Assessing Australia's Innovative Capacity: 2006 Update

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We thank IPRIA for financial assistance and Chamath De Silva and Alexandra Knight for research assistance. Parts of this report are drawn from Porter, Stern and COC (1999), Gans and Stern (2003), Gans and Hayes (2004) and Gans and Hayes (2005). All views expressed are solely those of the authors and do not necessarily represent those of the above individuals and organisations. Responsibility for all errors lies with the authors.

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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 a new 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 and 2005 updates (Gans and Hayes, 2004; Gans and Hayes, 2005).[1] 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.[2] Each weight is derived from regression analysis relating the **development** of new-to-the-

[1] These results have also been summarised in Gans and Hayes (2006).

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

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 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 2005. These measures are described in Gans and Stern (2003). We have obtained additional historical UNESCO and World Bank data allowing us to "fill in the gaps" in data for some earlier years, decreasing our isolated use of data interpolation. We have also added recent data. 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.[3]

In addition to extending the work by adding new early data and new recent data, we have also moved to our previous alternative specification that incorporates a measure of innovation SPECIALISATION, reflecting the presence and strength of industrial innovation clusters. We have continued to provide the estimation results for our previous specifications.

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

2.3 Findings on Innovative Capacity

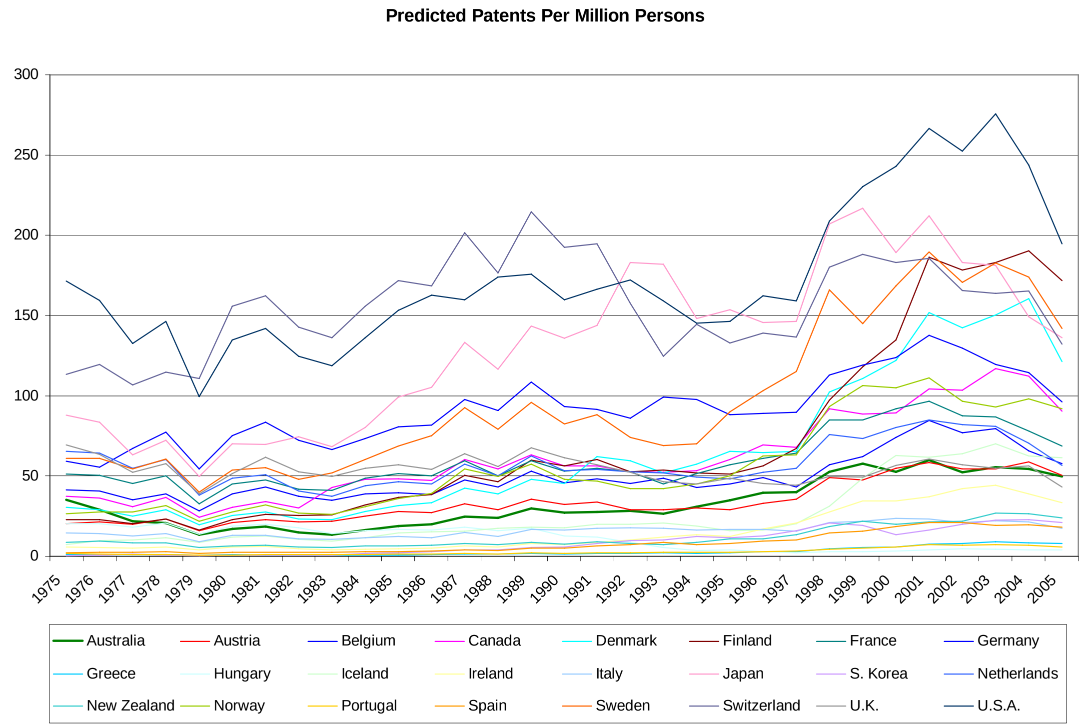
Stern, Porter, and Furman (2002) and Gans and Stern (2003) found that there was a strong and consistent relationship between various measures of national innovative capacity and per capita international patenting. The appendix details these for the expanded dataset using the original model and the alternative 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

[3] 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.

such, we refer the reader to Gans and Stern (2003) for a comprehensive discussion of these findings.

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	171.4
Switzerland	2	113.4
Japan	3	87.8
UK	4	69.3
Netherlands	5	65.2
Sweden	6	61.1
Germany	7	59.4
France	8	51.4
Belgium	9	41.4
Canada	10	37.3
Australia	**11**	**35.1**
Denmark	12	30.6
Norway	13	26.4
Finland	14	22.9
Hungary	15	20.4
Austria	16	20.2
Italy	17	14.6
New Zealand	18	8.8
Iceland	19	7.3
Ireland	20	5.8
Spain	21	2.3
Portugal	22	1.7
Greece	23	1.3
Mexico	24	1.2
S Korea	25	0.5

Country	1980 Rank	1980 Innovation Index
Switzerland	1	155.8
USA	2	134.7
Germany	3	75.3
Japan	4	70.1
Sweden	5	53.8
UK	6	51.5
Netherlands	7	48.6
France	8	45.0
Belgium	9	39.0
Canada	10	30.6
Norway	11	27.5
Denmark	12	25.5
Finland	13	22.9
Austria	14	21.1
Hungary	15	18.8
Australia	**16**	**17.1**
Italy	17	12.9
Iceland	18	11.8
New Zealand	19	6.7
Ireland	20	5.7
Spain	21	2.6
Mexico	22	1.8
Greece	23	1.0
Portugal	24	0.9
S Korea	25	0.6

