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Modelling the Research Output of Australian Universities by Discipline

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Abstract: This paper develops and estimates a cross-sectional model for forecasting research output across the Australian university system. It builds upon an existing literature that focuses either on institutional comparisons or studies of specific subjects, by providing discipline-specific results across all of the ten major disciplinary areas as defined by Australia's Department of Education, Science and Training (DEST). The model draws upon four discipline-specific explanatory variables; staff size, research expenditure, PhD completions, and student-staff ratios to predict output of refereed articles. When compared with actual averaged output for 2000-2004, the results are highly statistically significant.

I. Introduction

There is a growing focus in the Australian university system on quantitative research performance assessment. However, to date this has mainly concerned performance assessment in aggregate and this is inconsistent with the most recent policy emphasis on university diversity (Abbott & Doucouliagos 2004; Valadkhani & Worthington, 2006). Put bluntly, focusing on research performance at the institutional level ignores the varied performance that occurs at the disciplinary level, and the application of funding on this basis serves to stifle innovation in key research areas and maintain underperforming and outdated research areas. This approach serves as a disincentive to focused, responsive, innovative and diverse research in Australian universities. Where specific disciplines, such as economics, have been analysed, this has tended to be on an individual rather than comparative basis (Mein 2002; Pomfret & Wang 2003; Neri & Rodgers 2006; Johnes 1995). It is interesting to note that data on the number of published refereed articles by academic staff members affiliated to Australian universities have been reported and analysed only at the institutional (aggregate) level. We contribute to the debate on

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research performance by providing the discipline-specific estimates of the annual average number of refereed journal articles (referred to as research output hereafter) during the period 2000-2004.

The major objective of this study is to specify and estimate a cross-sectional model for the Australian university research output using all available discipline-specific data during the period 2000-2004.

The rest of the paper is organised as follows. In Section II we specify a model to explain the number of published refereed articles by university and discipline. Section III discusses the source, description and type of data employed in this forecasting exercise. Section IV presents and analyses the empirical results of the study, and Section V offers some concluding remarks.

II. Theoretical Framework

The research output (*Y*) in this paper has been proxied by the number of articles published in national and international refereed journals by academic staff members affiliated to Australian universities. The research-output determination model is specified as follows:

$$Ln(Y_i) = \beta_1 Ln(S_i) + \beta_2 Ln(RE_i) + \beta_3 Ln(SSR_i) + \beta_4 Ln(PhD_i) + \varepsilon_i \qquad (1)$$

where

Y_i=research output proxied by the annual average number of refereed journal articles published by university *i*,

S_i=the annual average number of "research only" and "teaching and research" academic staff members (full-time equivalent) in university *i*,

RE_i= the annual average expenditure on research and experimental development in university *i*,

SSR_i= the annual average full-year student-staff ratio in university *i*,

PhD_i= the annual average number of PhD completions in university *i*,

ε_i =homoscedastic residual term,

i=1,2,…n=37, and n denotes the number of Australian universities.

It is hypothesized that as the number of academic-staff members (S), whose job description requires undertaking research, increases, the magnitude of research output rises due to the size factor. This means that the expected sign for the size factor is positive $\beta_1 > 0$. It is also assumed that, *ceteris paribus*, the availability of more research funding and PhD students can boost the research output, suggesting that both β_2 and $\beta_4 > 0$. However, an increase in teaching and administration workload in a particular university (proxied by rising student-staff ratios) can curtail the research output. It is thus expected that $\beta_3 < 0$. It is postulated that if all the four explanatory variables in equation (1) are equal to zero (particularly the number of staff members), the research output will be equal to zero. Based on this argument, we have adopted a regression-through-the-origin model in this paper and as a result the intercept has been removed from equation (1).

