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Innovation Activity and Income Levels: A Summary of Indicators

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Michael O'Neil
Director
SA Centre for Economic Studies
April 2003

Innovation Activity and Income Levels: A Summary of Indicators[1]

Overview

This report presents indicators of innovation activity and incomes in the Australian States and Territories, and in the regions of the United States, Canada and Germany. Organisations such as the OECD publish comparative data on *national* innovation activity and income, but the emphasis in this document is on *within-country* variations in the data. This information is then used to explore correlations between the innovation indicators and income levels. No attempt is made to identify directions of causation.

The data show that, among the Australian States, the ACT has by far the highest R&D intensity. Of the rest, South Australia and Victoria have relatively high R&D intensity, while New South Wales, Western Australia and Queensland have significantly lower intensity. However, when one considers just business R&D spending, a different picture emerges: Victoria has the highest per capita expenditure, followed by Western Australia and New South Wales. The States with high business R&D also tend to be the States with high levels of patenting activity.

It is difficult to reach any confident conclusion about the existence of a correlation between R&D spending and incomes in the Australian context, mainly because the number of States with which to form a cross section is so small. Just six are available if one excludes the Territories. However, the data suggests rather tentatively that there is a correlation between business R&D spending and average earnings. There is also some evidence of a correlation between patent activity and earnings.

Australia as a nation has relatively low R&D spending when compared to other OECD nations. For instance, Australia's per capita expenditure of about $A500 per annum compares with $A1,017 in the United States, $A773 in Germany and $A600 in Canada. Low R&D levels for Australia can be explained in terms of low business spending; the other sectors (government, higher education and private non-profit) taken collectively spend a little more per capita in Australia than in the United States, Germany and Canada.

Because the Australian evidence is not entirely conclusive about the presence of correlations between innovation activity and income, it is useful to look at evidence from overseas regions.

A comparison of innovation activity and incomes within the Unites States proves to be quite fruitful. Because the United States has 50 States, interstate comparisons support conclusions about correlation with a much higher degree of confidence. There is a significant positive correlation between R&D activity and average earnings (see Figure 7 herein). Further analysis shows that the correlation persists when one compares R&D and earnings for office and administrative support workers across States – it is not just a reflection of a greater presence of skilled occupations in the higher R&D States. A significant correlation is also evident between patent activity and average earnings.

On the basis of this evidence, it is clear that there is a significant positive correlation between innovation activity and average earnings. One needs to be careful in drawing conclusions about the existence or directions of causation, but these data indicate that innovation activity is an important factor to consider when trying to understand the determinants of regional income variations. There is considerable support in the technical economics literature for the view that R&D does “cause” productivity increases. The mechanism of causation is imperfectly understood, but it is fairly clear that it extends beyond “inventions” arising from R&D. R&D also plays a crucial role in raising the “absorptive” capacity of an economy – i.e. its ability to identify inventions from outside the local economy, and then adapt them and incorporate them into local production activities.

1. Introduction

Governments around the world are increasingly interested in innovation as one of the determinants of regional economic success. The United States' experience in the second half of the 1990s, when its already world-leading productivity levels surged further, underscored the potential contribution of innovation and restructuring to productivity and income levels. In this report we present simple comparisons of innovation and income indicators and illustrate that a significant correlation does indeed exist.

The objective of this paper is to explore the empirical evidence for simple correlations between indicators of innovation and income levels. As such, it is essentially a summary of statistical indicators which illustrate *within-country* correlations between innovation and income indicators. The body of the report discusses the data and their interpretation and uses charts to illustrate. The derivation of the indicators and the sources of the underlying data are covered in the Appendix. We have not attempted to draw conclusions about the policies which might be employed by governments that seek to use innovation to boost regional productivity.

2. Possible indicators of innovation activity and income levels

The measures of innovation activity used in this Issues Paper are R&D spending, patent applications and patent grants. R&D spending is considered both in total, and also for the business sector. R&D spending is an *input* into the innovation process. Patent applications and patent grants are an *output* of the innovation process; there are of course others such as copyrighted knowledge, trade secrets, human capital enhancements and the adoption of innovations.

Patents can be lodged either in one jurisdiction or in several jurisdictions. In terms of sheer numbers the US Patent and Trademark Office handles the most patents, followed by the European Patent Office and the Japanese Patent Office. In addition, simultaneous multi-jurisdiction lodgement can be achieved by means of Patent Cooperation Treaty (PCT) lodgements. In this report, for reasons discussed later, we have generally used PCT patent applications data as the indicator of patent activity. Throughout the study we have sought to make regional allocations on the basis of the region of residence of the inventor (in contrast to, say, the owner of the patent or the filing organisation) and this constrains the choice of data sets somewhat.

The primary income indicator used in this analysis is average earnings. Some gross product data is presented, but we prefer average earnings data on the grounds that it is less susceptible to influence from factors such as differences in the age structure of the population and that it is more genuinely reflective of the income opportunities available to residents in a region. Gross product figures include income streams which may largely flow out of a region, such as income from mining operations, and are in that sense less likely to be reflective of local income levels. Furthermore, compilations of gross product data for regions within national economies are subject to significant measurement difficulties and may be less reliable. Finally, there is a technical reason to favour average earnings, this being that it does not run the risk of introduced spurious correlation which arises when one scales two aggregates with a common scaling factor.

When comparing innovation and income patterns across regions, an important question is how to allow for differences in the size of regions. In Australia, for instance, New South Wales has a population of 6.6 million compared with Tasmania's 472,000. Indicators which are in aggregate form, such as whole of State R&D spending, need to be scaled.

We could use regional gross product or regional populations as scaling factors. Where the comparison is between nations which use different currencies, if we deflate by population it is then necessary to convert to a common currency basis as well, which raises some complications. Do we convert according to the currencies' relative purchasing power or their exchange values? (The two are not necessarily the same.) In our view, the ideal approach in many contexts would be to deflate by population and convert currencies with a suitable purchasing power index. But often a purchasing power index is not available or would be controversial. An alternative, which is the OECD approach, is to deflate with gross product because the resultant indicator does not include a currency element. The problem with the resultant indicator is that a nation with a relatively high absolute level of R&D spending and high GDP may be rated as having equivalent R&D intensity to a nation with low absolute R&D spending and low GDP.

When comparisons are being made within a country, a common currency exists and therefore if one deflates by population the indicators are at least in a common currency. There is still some question as to whether there are regional variations in the purchasing power of that currency. But the alternative, deflating by gross product, gives an indicator which is influenced not just by R&D intensity but also by industrial structure, and is therefore also imperfect. In our view variations in R&D spending per capita across the regions within a nation are of considerable interest so long as one keeps in mind that variations may reflect differences in the R&D cost structure and variations in population structure, as well as variations in what we are ultimately interested in, which is R&D intensity.[2]

3. Summary of Australian data

Table 1 presents summary indicators of innovation activity and income levels for the Australian States and Territories.