Country	1985 Rank	1985 Innovation Index
Switzerland	1	171.9
USA	2	153.4
Japan	3	99.0
Germany	4	80.7
Sweden	5	68.6
UK	6	57.1
France	7	51.8
Canada	8	48.3
Netherlands	9	46.5
Belgium	10	39.5
Finland	11	36.6
Norway	12	36.0
Denmark	13	31.7
Austria	14	28.0
Australia	**15**	18.8
Hungary	16	16.8
Iceland	17	14.6
Italy	18	12.3
New Zealand	19	6.7
Ireland	20	4.9
Spain	21	3.0
S Korea	22	2.2
Mexico	23	2.1
Portugal	24	1.4
Greece	25	0.8

Country	1990 Rank	1990 Innovation Index
Switzerland	1	192.5
USA	2	159.7
Japan	3	135.7
Germany	4	93.2
Sweden	5	82.6
UK	6	61.5
Finland	7	56.4
Canada	8	56.3
Netherlands	9	53.3
France	10	53.1
Norway	11	48.0
Belgium	12	45.8
Denmark	13	45.2
Austria	14	32.2
Australia	**15**	**27.2**
Iceland	16	17.6
Italy	17	16.5
Hungary	18	12.9
New Zealand	19	7.8
Ireland	20	7.2
S Korea	21	5.9
Spain	22	5.2
Portugal	23	1.9
Greece	24	1.6
Mexico	25	0.8

Country	1995 Rank	1995 Innovation Index
Japan	1	153.7
USA	2	146.4
Switzerland	3	133.1
Sweden	4	90.1
Germany	5	88.4
Denmark	6	65.4
Canada	7	60.3
France	8	57.0
Finland	9	51.1
Norway	10	50.3
UK	11	48.6
Netherlands	12	48.3
Belgium	13	44.9
Australia	**14**	**34.9**
Austria	15	28.9
Italy	16	16.6
Iceland	17	15.9
Ireland	18	12.5
S Korea	19	11.7
New Zealand	20	11.0
Spain	21	7.8
Hungary	22	3.9
Portugal	23	2.6
Greece	24	2.3
Mexico	25	0.4
Turkey	26	0.3

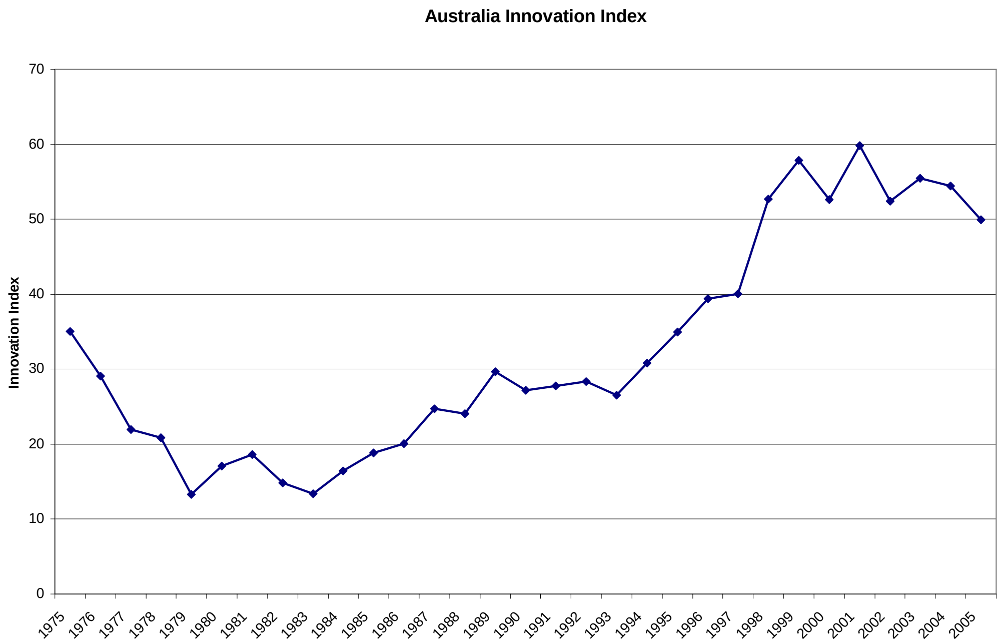
Country	2000 Rank	2000 Innovation Index
USA	1	242.8
Japan	2	189.4
Switzerland	3	183.2
Sweden	4	168.7
Finland	5	134.8
Germany	6	123.7
Denmark	7	121.9
Norway	8	104.8
France	9	91.9
Canada	10	89.5
Netherlands	11	80.4
Belgium	12	74.0
Iceland	13	62.7
UK	14	56.6
Austria	15	54.7
Australia	**16**	**52.6**
Ireland	17	34.4
Italy	18	23.7
New Zealand	19	19.9
Spain	20	18.6
S Korea	21	13.3
Portugal	22	5.9
Greece	23	5.9
Czech Rep	24	5.0
Slovak Rep	25	4.5
Hungary	26	3.3
Poland	27	3.0
Mexico	28	0.7
Turkey	29	0.6