In order to identify any possible outliers or abnormal observations we will compute $\hat{\sigma}_i = (Y_i - \hat{Y}_i) / Y_i$. If $|\hat{\sigma}_i| < 0.30$, we keep the ith observation in the estimation procedure, otherwise it will be excluded. Finally one can substitute the discipline-specific values of the four explanatory variables (rather than the aggregate figures as discussed above) into the final estimated equation (1) to obtain the discipline-specific values of research output in the following manner:

$$\hat{Y}_{ij} = S_{ij}^{\hat{\beta}_1} \cdot RE_{ij}^{\hat{\beta}_2} \cdot SSR_{ij}^{\hat{\beta}_3} \cdot PhD_{ij}^{\hat{\beta}_4} \quad (2)$$

where:

$\hat{Y}_{ij}$ is the estimated value of research output produced by the j^{th} discipline in the i^{th} university using the estimated coefficients of equation (1).

In order to ensure that the research outputs by various disciplines in a particular university add up to the actual aggregate research output for the concerned university, in equation (3) it is assumed that $\hat{\varepsilon}_i = \left(Y_i - \sum_{j=1}^{m=10} \hat{Y}_{ij}\right)$ or the difference between the actual total research output and the estimated sum of the research output by various disciplines in university *i*, will be proportionally distributed (adjusted) across various disciplines within each university. That is:

$$\tilde{Y}_{ij} = \hat{Y}_{ij} + \hat{\varepsilon}_i \frac{\hat{Y}_{ij}}{\sum_{j=1}^{m=10} \hat{Y}_{ij}} \quad (3)$$

Where $\tilde{Y}_{ij}$ is the forecasted (and adjusted) value of research output produced by the j^{th} discipline in the i^{th} university, *m* is equal to the number of disciplines.

III. The Database

Before embarking on our empirical quest, it is important to look at the sources and definitions of the data employed in this analysis. Thirty-seven Australian universities have been included in the analysis, all of which are publicly funded and members of the Australian Vice-Chancellor's Committee (AVCC). The total number of refereed articles published within each of these universities has been obtained from a report entitled “Higher Education Research Data Collection Time Series Data 1992-2004” published by The Australian Vice-Chancellors’ Committee (AVCC, 2006).

An unpublished database used in this study was purchased from the Department of Education, Science and Training (DEST) in December 2005 (see below for more details). The data includes the number of PhD completions (the DEST source reference number OZUP-2002-2004) as well as the number of academic staff members (the DEST source reference number: Staf2001.dat - Staf2004.dat) by institution and across 10 consistently defined broad fields of education, all of which we have averaged using available annual observations within the period 2000-2004. These 10 broad fields of education (which are also referred to as disciplines interchangeably) are shown in Tables 2 and 3. In order to minimise bias in our results, we consider only those academic staff members who are classified as undertaking ‘research-only’ and ‘teaching-and-research’ activities. In other words, the variable that is referred to as academic staff (*S*) does not include ‘teaching only’ staff.

The next variable RE_{ij} or the annual average expenditure on research and experimental development, also available by university and the same disciplines, was averaged in the same way using all available data during the period 2000-2002 ($A'000). This variables includes: (1) National Competitive Research Grants (*i.e.* Commonwealth Schemes and Non-Commonwealth Schemes); (2) State and Local Government; (3) Other Commonwealth Government; (4) Other Australian Sources (*i.e.* Business Enterprises; General University Funds; and Other); and (5) Overseas sources. The last variable employed in this paper is SSR_{ij} or the average full-year student-staff ratio (all students) which is also available by institution and the same 10 consistently defined broad fields of education for the period 2002-2003. Similarly we averaged all available observations during this period to avoid any possible abnormal observation for a particular discipline within any university. Both RE_{ij} and SSR_{ij} are also available from the DEST website. The full database employed in this paper has been included in Appendix.