Table 1
Gross product, wages, R&D spending and patent activity in the Australian States

	Per capita gross state product ($A) average 98-99 to 00-01	Ave weekly ordinary time earnings of adult full-timers ($A) 99-00	Business R&D spending average of 98-99 and 00-01		Total R&D spending per capita ($A) average of 98-99 and 00-01		PCT patent applications with local investor per 100,000 residents	
			$A per capita	% of GSP	$A per capita	% of GSP	2001	Average 1997 to 2001
NSW	34,995	808	240	0.7	449	1.3	10.9	7.4
Vic	33,940	755	330	1.0	596	1.8	9.7	7.6
Qld	28,966	714	134	0.5	356	1.2	7.1	5.3
SA	27,660	714	182	0.7	524	1.9	7.6	7.0
WA	36,782	782	244	0.7	470	1.3	10.7	5.2
Tas	24,165	721	93	0.4	434	1.8	3.6	2.9
NT	39,228	784	83	0.2	421	1.1	3.0	1.9
ACT	40,842	889	111	0.3	1962	4.8	9.3	14.0
Aus	33,084	768	231	0.7	500	1.5		

Source: See Appendix A.

Table 2 presents correlation coefficients (and t-statistics) for a comparison of average weekly ordinary time earnings of adult full-timers and three measures of innovation intensity.

Table 2
Correlation coefficients between average weekly earnings and innovation indicators for the Australian States (t-statistics in brackets)

Innovation indicator	6 States and 2 Territories	6 States only
Per capita total R&D spending	0.80 (3.26)	0.16 (0.33)
Per capita business R&D spending	-0.06 (-0.14)	0.62 (1.59)
Per capita PCT patent applications	0.39 (1.05)	0.80 (2.69)

Note: Correlation coefficients and associated t-statistics are presented to support the graphical material in this section. It should be noted however that the small number of observations used to produce this data brings into question the meaning of the correlation coefficients and, even more so, the t-statistics. For some innovation/earnings comparisons the t-statistics in concert with calculated correlation coefficients would appear to strongly support the existence of a significant underlying connection. However, the ability of the t-statistics to support such a conclusion in small samples depends upon the normality of the underlying sampling distributions, and we are not able to make a judgment about that. (For further discussion see James L. Kenkel (1989), *Introductory Statistics for Management and Economics* PWS-Kent, Boston Mass)

Source: Calculations based on data in Table 1.

3.1 Incomes

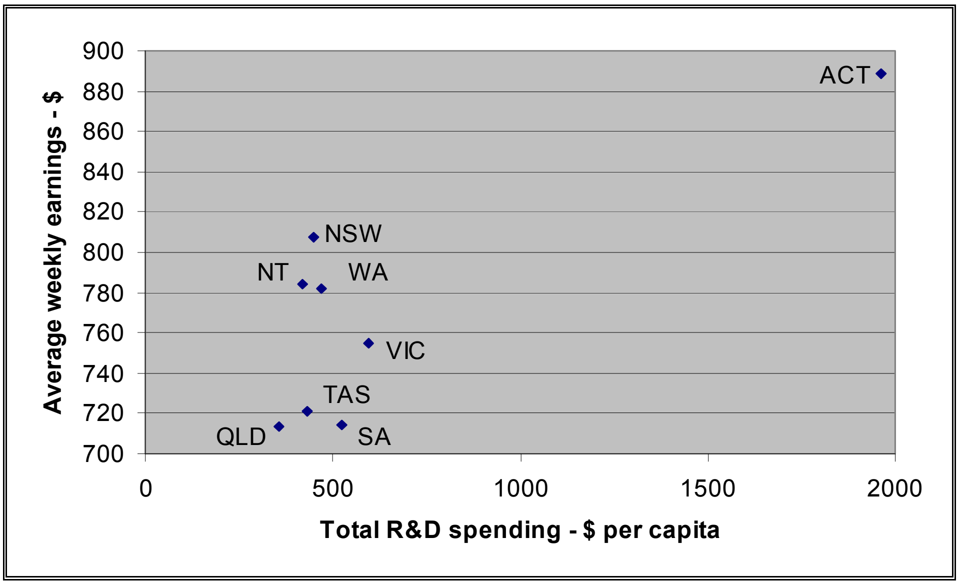
The two indicators of income, GSP per capita and average weekly ordinary time earnings, produce similar but not identical, rankings of the States, with the Australian Capital Territory, New South Wales, the Northern Territory and Western Australia at the high end, and Victoria around the middle. Queensland, South Australia and Tasmania are below average on either measure.

3.2 R&D spending

Table 1 shows that, among the six States, Victoria had the highest per capita level of R&D spending, followed by South Australia. Queensland had the lowest level of R&D spending. Table 1 also presents the ratios of R&D spending to gross product. The R&D intensity of the States according to this indicator is a little different than with the per capita measure.

Figure 1 shows per capita spending on R&D by all sectors, and average weekly ordinary time earnings, within each Australian State and Territory. There is no apparent correlation between earnings and R&D spending unless one includes the rather unusual case of the ACT (see also Table 2).

Figure 1
Total R& D and average weekly ordinary time earnings in the Australian States and Territories ($A)

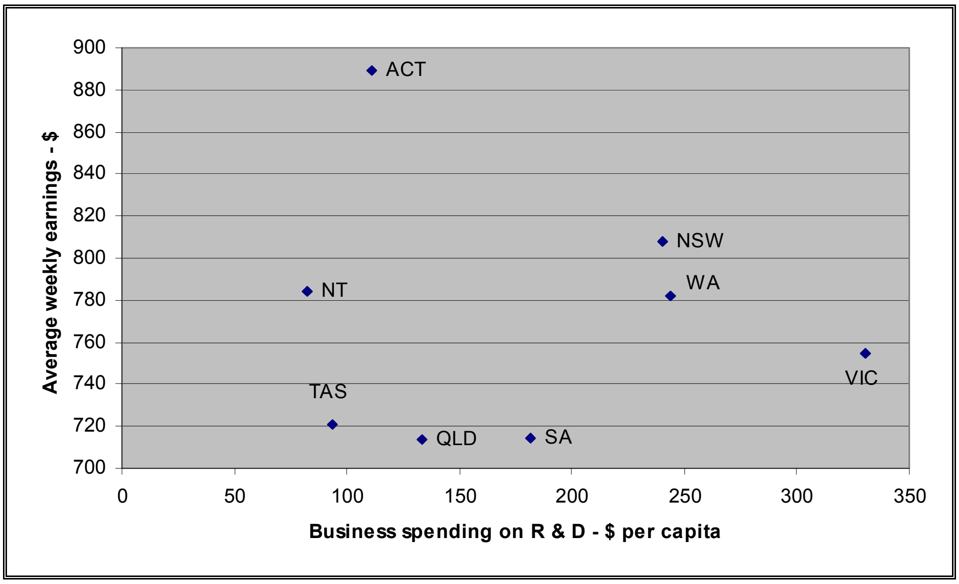


Note: R&D is average of 1998-99 and 2000-01. Average earnings are for 1999-2000.