Country	2004 Rank	2004 Innovation Index
USA	1	243.7
Finland	2	190.2
Sweden	3	173.9
Switzerland	4	165.1
Denmark	5	160.4
Japan	6	149.4
Germany	7	114.4
Canada	8	112.2
Norway	9	98.2
France	10	78.1
Netherlands	11	70.6
Belgium	12	65.8
Iceland	13	62.6
Austria	14	58.8
UK	15	56.5
Australia	**16**	**54.5**
Ireland	17	39.0
New Zealand	18	26.6
S Korea	19	22.8
Italy	20	21.3
Spain	21	19.7
Greece	22	8.4
Portugal	23	6.9
Czech Rep	24	6.7
Hungary	25	3.9
Slovak Rep	26	3.3
Poland	27	2.6
Mexico	28	0.8
Turkey	29	0.5

Country	2005 Rank	2005 Innovation Index
USA	1	194.7
Finland	2	171.7
Sweden	3	142.1
Japan	4	136.2
Switzerland	5	132.2
Denmark	6	121.3
Germany	7	96.1
Norway	8	92.0
Canada	9	90.5
France	10	68.8
Iceland	11	61.4
Belgium	12	57.9
Netherlands	13	56.6
Austria	14	50.4
Australia	**15**	**49.9**
UK	16	43.4
Ireland	17	33.4
New Zealand	18	24.1
S Korea	19	20.9
Spain	20	18.3
Italy	21	17.4
Greece	22	7.9
Portugal	23	5.9
Czech Rep	24	5.8
Hungary	25	4.1
Slovak Rep	26	2.7
Poland	27	2.3
Mexico	28	0.9

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 sizable decline. However greater declines by other countries actually saw Australia's ranking move up one position from 16th in 2004 to 15th in 2005.[4]

[4] Our 2005 update had Australia's ranking fall one position to 15th in 2004.yet here we report Australia's ranking as 16th in 2004. The addition of new data each year means that the weights for the index move slowly between index updates, reflecting improved understanding of the drivers of innovative capacity. As a result of this the historical position of countries can slowly change over time. This happened this year for Australia.

What explains this fall in the innovation index for 2005? The innovation index for 2005 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. Australia recorded strong growth in R&D expenditure from 2002 to 2003, in constant US dollar terms, due to increased expenditure and a stronger Australian dollar. This follows a period of several years of relative stagnation. Employment of R&D personnel continued to climb after a long period of relative decline compared to the rest of the OECD. Although these factors do not explain the 2005 dip they remain an area to watch due to their large importance in driving innovative capacity.

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. The decline in 2003 was quite small and has not made a major difference to the index this year. Still if the IP protection value for 2001 had remained constant into 2003 then Australia's overall Index decline this year would have been halved, 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.

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.

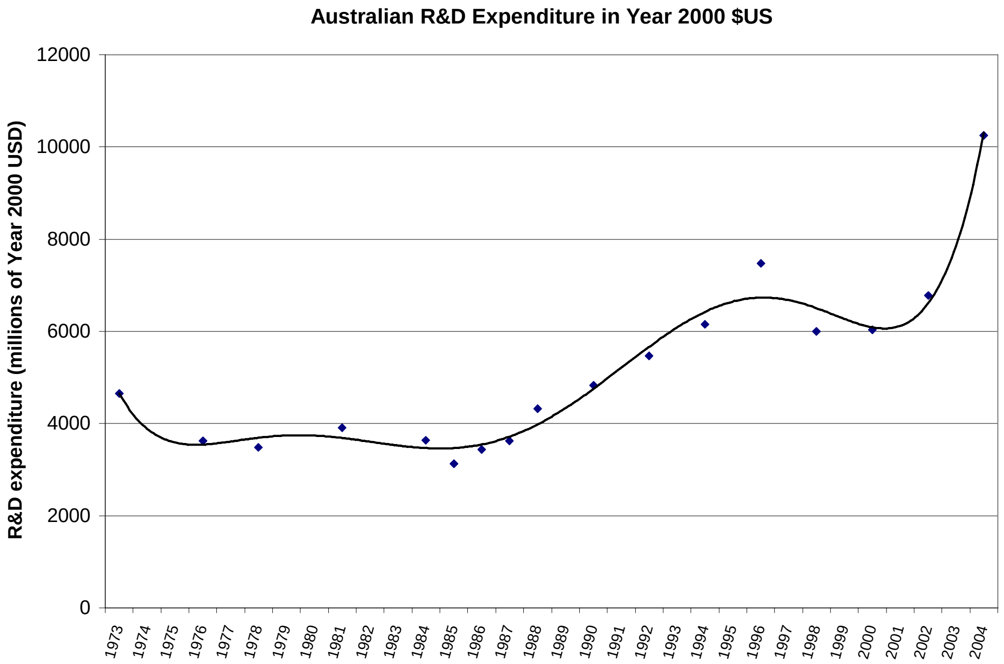
An intriguing feature of Australia's innovative capacity is its recent rapid increase in technological specialisation. Between 2004 and 2005, Australia's specialization indices almost doubled. The main driver of this spectacular increase was an apparent burgeoning capability in miniaturised printing. Silverbrook Research, a Sydney-based nanotechnology company has led this patenting surge. Little is known about this secretive company although its primary inventor and owner, Kia Silverbrook, is among the top living patenters. The secrecy of the firm, and its position as a very dominant driver of Australia's patenting performance in this area mean that the extent to which this represents a true technological cluster is difficult to tell at this stage.