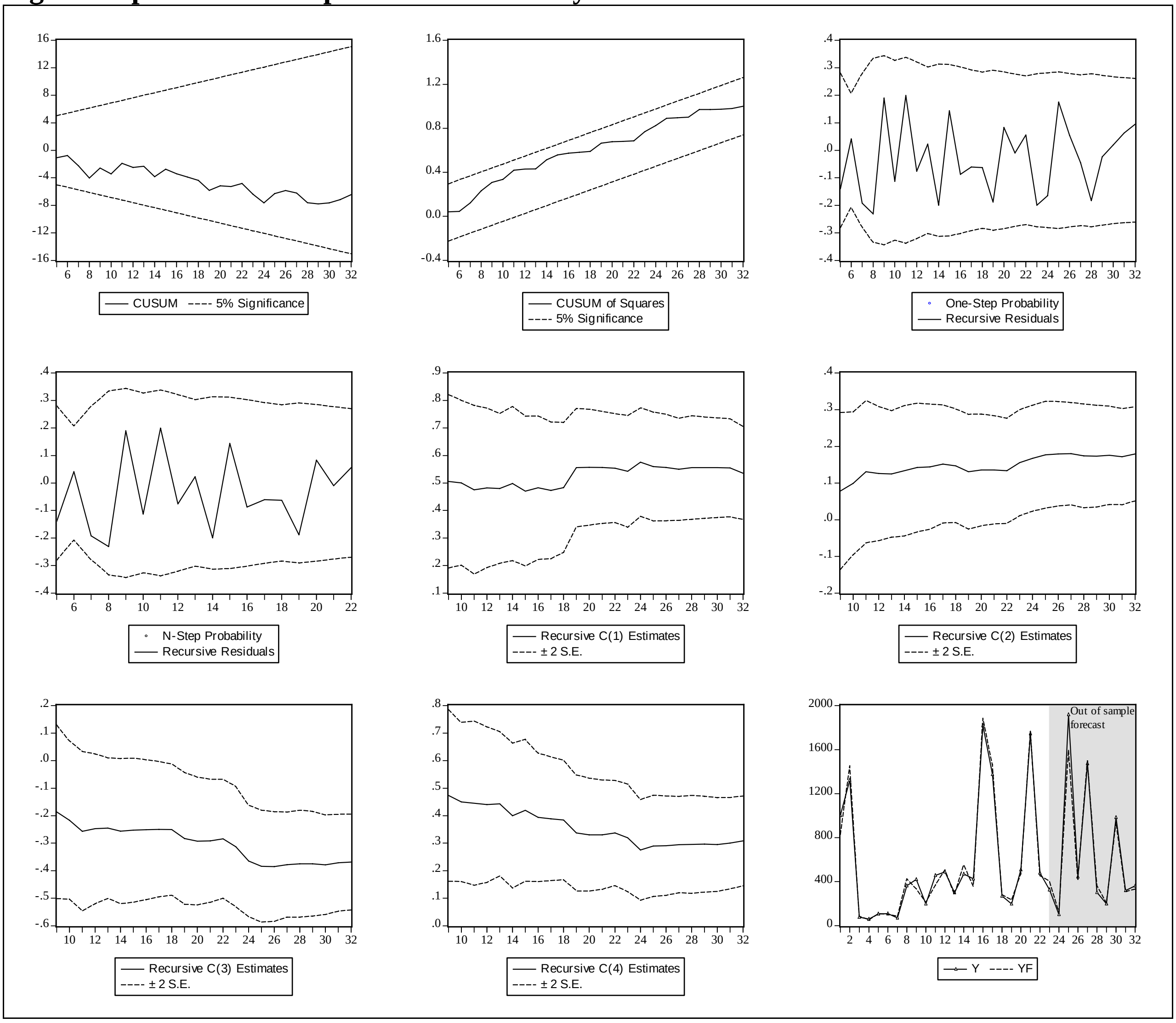
IV. Empirical Results and Policy Implications

The estimation procedure involved the following three steps. First, the OLS method was used to estimate equation (1) using all 37 cross-sectional (university level) data. We looked at the resulting residuals and if $|\hat{\sigma}_i| < 0.30$, we included the i^{th} university in our sample. Based on this criterion, we excluded the following 5 universities: Charles Sturt, RMIT, Southern Queensland, Sunshine Coast and Swinburne. The relationship between the research output and its four major determinants (as specified in equation 1) for these 5 universities was very different from the other 32 universities ($0.30 < |\hat{\sigma}_i| < 0.58$). Third, we then used the aggregate university-level data (32 universities sorted in alphabetical order) to estimate equation (1) and the results are presented in Table 1.