Figure 2 shows per capita spending on R&D by business, and average weekly earnings, for the Australian States and Territories. It is possible to see a correlation if the NT and ACT are excluded from consideration (the correlation coefficient is 0.62). That the correlation is imperfect is not surprising.

Among the six States, Victoria had the highest per capita level of business R&D spending, followed by Western Australia and New South Wales. Tasmania had the lowest level of business R&D spending.

Figure 2
Business R& D and average weekly ordinary time earnings in the Australian States and Territories ($A)

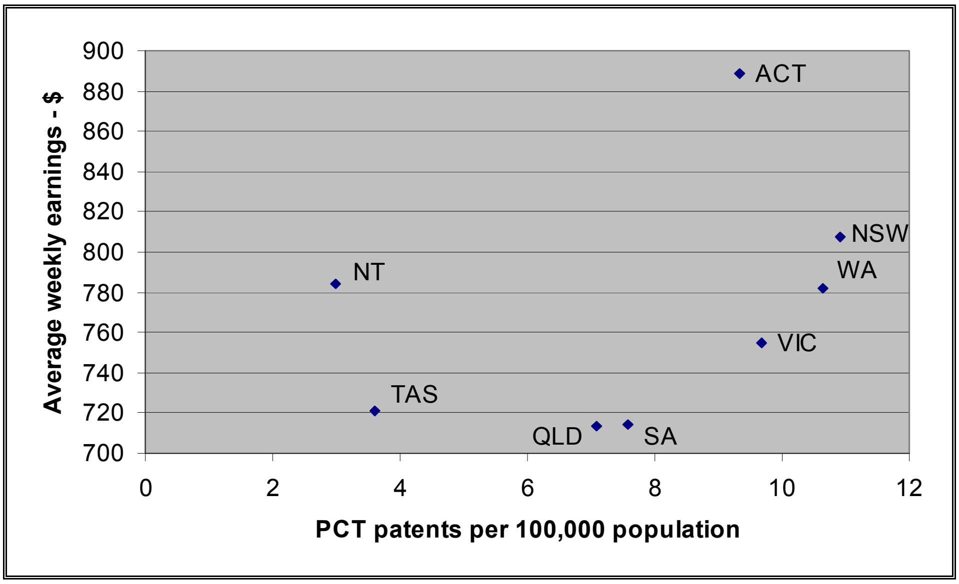


Note: R&D is average of 1998-99 and 2000-01. Average earnings are for 1999-2000.

3.3 Patents

Figure 3 compares PCT patents invented per 100,000 residents with average wages. (PCT patents are patents lodged under the Patent Cooperation Treaty which provides protection for the intellectual property in all signatory countries.) The State allocation is based on State of residence of the inventor(s) of PCT patents. In 2001 NSW had the highest level of PCT patents granted per capita (10.9 per 100,000 population), closely followed by Western Australia with 10.7. Victoria had 9.7, while South Australia (7.6) and Queensland (7.1) were lower again. Patenting activity was much lower in Tasmania. There appears to be some correlation between patent application rates and average wages for the 6 States (the correlation coefficient is 0.80) although the number of observations (just 6) is too small to be confident about the stability of such a relation.

Figure 3
PCT patents and average weekly ordinary time earnings in the Australian States and Territories ($A)

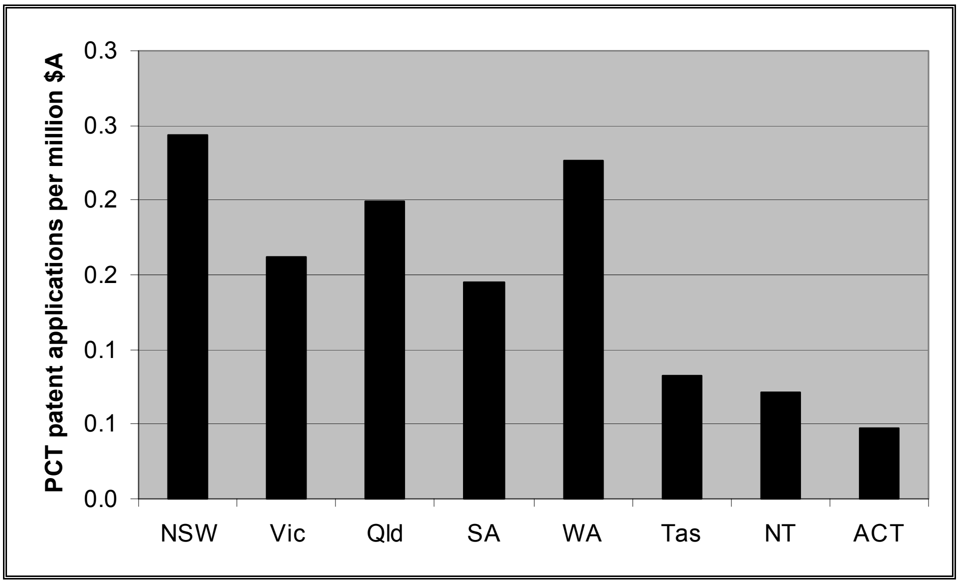


Note: PCT patent data is for 2001. Average earnings are for 1999-2000.

3.4 R&D productivity

Figure 4 presents a partial measure of productivity for R&D activity. It shows the number of PCT patents per million $A spent on total R&D. There is considerable variation across the States. For instance, New South Wales had the highest number of patents (0.24) per million $A spent, whereas South Australia had just 0.14 and Tasmania 0.08. This measure tends to be high for States with a strong *business* R&D component.

Figure 4
Number of PCT patents per $ million expenditure on R&D ($A)
Australian States and Territories



Note: R&D is average of 1998-99 and 2000-01. PCT patent data is for 2001.

These variations may reflect differences in the structure of the R&D effort. For instance, if a State puts a relatively large amount of R&D into basic research or applied research with relatively limited patenting prospects (e.g., land and hydrological management techniques), then the ratio of patents per R&D dollar will be low. In these cases, patents are an inadequate indicator of the output resulting from R&D.