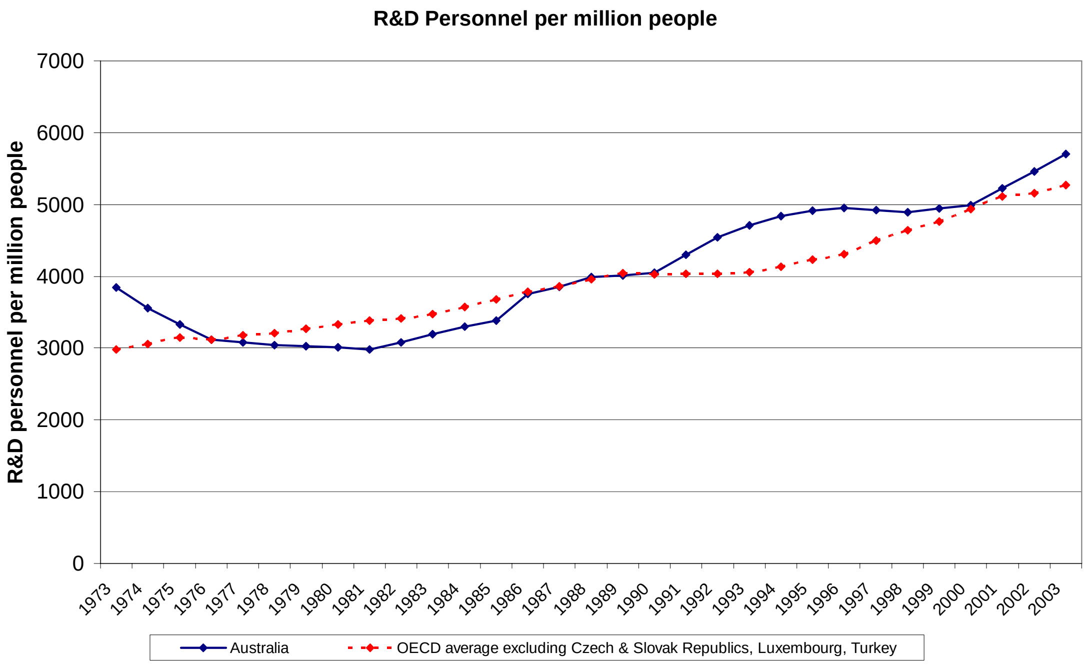
An important note is that the Index rose for only two of the OECD countries in 2005 despite generally increasing resource and policy commitments to innovation across the OECD. Part of the explanation for this lies in a "raising the bar" trend for new to the world technology, where increasing resource 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).

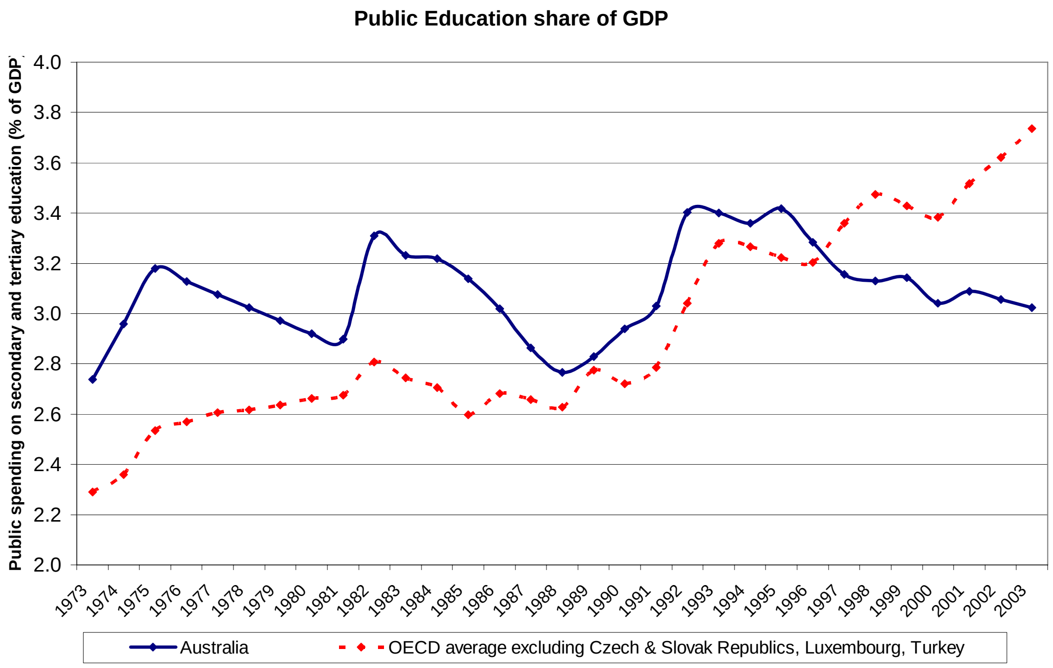
There have also been some media claims that the time between patenting applications and patent grant has increased in some fields, such as in nanotechnology. The USPTO has maintained its advice that there is an average 2 year lag between the time of patent application and its eventual grant. USPTO representatives have instead pointed to initiatives to improve patent quality contributing to a decline in total patents issued by the office in 2005. This decline in total patents issued would have the short term effect of increasing the resources and policy commitments needed to generate the same level of new to the world innovations.

