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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 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

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.

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

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

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.

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)

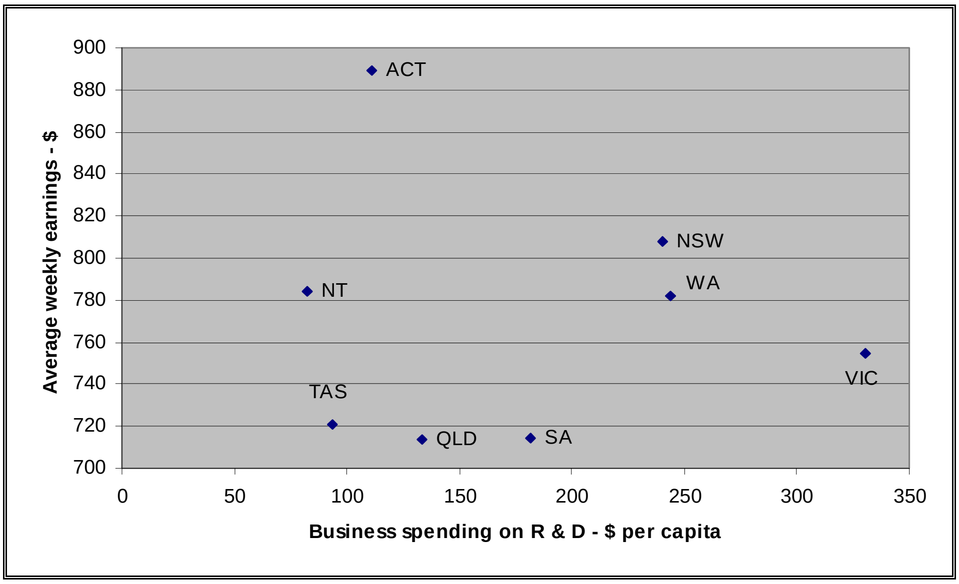
Note: Correlation coefficients and associated t-statistics are presented to support the graphical material in this section. It should be noted however that the small number of observations used to produce this data brings into question the meaning of the correlation coefficients and, even more so, the 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)

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.

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.

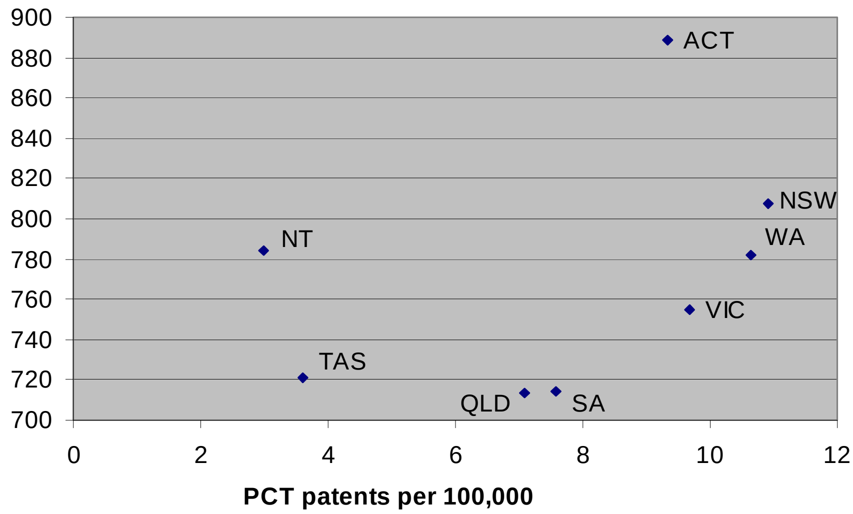
Figure 1 shows per capita spending on R&D by all sectors, and average weekly ordinary time earnings, within each Australian State and Territory. There is no apparent correlation between earnings and R&D spending unless one per cap(on8ludes10(the)-1iose i unusualpitse)]T able 1 s2) Vict

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.