4. Comparisons between countries

4.1 R&D spending

Ratio of R&D to Gross Product

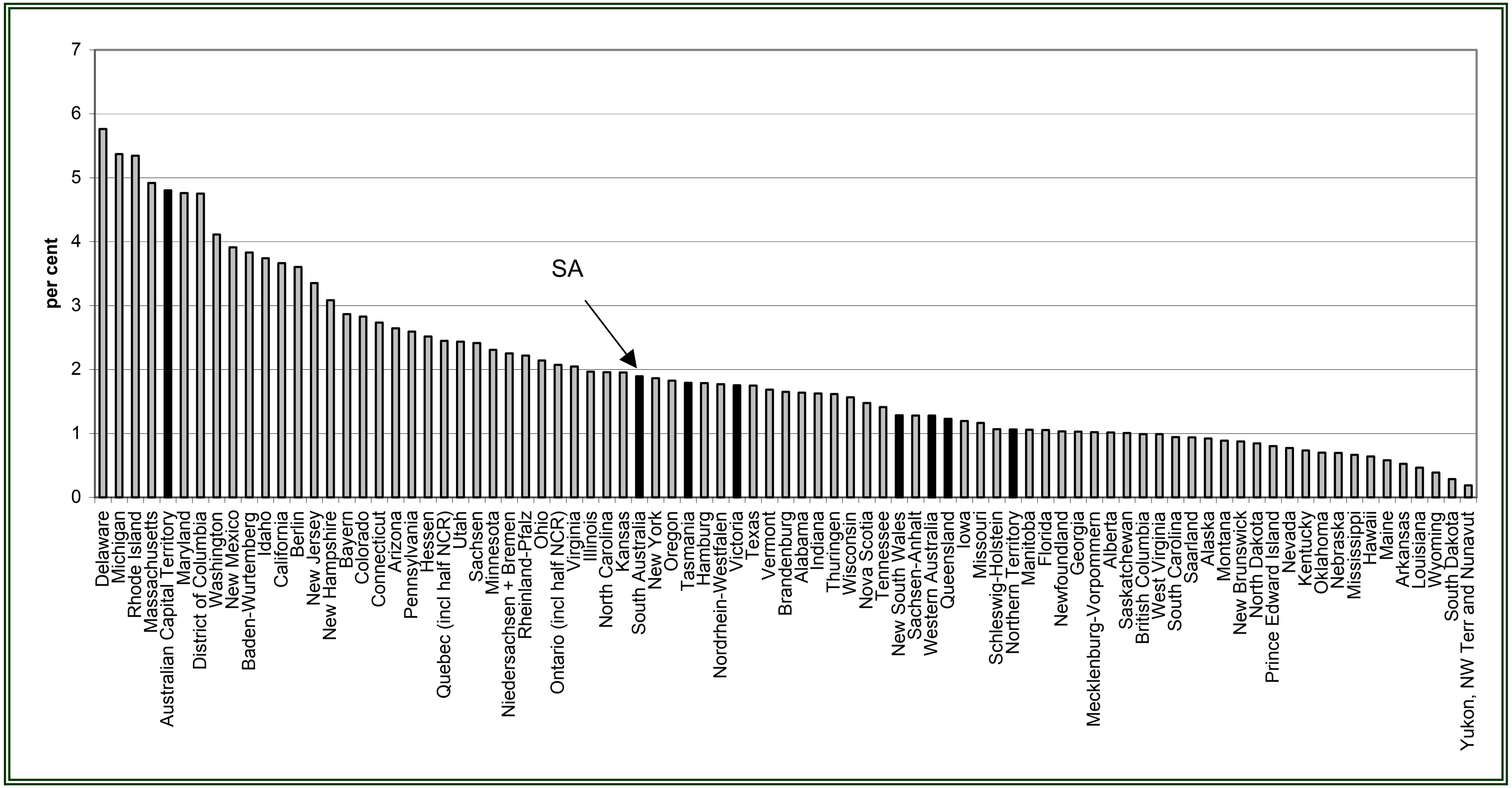
To compare R&D spending across countries, the OECD uses home currency GDP as a scaling factor for home currency R&D effort. It calculates the ratio of gross expenditure on research and development to GDP ("the GERD to GDP ratio").

In 1998 the GERD to GDP ratio in Australia was 1.5 per cent, compared with 2.2 per cent for the OECD as a whole (1999 figure). Among the G-7, Japan had a ratio of 3.0, the US had 2.6, Germany 2.4, France 2.2, the UK 1.9, Canada 1.7 and Italy 1.0. Thus, according to this measure, Australia has a relatively low level of R&D intensity, at least in contrast with the larger OECD nations, although less developed OECD members generally had ratios below 1.0 per cent.

It is possible to calculate the GERD/GDP ratio for sub-national regions, subject to the availability of GERD and GDP estimates at the regional level. Figure 5 shows the ratio of gross expenditure on research and development for selected regional economies in Australia, Canada, the United States and Germany.

The ACT appears near the top of this ranking (5th), slightly below Massachusetts (4th) and moderately above California (12th). South Australia is second among the Australian "States" (34th on the international comparison). The other Australian States, in order, are: Tasmania (37), Victoria (40), NSW (50), Western Australia (52), Queensland (53) and the Northern Territory (57).

Figure 5
Ratio of gross expenditure on R&D to regional gross product
Regions of Australia, Canada, US and Germany

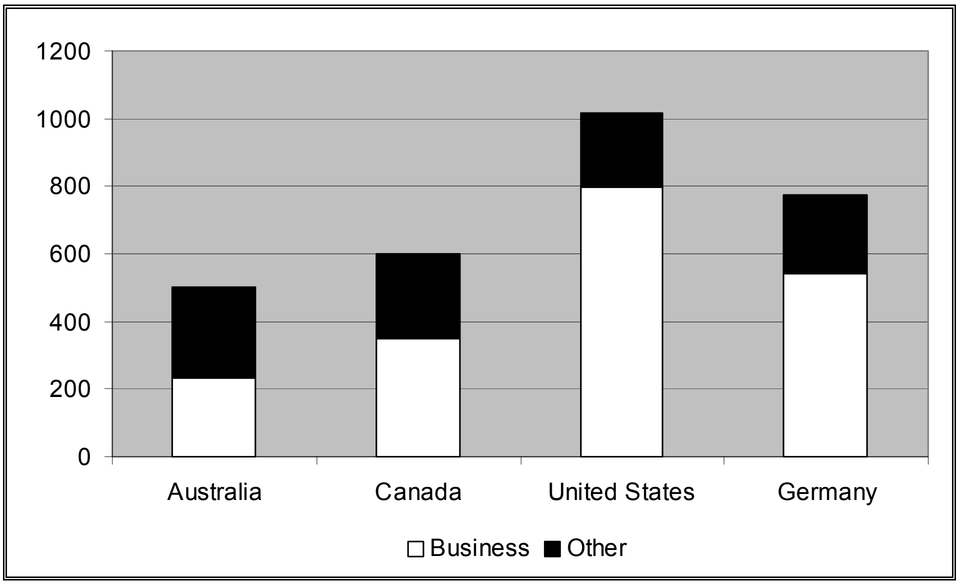


Note: Australian figures refer to average of 1998-99 and 2000-01; Canada and US to average of 1998 and 1999; Germany to 1999.