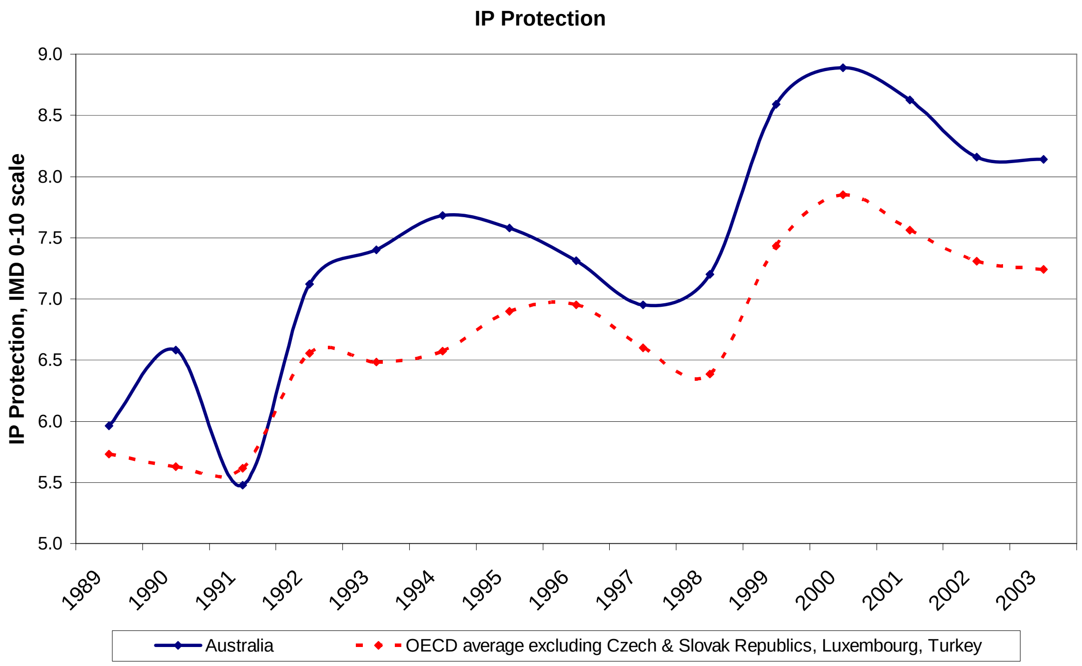
Figure 3-4: Drivers of Australia's Innovative Capacity

