4	199.1
1999	146.4	180.4	0.8	43.9	227.1
2000	168.9	176.6	0.7	49.1	251.8
2001	188.9	179.5	0.8	54.4	270.5
2002	169.6	158.3	0.9	50.6	274.5
2003	180.3	155.7	0.7	51.2	276.7
2004	175.9	156.6	0.6	50.4	254.7

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