Absolute per capita R&D levels

Figure 6 shows absolute per capita R&D spending for Australia, Canada, the US and Germany. Australian spending of $A500 is less than half the Unites States ($A1,017) and below Germany ($A773) and Canada ($A600).[3] Low R&D in Australia is entirely attributable to low R&D spending by the business sector; spending by the "other" sector (which includes higher education and government) is in fact slightly greater than in the other countries.

Figure 6
Absolute per capita R&D spending ($A)



Note: Australian figures refer to average of 1998-99 and 2000-01; Canada and US to average of 1998 and 1999; Germany to 1999. Currency conversion is on a purchasing power parity basis.

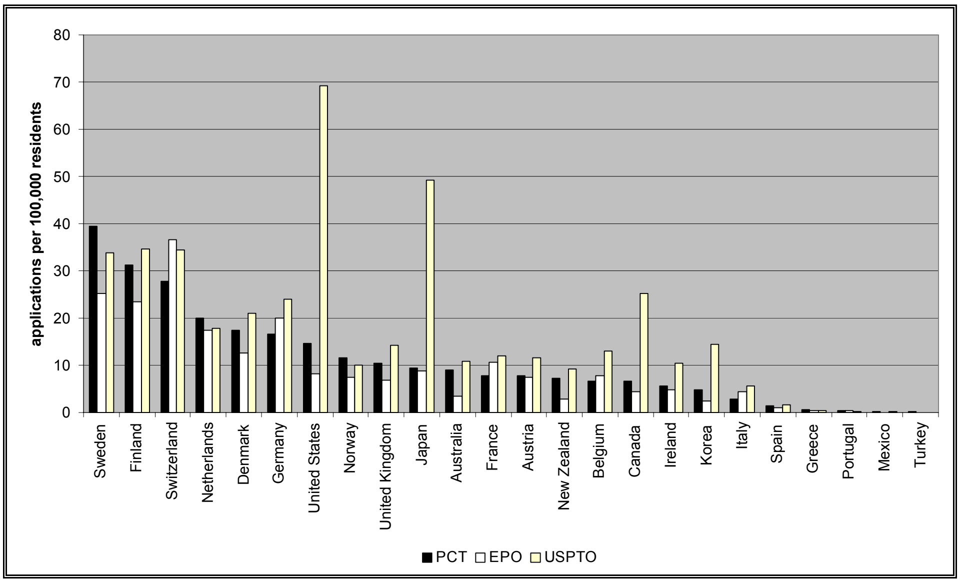
4.2 Patents

Comparison of patent activity across countries is made difficult by the existence of home country bias in patent applications to domestic patent offices. Figure 7 shows patent applications per 100,000 population for OECD members under three lodgement systems: PCT applications European Patent Office (EPO) applications and United States Patent and Trademark Office (USPTO) applications.[4]

The PCT applications data show that Australian rates of patent applications are well below those of the OECD leaders. Patent application rates are highest among the northern European nations. The PCT application rate for the United States (about 14.5 per 100,000 population) is about 50 per cent higher than Australia's (9.0) although US application rates are much greater on the basis of USPTO applications.

The EPO and USPTO data indicate even lower application rates for Australia. This may to a degree reflect a preference for other patent channels, but the overall conclusion seems clear: Australians tend to apply for patents less often than the residents of our peer nations in the developed world.

Figure 7
Patent applications in the OECD: PCT, EPO and USPTO applications per 100,000 population



Note: PCT and EPO patent applications are for 2001, USPTO applications for Fiscal Year 2001.

5. Analysis of within-country correlations: United States, Canada and Germany

One of the difficulties arising in the comparison of Australian innovation activity and earnings by State is that the small number of States makes it hard to draw robust conclusions about whether there is any correlation between innovation activity and incomes on the basis of cross-section data.

It is interesting therefore to extend the analysis to overseas nations. By considering inter-regional variations *within* overseas countries, one can still avoid the major difficulties that arise with cross-country comparisons. [5] For this purpose we have chosen 3 advanced economies with a federal structure for investigation: the United States, Canada and Germany. Table 3 presents correlation coefficients and test statistics for innovation and income indicators within those three countries.

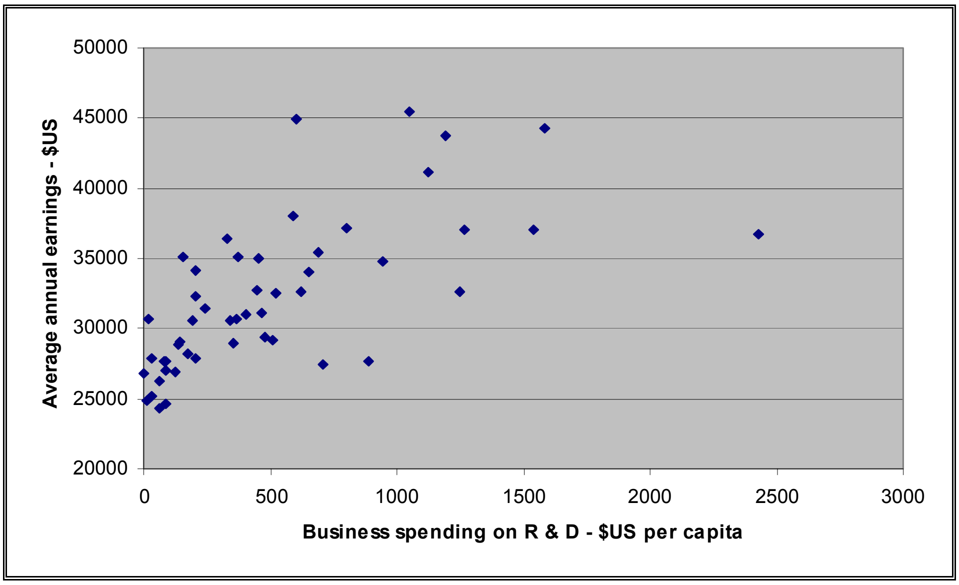
5.1 Within country variations in R&D spending and average earnings

Figure 8 shows a plot of average annual earnings and business R&D spending per capita in the United States. It is clear from visual inspection that there is a correlation between R&D spending and average wages, albeit less than perfect. The correlation is highly significant, as the t-statistic in Table 3 shows.