Common Innovation Infrastructure

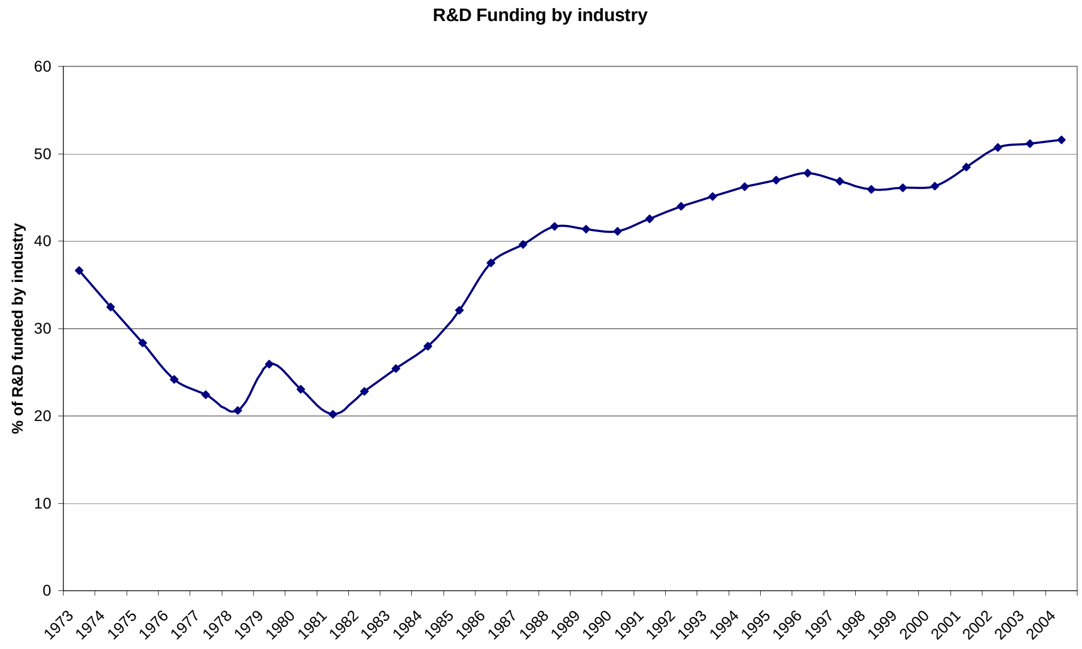


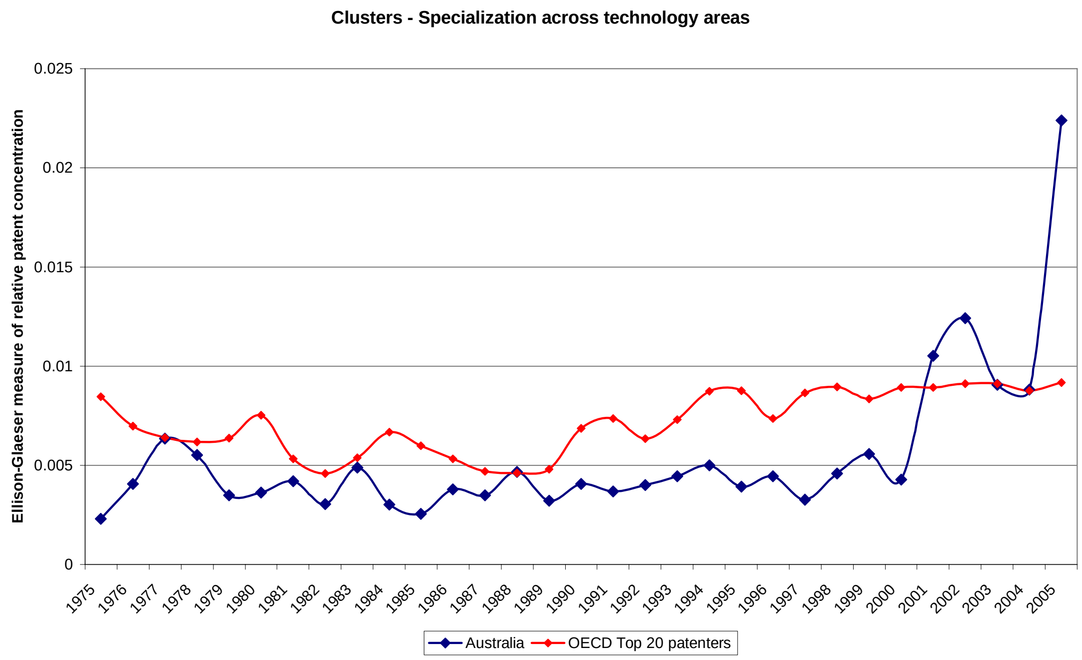



Public Education share of GDP
Public spending on secondary and tertiary education (% of GDP)
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003
Australia
OECD average 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 2003
Australia
OECD average excluding Czech & Slovak Republics, Luxembourg, Turkey

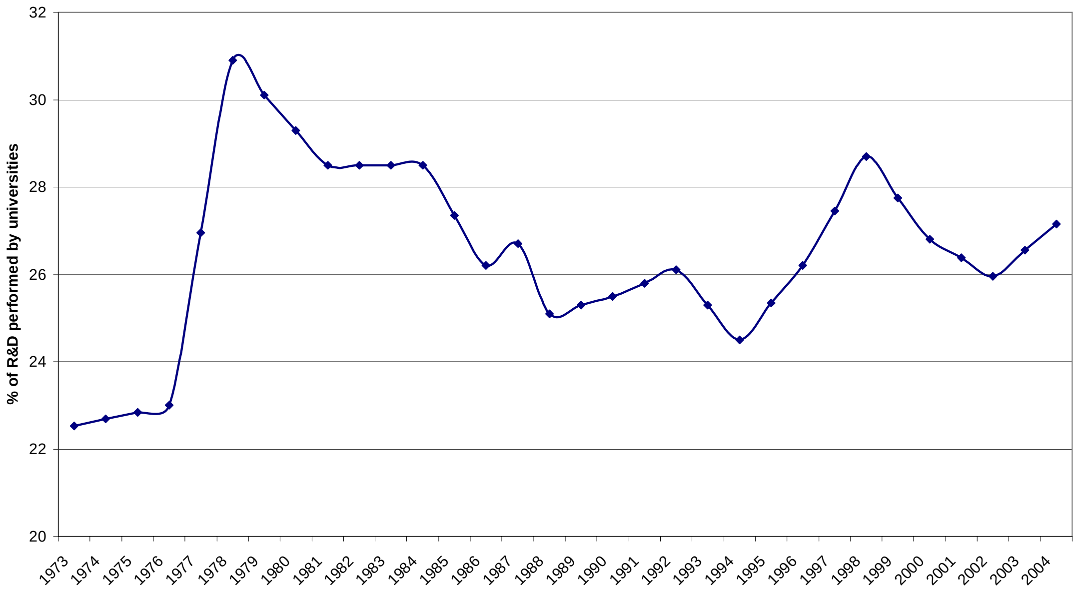
Cluster-Specific Environment





Quality of Linkages

R&D Performed by universities



4 Summary

Given the robustness of the conclusions of Gans and Stern (2003), it is appropriate to reiterate their policy recommendations for Australian innovation. They continue to hold despite their three year age. 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 continues to have an **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 2005. 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.[5] 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.

New 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.

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.

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.

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[5] 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 of specialisation excluding the US. It remains an area for future development.

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 increase in specialisation recorded for Australia making only a very small quantitative difference to the Index for 2005. This driver of innovative capacity remains an area for future development.

Table A-1: Variables & Definitions

VARIABLE	FULL NAME	DEFINITION	MAIN SOURCE[6]
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	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

[6] Minor sources include Australian Bureau of Statistics, US National Science Board, UNESCO Institute for Statistics, Eurostat, US National Center for Education Statistics, some author interpolations and extrapolations

Table A-2: Sample Countries

REGRESSION DATA FROM 1973-2003 INDEX CALCULATIONS FROM 1975-2005				
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 alternative 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	670	3824	10313
QUALITY OF THE COMMON INNOVATION INFRASTRUCTURE			
FTE R&D PERS	670	196574	395221
R&D $	670	18899	41231
IP	670	6.50	1.19
ED SHARE	670	3.15	1.12
OPENNESS	670	57.1	31.7
GDP/POP	670	18727	7531
GDPBASE	670	512	964
CLUSTER-SPECIFIC INNOVATION ENVIRONMENT			
PRIVATE R&D FUNDING	670	50.5	14.5
SPECIALISATION	670	0.0123	0.0361
QUALITY OF LINKAGES			
UNIV R&D PERF	670	21.8	7.0