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

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.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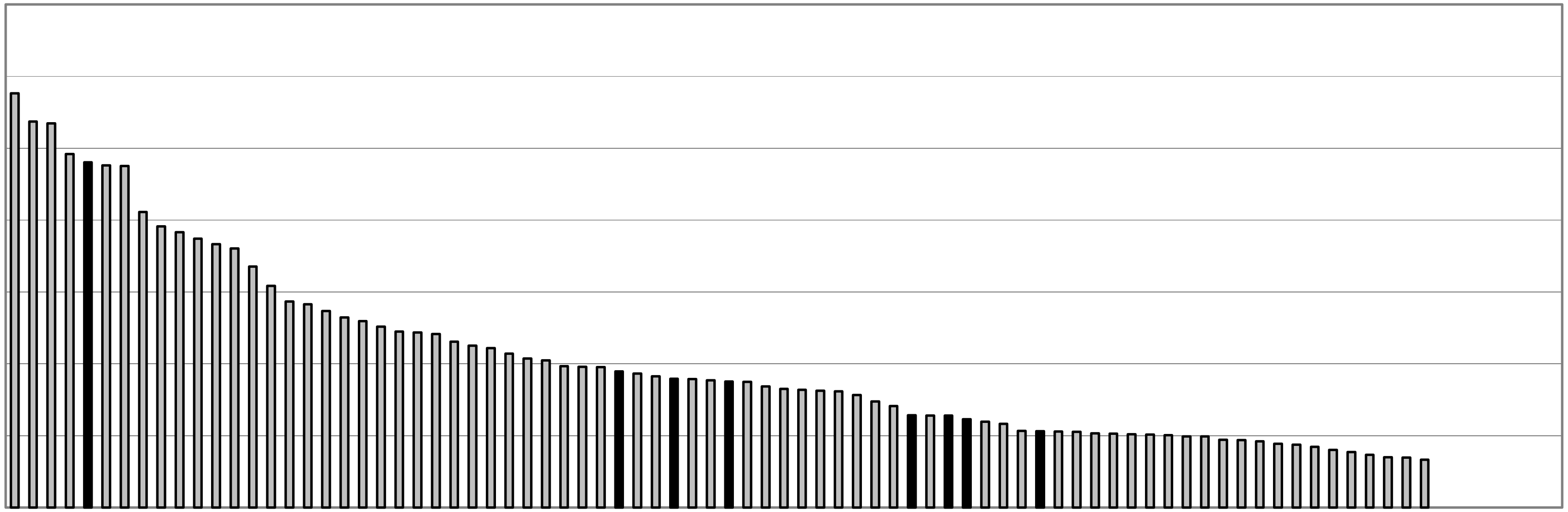
PCT patents per 100,000

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.

Ratio of R&D to Gross Product

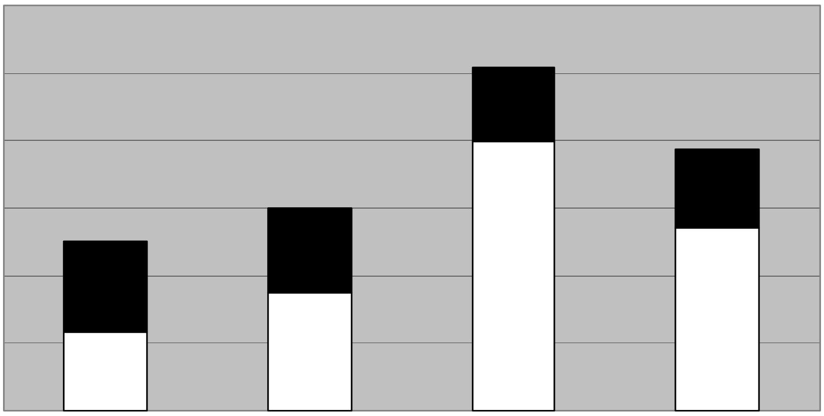
To compare R&D spending across countries, the OECD uses home currency GDP as a scaling factor for home currency R&D effort. It