Table 3
Correlation coefficients between earnings/wages and innovation indicators for the United States, Canada and Germany (t-statistics in brackets)

US States	
Business R&D vs earnings	0.66 (6.11)
Business R&D vs earnings of office and administrative support workers	0.61 (5.32)
Patent applications vs earnings	0.42 (3.24)
Canada	
Business R&D vs hourly wages	0.77 (3.40)
Germany	
Business R&D vs hourly wages	0.62 (2.86)
Business R&D vs hourly wages former West Germany Länder only	0.11 (0.31)

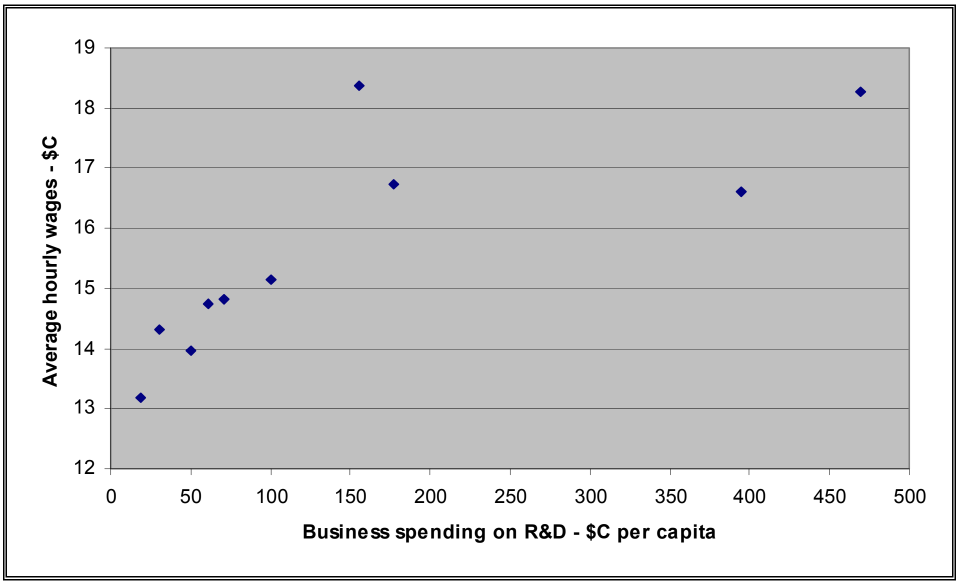
Figure 8
Business R&D and average annual earnings in the US States ($US)



Note: R&D is average of 1998 and 1999. Average earnings are for 2000.

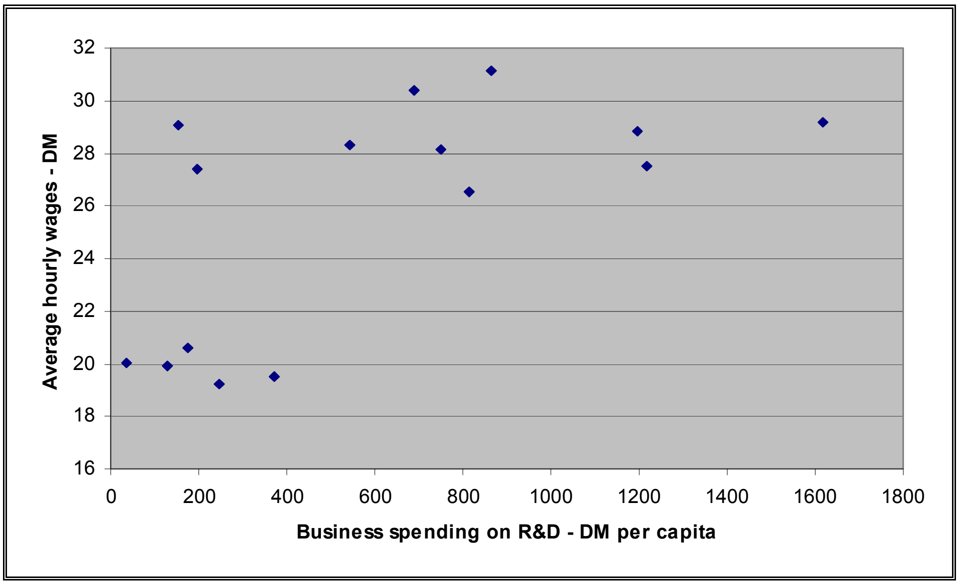
Figures 9 and 10 show similar comparisons for Canadian and German regions. The results are less conclusive than for the United States, at least partly because there are less observations available. The Canadian data demonstrate a positive correlation. However, in the German case, the five low earning regions are from the former East Germany. There is no apparent correlation within the former West Germany in its own right.

Figure 9
Business R&D and average hourly wages in the Canadian Provinces ($C)



Note: R&D is average of 1998 and 1999. Average hourly wages are for 1998.

Figure 10
Business R&D and average hourly wages in the German Länder (DM)



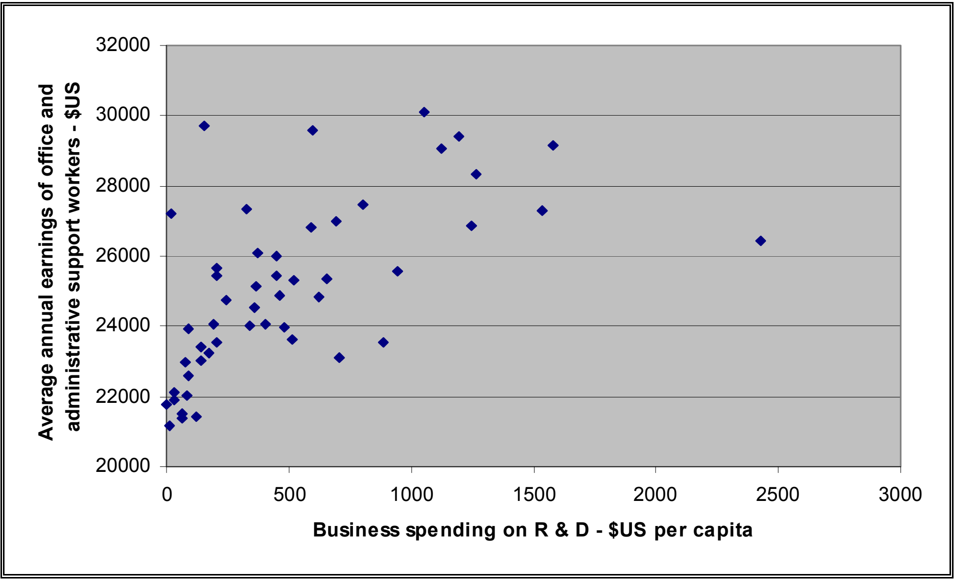
Note: R&D is for 1999. Average hourly wages are for 2000.

Compositional influences

The evidence from the United States, and to a lesser extent Canada, shows a strong correlation between business R&D and average earnings. But it is interesting to consider this correlation more closely. Does it exist because R&D intensive locations employ relatively more highly skilled (and therefore more highly paid) workers – e.g., scientists? Or does it exist because there are generally higher wages for all workers in an R&D intensive location? Differences in average earnings across States reflect both differences in occupational structures and differences in earnings within occupations. To illustrate, one can consider the average across the US States of the difference between State and national average earnings at the aggregate level and within occupations. The average variation of State average earnings from the national average is 14 per cent. In contrast, to take an example, the average variation of State average earnings for office and administrative support workers is from the national average is 9 per cent. These data are consistent with the view that differences in State average earnings reflect both occupation structure effects and within-occupation differences.