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 - SPECIALISATION	Previous model – Baseline GDP
L FTE R&D PERS	1.050 (0.040)	1.252 (0.073)
L R&D $	0.127 (0.041)	0.157 (0.045)
IP	0.119 (0.025)	0.100 (0.026)
ED SHARE	0.120 (0.014)	0.112 (0.014)
OPENNESS	0.0016 (0.0006)	0.0013 (0.0006)
L GDP/POP	0.732 (0.065)	0.776 (0.066)
L GDPBASE		-0.240 (0.073)
PRIVATE R&D FUNDING	0.0150 (0.0018)	0.0143 (0.0018)
SPECIALISATION	0.656 (0.360)	
UNIV R&D PERF	0.0098 (0.0035)	0.0156 (0.0037)
US DUMMY	-0.0307 (0.0436)	-0.0443 (0.0479)
YEAR EFFECTS	Significant	Significant
R SQUARED	0.996	0.996
NUMBER OF OBSERVATIONS	670	670

The base model is:

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

This specification is an analogue of equation 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 SPECIALISATION, which is significant at the 10% level. For the alternative model all coefficients on the variables are significant at the 5% level. The model of previous years has all coefficients significant . However we prefer the new base model using specialisation and excluding GDP in a base year. PSecialisation reflects the importance of clusters in innovation. It also more directly reflects the difficulty large economies have in growing their patenting intensities over time than does a baseline GDP. 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:

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

To make our results comparable across countries, we included the U.S. DUMMY coefficient in the calculation, despite it being insignificant in the regression. 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 1975-2005

Year	Australia	Austria	Belgium	Canada	Czech Republic	Denmark
1975	35.1	20.2	41.4	37.3		30.6
1976	29.0	21.6	40.7	36.4		29.0
1977	22.0	20.1	35.1	30.8		25.0
1978	20.9	23.2	38.8	36.5		29.1
1979	13.3	16.1	28.2	24.3		19.4
1980	17.1	21.1	39.0	30.6		25.5
1981	18.6	22.9	43.1	34.0		27.5
1982	14.8	21.5	37.4	30.2		23.2
1983	13.4	21.8	34.7	42.7		23.1
1984	16.4	25.0	38.9	48.1		28.1
1985	18.8	28.0	39.5	48.3		31.7
1986	20.1	27.1	38.7	47.2		33.4
1987	24.7	32.6	47.6	60.5		42.5
1988	24.0	29.0	43.4	54.6		38.9
1989	29.7	35.5	53.0	63.2		47.9
1990	27.2	32.2	45.8	56.3		45.2
1991	27.8	33.9	48.1	56.3		62.1
1992	28.4	29.0	45.5	52.5		59.6
1993	26.5	29.0	48.6	52.2		51.9
1994	30.8	30.0	43.0	53.3		57.5
1995	34.9	28.9	44.9	60.3		65.4
1996	39.4	33.0	48.9	69.4		64.6
1997	40.0	35.7	43.2	67.9	4.2	65.4
1998	52.7	49.0	57.1	92.0	5.0	102.3
1999	57.8	47.7	62.1	88.5	5.0	110.8
2000	52.6	54.7	74.0	89.5	5.0	121.9
2001	59.8	58.3	84.8	104.4	5.0	151.7
2002	52.4	54.3	77.0	103.4	4.7	142.3
2003	55.5	54.4	79.5	116.9	6.2	150.3
2004	54.5	58.8	65.8	112.2	6.7	160.4
2005	49.9	50.4	57.9	90.5	5.8	121.3

Year	Finland	France	Germany	Greece	Hungary	Iceland
1975	22.9	51.4	59.4	1.3	20.4	7.3
1976	22.9	50.5	55.7	1.2	20.2	9.9
1977	20.3	45.4	67.2	1.1	18.2	10.0
1978	23.2	50.1	77.2	1.2	20.6	11.7
1979	16.2	32.8	54.5	0.8	14.0	8.6
1980	22.9	45.0	75.3	1.0	18.8	11.8
1981	26.3	47.7	83.5	0.9	20.2	12.6
1982	25.3	41.8	72.2	0.8	17.8	10.7
1983	25.8	41.0	66.6	0.7	14.2	9.5
1984	31.9	48.8	73.4	0.8	16.1	11.5
1985	36.6	51.8	80.7	0.8	16.8	14.6
1986	38.5	50.3	81.7	1.0	16.4	15.2
1987	50.5	59.4	97.6	1.5	18.1	15.8
1988	46.4	50.1	91.0	1.3	16.0	17.4
1989	60.1	59.4	108.6	1.7	17.4	18.0
1990	56.4	53.1	93.2	1.6	12.9	17.6
1991	60.4	54.8	91.4	1.9	11.8	20.0
1992	52.8	52.5	86.2	1.9	8.8	20.0
1993	53.9	44.9	99.2	2.1	5.5	20.7
1994	52.1	51.7	97.7	1.9	3.8	19.0
1995	51.1	57.0	88.4	2.3	3.9	15.9
1996	56.4	61.1	89.0	2.8	3.0	16.4
1997	67.3	64.1	89.8	3.1	2.3	20.2
1998	97.4	85.0	113.1	4.7	2.9	31.4
1999	118.0	84.9	119.1	5.4	3.0	48.8
2000	134.8	91.9	123.7	5.9	3.3	62.7
2001	186.2	96.6	137.7	7.5	3.8	61.8
2002	178.3	87.5	129.8	7.9	4.7	63.9
2003	183.1	86.6	119.4	9.2	4.2	70.1
2004	190.2	78.1	114.4	8.4	3.9	62.6
2005	171.7	68.8	96.1	7.9	4.1	61.4