Table 1. The estimated equation for Australia university research output, $Ln(Y_i)$

Variable or test statistics	Coefficient	*t*-ratio	P-value
$Ln(S_i)$	0.536	6.4	0.00
$Ln(RE_i)$	0.179	2.8	0.01
$Ln(SSR_i)$	-0.369	-4.2	0.00
$Ln(PhD_i)$	0.308	3.8	0.00
R^2	0.984		
$\bar{R}^2$	0.982		
Jarque-Bera statistics	χ^2=1.31		0.52
White Heteroskedasticity Test:			
without cross terms	*F*(8,23)=0.51		0.83
with cross terms	*F*(14,17)=0.55		0.87
Ramsey RESET Test	*F*(1,27)=0.10		0.76
Chow Breakpoint Test: 16th observation	*F*(4,24)=1.08		0.39
Chow Forecast Test: Forecast from 23 to 32	*F*(10,18)=0.82		0.61
Out of sample forecast period using the last 10 observations	Theil Inequality Coefficient=0.065 Bias Proportion=0.046 Variance Proportion=0.44 Covariance Proportion=0.51		

Fig.1. Graphical tests for parameter constancy



As can be seen, the estimated equation performs very well in terms of goodness-of-fit $\bar{R}^2 = 0.981$, each and every coefficient being statistically significant (at the 1 per cent level or better), and having the expected theoretical signs. In other words, *ceteris paribus*, if the number of academic staff members increased, say by 10 per cent, on average this would led to a rise of 5.4 per cent in the number of refereed journal articles in these 32 universities. On the other hand, a similar 10 per cent rise in the expenditure on research and experimental development and the number of PhD completions would have resulted in a 1.8 and 3.1 per cent rise in the research output, respectively. Consistent with theoretical expectations, it is also found that an increase in the student-staff ratio (by say 10 per cent) leads to a fall of 3.9 per cent in the research output.

The equation passes successfully all of the reported diagnostic tests: the Jarque-Bera normality test, the White heteroskedasticity test (with or without cross terms), the Ramsey RESET specification test, the Chow breakpoint test (splitting the sample in the middle, *i.e.* the 12^{th} observation), and the Chow forecast test (using the last 10 observations for out of sample forecasts). The Theil inequality coefficient for the out-of-sample forecast is also as low as 0.065. These results clearly show the ability of our model to forecast beyond its estimation sample.

One problem associated with analysis of this kind is non-constancy of estimated coefficients which can create economic and econometric complications in deriving any inference from the empirical model. Given differences among the 32 universities in terms of their size, portfolios and research activities, parameter constancy is pivotal in modelling the determinants of research output. Therefore, the estimated model in Table 1 has been evaluated by a number of recursive diagnostic tests, which are displayed in Figure 1 in the following order: $\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}$ where panel (a) displays the CUSUM test; panel (b) shows the CUSUM of squares; panels (c) and (d) depict the recursive residuals and the associated one-step and n-step probabilities, respectively; panels (e) to (h) show the recursively estimated 4 coefficients using observations 9-32 in the same order that these coefficients appear in Table 1 (from top to bottom); and finally panel (i) presents the actual research output as well as the forecasted values, $\hat{Y}_i$, of both in-sample (the first 22 universities) and out-of-sample (the last 10 universities). These evaluative tests are useful in assessing the parameter constancy of the model, as recursive algorithms avoid arbitrary splitting of the sample. Overall, the graphical tests reported in Figure 1 point to the in-sample and out-of-sample constancy of the estimated coefficients. It should be noted that all observations (universities) in our samples are sorted in alphabetical order.