Figure 11 shows a plot of average annual earnings for *office and administrative support workers* and per capita business R&D spending for the US States. This earnings measure is much less prone to differences in the skill and quality composition of the labour force than the average across all workers.[6] It is clear that a strong correlation still exists: Office and administrative support workers tend to be paid more in locations with high per capita R&D spending (Table 3 presents the correlation coefficient and t-statistics). Although differences in occupation structure may go some way toward explaining differences in average earnings across the labour force, it appears that within occupation variations have a major part to play.

Figure 11
Business R&D and average annual earnings for office and administrative support workers in the US States ($US)



Note: R&D is average of 1998 and 1999. Average earnings are for 2000.

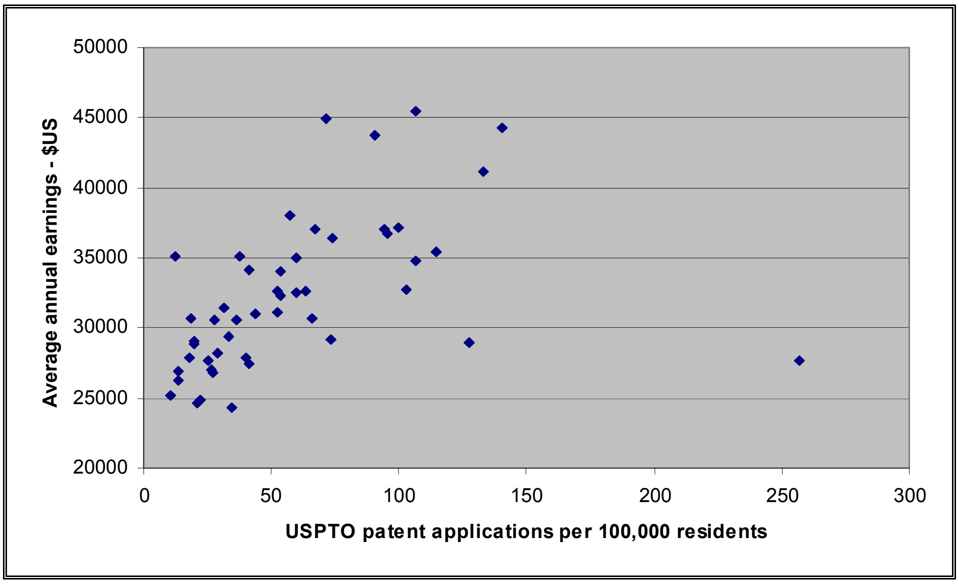
5.2 Patent rates in the US States

Comparison of PCT application rates within countries is made difficult by the structure of the PCT database. It is time-consuming to extract the data, and although we have carried out the exercise for Australia, it is not practical to do it for all of the regions of other federal nations. However, for purposes of comparison, PCT patent data was collected for five high and five low ranked US States in terms of R&D spending per capita.

Amongst these ten States the highest rate of PCT applications per 100,000 population was Massachusetts, with 54.8, followed by Maryland (26.2), District of Columbia (26.4), Rhode Island (22.7) and Michigan (15.4). [7] The highest PCT application rate among the "low R&D" States was Wyoming (8.5), followed by Louisiana (7.8), Arkansas (3.4), South Dakota (2.6) and Mississippi (2.4). A comparison with the Australian figures in Table 1 shows that none of the Australian States are as productive of PCT patent applications as the "high R&D" US States, but that NSW, Western Australia and Victoria are above the "low R&D" States and South Australia and Queensland are comparable with the better performing of the "low R&D" US States.

Figure 12 plots patent grants in the US Patent and Trademark Office per 100,000 residents for the US States and average annual earnings. It is clear that there is a correlation, albeit imperfect, between States' earnings and patent activity, and this is confirmed by the correlation coefficient and t-statistic in Table 3.[8]

Figure 12
USPTO patent applications and average annual earnings in the US States ($US)



Note: USPTO patent applications are for 2001. Average earnings are for 2000.

6. Conclusion

The data in this study show that, in a comparison of the Australian States, there is no meaningful correlation between total R&D spending and average wages. However, there is a correlation between business R&D spending and average wages if one excludes the two Territories from consideration. There is also a correlation between average wages and inventions that lead to PCT patent applications.

Because Australia has just the six States and two Territories, there is not much data to support cross-sectional analysis of innovation activity and income levels.

Earnings/wages data and business R&D data were collected for the United States, Canada and Germany to explore whether a correlation is observed elsewhere. Correlations between earnings/wages measures and R&D spending were observed within those countries, although in the case of Germany there was no evidence of correlation within the former West Germany. Patent application data was collected for the US and shows a significant correlation with earnings.

In our view, these data support the view that there is a connection between incomes and innovation activity levels across regions. It is notable that, at least in the Australian case, the connection is more apparent when one considers just business R&D.

In itself, the data collection here cannot support any conclusion about whether innovation activity "causes" incomes, or vice versa, or indeed whether each is driven by some common third influence.

Innovation is of course just one of many potential determinants of productivity and incomes at the regional level. Mitchener and McLean (2001), in a consideration of the fundamental determinants of productivity differences between the US States, conclude that institutional characteristics, physical geography and resource abundance each have an important role to play.[9] And the "new" economic geography pays particular attention to the self-reinforcing behaviour of urban centres: in varying degrees they act as magnets to economic activity, regardless of the fundamentals that initially inspired their settlement.

Because there are likely to be feedbacks from productivity levels onto innovation levels, it must be recognised that innovation levels cannot be treated as a "fundamental" determinant in a statistical sense. One needs to be wary of what our colleague Owen Covick describes as a "Bollinger effect", which is erroneous reasoning along the lines that "successful business people drink Bollinger, therefore I shall drink Bollinger in order to become successful".[10] But innovation levels obviously are of interest to a policy maker seeking to identify policy instruments to raise productivity levels. It is interesting for this reason at least to consider the relationship between innovation and income. In this study we have demonstrated the existence of such a relation, but we have not attempted to explain how it works.

Appendix A

Data Sources

Gross product data

Australian data are from Australian Bureau of Statistics (2001), *Australian National Accounts: State Accounts* Cat. No. 5220.0.

Canadian data are from Statistics Canada, *Gross domestic product, expenditure-based, provinces and territories.*
http://www.statcan.ca/english/Pgdb/Economy/Economic/econ15.htm
[20/08/2002]

German data are from the website of Statisches Bundesamt Deutschland [Federal Statistical Office of Germany] http://www.destatis.de/

US data are from Bureau of Economic Analysis, *Regional Accounts Data, Gross State Product Data*.
http://www/bea/gov/bea/regional/gsp/action.cfm [20/08/2002]

Population data

Australian estimates are derived from Australian gross state product and per capita gross state product data from Australian Bureau of Statistics (2001), *Australian National Accounts: State Accounts* Cat. No. 5220.0.