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

Year	Ireland	Italy	Japan	Mexico	Netherlands	New Zealand
1975	5.8	14.6	87.8	1.2	65.2	8.8
1976	5.6	14.1	83.4	1.4	64.3	9.4
1977	5.2	12.6	63.1	1.4	55.0	8.2
1978	5.7	14.2	72.4	1.7	60.2	8.5
1979	3.9	9.0	49.7	1.2	38.3	5.4
1980	5.7	12.9	70.1	1.8	48.6	6.7
1981	6.0	13.2	69.7	2.0	50.8	6.7
1982	4.6	11.0	74.3	1.9	40.8	5.9
1983	3.9	10.7	68.3	2.0	37.3	5.5
1984	4.3	11.7	80.2	2.2	43.9	6.4
1985	4.9	12.3	99.0	2.1	46.5	6.7
1986	5.1	11.7	105.2	2.0	45.0	6.7
1987	6.5	14.7	133.3	2.1	57.3	8.1
1988	5.9	12.3	116.5	1.3	50.0	7.1
1989	7.9	16.6	143.4	1.2	62.6	8.8
1990	7.2	16.5	135.7	0.8	53.3	7.8
1991	8.7	17.5	144.0	0.7	54.1	9.2
1992	10.2	17.7	183.0	0.9	52.7	8.1
1993	12.0	17.3	181.9	1.1	51.8	7.3
1994	13.5	16.3	148.3	0.7	49.2	8.7
1995	12.5	16.6	153.7	0.4	48.3	11.0
1996	17.2	16.5	145.7	0.6	52.2	11.0
1997	20.6	15.6	146.3	0.5	55.0	13.5
1998	27.5	20.9	207.0	0.7	76.0	18.4
1999	34.6	21.6	216.9	0.7	73.3	21.7
2000	34.4	23.7	189.4	0.7	80.4	19.9
2001	37.0	23.4	212.0	0.7	85.1	21.6
2002	42.2	21.1	182.9	0.8	82.0	21.7
2003	44.3	22.2	181.2	0.8	81.2	26.9
2004	39.0	21.3	149.4	0.8	70.6	26.6
2005	33.4	17.4	136.2	0.9	56.6	24.1

Year	Norway	Poland	Portugal	Slovak Republic	South Korea	Spain
1975	26.4		1.7		0.5	2.3
1976	27.6		1.5		0.9	2.6
1977	27.4		1.1		1.3	2.4
1978	31.7		1.1		0.6	2.8
1979	21.8		0.7		0.3	2.0
1980	27.5		0.9		0.6	2.6
1981	31.9		1.1		0.6	2.6
1982	27.0		1.0		0.6	2.4
1983	26.3		1.0		0.7	2.4
1984	30.8		1.2		1.7	2.8
1985	36.0		1.4		2.2	3.0
1986	39.2		1.3		2.8	3.3
1987	54.4		1.7		4.0	3.9
1988	49.7		1.5		4.1	3.8
1989	57.5		2.1		5.6	5.0
1990	48.0		1.9		5.9	5.2
1991	46.8		2.2		8.0	6.4
1992	42.0		2.1		9.7	7.3
1993	42.2		2.7		10.2	8.7
1994	45.0		2.5		12.2	7.3
1995	50.3		2.6		11.7	7.8
1996	62.5	1.7	2.8		12.6	9.5
1997	63.3	1.8	3.4	3.3	16.1	10.2
1998	93.5	3.3	4.3	3.9	20.9	14.5
1999	106.4	3.3	5.2	4.8	19.2	15.7
2000	104.8	3.0	5.9	4.5	13.3	18.6
2001	111.0	3.4	7.2	3.7	16.2	21.0
2002	96.7	2.9	6.7	3.4	20.1	20.9
2003	93.1	3.0	7.4	3.4	22.5	19.1
2004	98.2	2.6	6.9	3.3	22.8	19.7
2005	92.0	2.3	5.9	2.7	20.9	18.3

Year	Sweden	Switzerland	Turkey	United Kingdom	United States
1975	61.1	113.4		69.3	171.4
1976	61.1	119.4		63.7	159.5
1977	54.5	106.8		52.4	132.7
1978	60.8	114.9		57.6	146.4
1979	39.9	110.7		38.8	99.5
1980	53.8	155.8		51.5	134.7
1981	55.0	162.3		61.6	142.0
1982	47.8	142.7		52.6	124.7
1983	52.0	136.1		49.8	118.9
1984	60.4	155.9		54.9	136.1
1985	68.6	171.9		57.1	153.4
1986	75.3	168.5		54.2	162.7
1987	92.6	201.7		64.0	159.7
1988	79.1	176.4		56.0	173.9
1989	95.7	214.7		67.7	175.9
1990	82.6	192.5		61.5	159.7
1991	88.1	194.8		57.1	166.4
1992	74.2	157.6	0.5	52.4	172.1
1993	68.9	124.7	0.5	46.3	158.9
1994	70.2	144.4	0.4	45.1	145.3
1995	90.1	133.1	0.3	48.6	146.4
1996	103.1	139.0	0.3	45.3	162.2
1997	115.0	136.4	0.3	44.1	159.1
1998	165.9	180.1	0.5	49.6	208.8
1999	144.9	188.2	0.7	49.4	230.3
2000	168.7	183.2	0.6	56.6	242.8
2001	189.5	185.6	0.6	60.7	266.4
2002	170.6	165.4	0.7	56.9	252.3
2003	182.8	163.8	0.6	54.9	275.8
2004	173.9	165.1	0.5	56.5	243.7
2005	142.1	132.2		43.4	194.7

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