Given the fact that discipline-specific average values of the four explanatory variables in equation (2) can be obtained during the period 2000-2004, we can now predict the number of refereed articles by discipline or $\hat{Y}_{ij}$. The forecasts are presented in Table 2. As explained in Section II, we also calculated the difference between the total actual research output and the total predicted research output for each university using $\left(Y_i - \sum_{j=1}^{m=10} \hat{Y}_{ij}\right)$. In order to maintain the equality between the total research output and the sum of the discipline-specific research outputs within each university, equation (3) is used to proportionally distribute the difference across the 10 disciplines to obtain $\tilde{Y}_{ij}$. The results are then presented in Table 3 in which $Y_i = \sum_{j=1}^{m=10} \tilde{Y}_{ij}$.

To ease the comparisons and validate our results, the values of Y_i, $\hat{Y}_i$ and $\sum_{j=1}^{m=10} \hat{Y}_{ij}$ and the resulting deviations among them are also presented in Table 4. As can be seen, all the reported deviations, using both aggregate-university data and discipline-level data, are less than 0.30 for each and every university. In fact, the average absolute values of the above deviations, *i.e.* Y_i, $\hat{Y}_i$, are $\left|\bar{\hat{\sigma}}\right| = 0.11$ and $\left|\bar{\hat{\sigma}}_{d1}\right| = 0.09$, respectively. Both $\hat{Y}_i$ and $\sum_{j=1}^{m=10} \hat{Y}_{ij}$ track the actual data or Y_i so well that if we had presented Y_i, $\hat{Y}_i$ and $\sum_{j=1}^{m=10} \hat{Y}_{ij}$ in one-single graph, they would have become almost indistinguishable, the corresponding R^2 between $Y_i \leftrightarrow \hat{Y}_i$ and $Y_i \leftrightarrow \sum_{j=1}^{m=10} \hat{Y}_{ij}$ being 0.979 and 0.982, respectively. Both $\sum_{j=1}^{m=10} \hat{Y}_{ij}$ and $\hat{Y}_i$ are also very highly correlated R^2 =0.998 (see also $\left|\bar{\hat{\sigma}}_{d2}\right| = 0.08$ in Table 4).

We also argue that the differences among universities can be as substantial as the differences among various disciplines within the same universities. Therefore, if the relationship between research output and its four major determinants works so well among so many different universities, the same average relation can probably be applicable in the prediction of research output across difference disciplines within each university. Finally, the final discipline-specific number of refereed articles in Table 3 can be used to identify the key research areas across Australian universities.

V. Conclusion

Our paper provides a vital bridge in the existing literature between those studies comparing institutions in the broad and those focused upon specific subject areas. Our results, which are highly robust, provide evidence of recent discipline level output across most Australian universities, enabling institutions to analyse the performance of each subject area both across that university and with cognate disciplines in other universities. Besides its diagnostic value, it also provides an accurate forecasting tool, indicating the relative importance of different explanatory variables in planning future output, of which staff numbers and student-staff ratios are the most potent.

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Table 2. The forecasted-annual number of refereed articles published by institution and discipline (averaged 2000-2004)