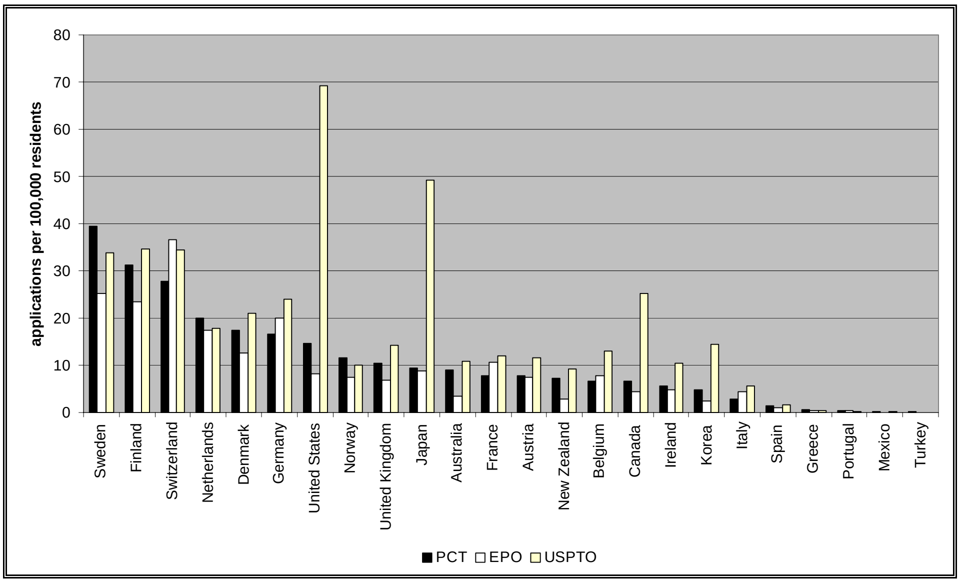
Note: Australian figures refer to average of 1998-99 and 2000-01; Canada and US to average of 1998 and 1999; Germany to 1999.

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.



apply for patents less often than the residents of our peer nations in the developed world.



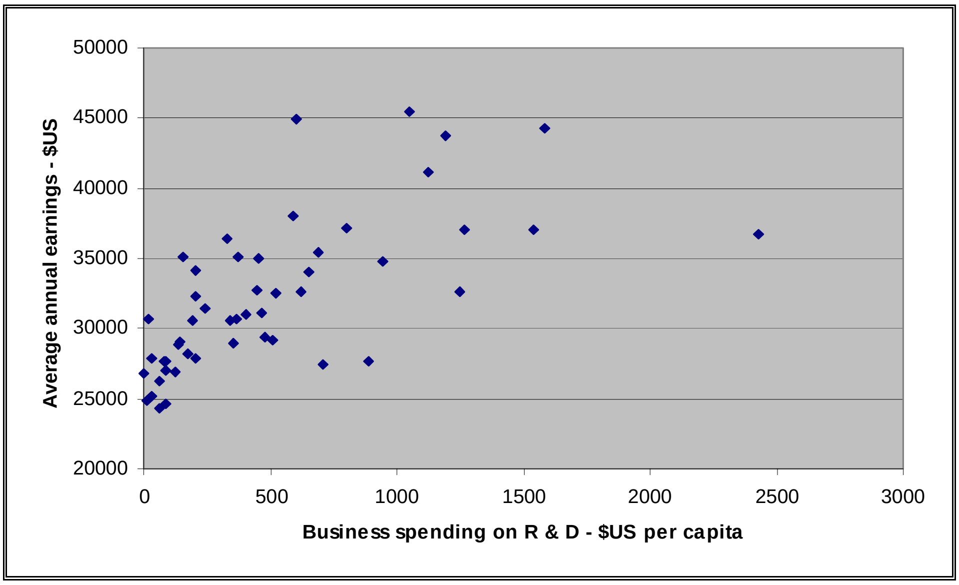
Note: PCT and EPO patent applications are for 2001, USPTO applications for Fiscal Year 2001.