Canadian data are from Statistics Canada, *Population*.
http://www.statcan.ca/english/Pgdb/People/Population/demo02.htm [22/08/2002]

German data are from the website of Statisches Bundesamt Deutschland [Federal Statistical Office of Germany] http://www.destatis.de/

US data are from Bureau of Economic Analysis, *Regional Accounts Data, Annual State Personal Income*.
http://www/bea/gov/bea/regional/spi/drill.cfm [21/10/2002]

Earnings and wages data

Australian data are from Australian Bureau of Statistics (2001), *Average Weekly Earnings: States and Australia* Cat. No. 6302.0, November 2000. Figures are average of August 1999, November 1999, February 2000 and May 2000 estimates of full-time adult ordinary time earnings.

Canadian average hourly wages data are from Kamal K. Sharan (2000), *Sources of Differences in Provincial Earnings in Canada* Statistics Canada, Income Statistics Division. Data is from Survey of Labour and Income Dynamics, 1998.

German data are from the website of Statisches Bundesamt Deutschland [Federal Statistical Office of Germany] http://www.destatis.de/

US data are from Bureau of Labor Statistics *Table 1.State 1/ average annual pay for 1999 and 2000 and percent change in pay for all covered workers 2/* http://stats.bls.gov/news.release/annpay.t01.htm [20/02/2002]

R&D data

Two types of data are used: total R&D and business R&D. Business R&D refers to R&D *by* business. Thus it encompasses work carried out which is funded by government, and does not include work which is carried out by universities on contract to business.

Australian data are from Australian Bureau of Statistics (2002), *Research and Experimental Development* Cat. No. 8112.0.

OECD data for ratios of R&D to GDP are from:
http://www1.oecd.org/publications/e-book/92-2001-04-1-2987/

Canadian data are from Statistics Canada (2001), *Estimates of Canadian Research and Development Expenditures (GERD), Canada, 1990 to 2001e and by Province 1990 to 1999* Cat. No. 88F0006XIE01014.

German data are from Bundesminsesterium für Bildung und Forschung [Federal Ministry for Education and Research] (2002), *Faktenbericht Forschung 2002* [our translation: Research: Facts and Figures, 2002], Bonn: the Ministry.

US data are from National Science Foundation (various years) *Research and Development in Industry, Academic Research and Development Expenditures, Federal Funds for Research and Development.* http://www.nsf.gov/sbe/srs

Patent data

There are difficulties getting data at the regional level from some patent collections. In addition, there are problems of "home country bias" with collections from national and regional patent offices. Our preferred data source is PCT patent applications, but we have also supplemented this with European Patent Office and United States Patent and Trademark Office data.

PCT patent applications

Under the Patent Cooperation Treaty, a patent application can be lodged at the national patent office and then cover all the countries which are signatories to the treaty. The consistency of lodgement requirements across countries lends a degree of comparability to PCT applications across countries. In addition, the more stringent tests for PCT patents and the greater costs involved mean that PCT patents tend to be at the higher end of the quality spectrum. Australian inventors' applications for Australian patents outnumber their PCT patent applications by about 5 to 1.

The PCT data are from the World Intellectual Property Organisation. Their database allows a search of inventors (who are natural persons) by Australian State of residence, and this is the basis on which PCT applications figures have been compiled for the Australian States. For example, if a patent had an inventor in NSW, a patent was tallied for NSW. And if it had inventors from both NSW and Victoria, a patent was tallied to each of NSW and Victoria. This means that there will be some multiple counting in the data, so State counts cannot simply be summed to produce a national count, nor can they be compared directly with a national count.

There may also be some mismatching of the locations of inventor residence, R&D activity and inventor employment, e.g., an inventor working in Canberra but resident in Queanbeyan would affect ACT earnings and R&D data but New South Wales PCT application data.

The extraction is time consuming and we have not carried it our for all of the regions of any overseas federations, although figures for a few US States have been presented.

EPO patent applications

Data on European Patent Office applications are presented simply for a comparison with PCT data, and because this data are used by the OECD. It shows the significant differences that emerge from the different data sources. Data are from the European Patent Office.

USPTO patent applications and grants

Data on patent applications to the US Patent and Trademark Office are used to illustrate patent behaviour for the US States. They are from *Performance and Accountability Report Fiscal Year 2001*, p. 112.

The USPTO grants data are from *Patent Counts: States and Countries of Origin, Calendar Year 2001* ftp://ftp.uspto.gov/pub/taf/st_co_01.htm [3/3/03].

The compilation of the USPTO data differs from PCT data in that each patent application is attributed to the State of residence of the first named inventor and is thus allocated only once.

Purchasing power parities

Purchasing power parities are from OECD (2002), *Main Economic Indicators* October 2002.

End Notes

1 The authors are grateful to Owen Covick for helpful comments he provided. However, responsibility for the material in this study lies with the authors.

2 For example, wages are a significant component of R&D costs, and therefore a region with high wages might have high R&D spending even if the volume of R&D work carried out was not high. And a region with a high proportion of retirees might have a low per capita R&D even though intensity relative to the workforce was at an average level.

3 Currency conversions are carried out using "purchasing power parity" (PPP) exchange rates. This is a common approach when comparing value aggregates in different nations. The PPP exchange rate is the conversion rate at which $A1 would buy the same amount in an overseas country as it would in Australia. Its significant strength is that by using it one gets an estimate of the quantity of R&D effort that is being purchased. If the conversions were carried out using actual exchange rates, the differences between Australia's and these other nations' R&D spending would be even larger.

4 All three measures are included to illustrate the scope for home country bias. Not surprisingly, European nations have a relatively high propensity to lodge with the European patent office and American residents tend to use USPTO. Our preferred measure is PCT applications because it should minimise the home country bias.

5 In the following discussion, average annual earnings are used to indicate income levels in the US States, and hourly wage rates are used for Canada and Germany. In addition, there may be differences from country to country in the coverage of these collections. Therefore it should not be assumed that the earnings/wages distributions are comparable across countries.

6 This occupation group is chosen because it is relatively large and likely to have a high degree of similarity in terms of functional requirements across States. It needs to be recognised that within an occupation group there may still be quality differences across States that would offer a human capital explanation for observed across-States wage differences, but we have no information on the extent of these.

7 Delaware had the highest GERD per capita of the US States, but could not be included due to data extraction issues in the PCT patent database.

8 The outlier at the right of Figure 12 is Idaho. Its high level of patent activity seems to be primarily attributable to the presence of a chip developer (Micron Technology Inc and related entities) which in 2001 was the assignee for over 80 per cent of patent grants to inventors resident within the State.

9 Mitchener, Kris James and Ian W. McLean (2001), 'The Productivity of the U.S. States since 1880' University of Adelaide School of Economics Working Paper 01-8.

10 Indecs (1995), *State of play 8: the Australian economic policy debate.* Allen & Unwin. St Leonards, NSW. p.334.