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.

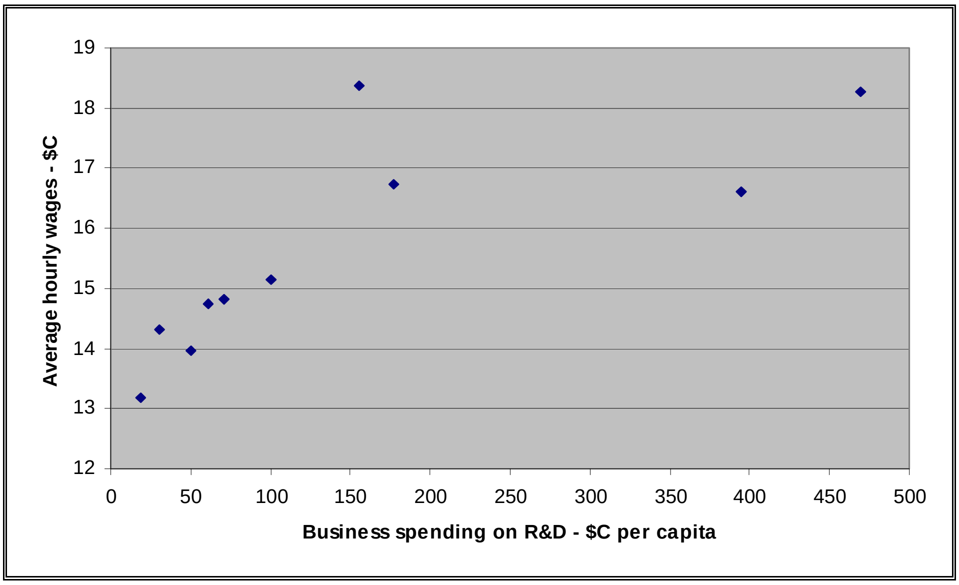
Figure 8 shows a plot of average annual earnings and business R&D spending per capita in the United States. It is clear from visual inspection that there is a correlation between R&D spending and average wages, albeit less than perfect. The correlation is highly significant, as the t-statistic in Table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

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)

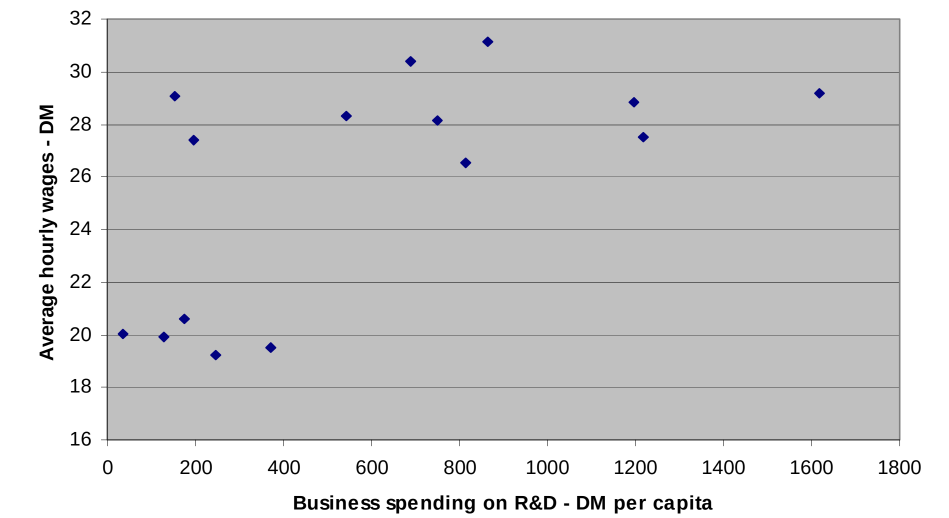


Note: R&D is average of 1998 and 1999. Average earnings are for 2000.

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.



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



Amongst these ten States the highest rate of PCT applications per

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 dge

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]

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.

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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]

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

[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.