University	Natural and Physical Sciences	Information Technology	Engineering & Related Technologies	Architecture & Building	Agriculture, Environmental & Related Studies	Health	Education	Manag. & Commerce	Society & Culture	Creative Arts	$\hat{Y}_i = \sum_{j=1}^{m=10}$ total	Y_i total	$\hat{\sigma}_i$
Adelaide	282	0	54	6	125	255	5	16	93	17	854	1003	0.15
ANU	652	20	80	0	50	102	0	31	449	66	1450	1323	-0.10
Australian Catholic	0	0	0	0	0	15	27	0	31	0	73	79	0.07
Ballarat	9	6	0	0	0	10	4	4	10	3	46	59	0.23
Canberra	21	6	3	7	0	5	10	12	28	5	97	107	0.10
Central Qld	26	9	12	0	0	7	12	6	16	2	89	109	0.18
Charles Darwin	19	0	0	0	0	7	12	2	20	4	65	71	0.08
Curtin	72	11	49	3	11	82	13	29	92	8	369	364	-0.01
Deakin	47	19	20	9	1	60	30	24	84	0	293	420	0.30
Edith Cowan	11	17	8	0	0	24	34	24	45	21	184	197	0.07
Flinders	55	7	0	0	0	166	16	4	103	0	351	457	0.23
Griffith	92	26	32	0	0	43	38	50	111	59	451	489	0.08
James Cook	110	5	16	0	28	30	16	8	35	8	256	301	0.15
La Trobe	123	9	14	0	15	126	24	24	153	16	504	471	-0.07
Macquarie	99	15	6	0	7	2	23	36	150	8	348	427	0.19
Melbourne	451	25	133	24	116	531	96	50	310	56	1790	1818	0.02
Monash	349	114	172	0	0	325	49	88	255	38	1389	1375	-0.01
Murdoch	87	8	9	0	35	19	18	20	57	9	262	270	0.03
New England	42	5	0	0	46	10	36	12	69	4	224	197	-0.13
Newcastle	95	0	73	10	0	94	25	16	91	36	442	508	0.13
Queensland	473	76	178	17	118	454	64	60	273	19	1730	1746	0.01
QUT	88	26	54	15	0	65	44	36	55	29	413	480	0.14
South Australia	38	10	82	15	0	55	31	64	43	19	357	328	-0.09
Southern Cross	24	3	0	0	0	13	7	27	18	10	102	103	0.01
Sydney	359	21	104	19	67	564	55	61	270	76	1596	1918	0.17
Tasmania	117	9	15	5	65	59	22	13	68	27	400	444	0.10
UNSW	326	33	265	31	0	533	19	81	196	50	1533	1474	-0.04
UTS	78	18	41	15	0	22	43	54	30	23	325	302	-0.08
Victoria	30	7	27	0	0	23	9	29	55	7	185	199	0.07
Western Australia	271	12	81	7	68	315	20	49	125	11	959	985	0.03
Western Sydney	49	10	17	4	0	33	27	24	76	23	264	320	0.17
Wollongong	79	21	73	0	2	24	23	25	62	17	326	361	0.10

Source: The Authors' calculations.

Note: If the corresponding S_{ij} and/or SSR_{ij} are zero, Y_{ij} are also assumed to be zero. In almost all cases when S_{ij} was zero, SSR_{ij} was zero too, implying no staff, no students and consequently no publication.

Table 3. The forecasted and adjusted annual number of refereed articles published by institution and discipline (averaged 2000-2004)

University	Natural and Physical Sciences	Information Technology	Engineering & Related Technologies	Architecture & Building	Agriculture, Environmental & Related Studies	Health	Education	Manag. & Commerce	Society & Culture	Creative Arts	Y_i total
Adelaide	331	0	64	8	147	300	6	19	110	19	1003
ANU	595	19	73	0	46	93	0	28	410	60	1323
Australian Catholic	0	0	0	0	0	16	28	0	33	0	79
Ballarat	12	7	0	0	0	13	6	5	13	4	59
Canberra	23	6	3	7	0	6	12	14	30	6	107
Central Qld	32	11	14	0	0	8	15	7	19	2	109
Charles Darwin	21	0	0	0	0	8	13	3	21	4	71
Curtin	71	11	48	3	11	81	13	28	91	7	364
Deakin	67	27	29	13	1	86	43	34	121	0	420
Edith Cowan	12	18	9	0	1	26	36	26	48	23	197
Flinders	72	9	1	0	0	216	21	5	134	0	457
Griffith	100	28	34	0	0	47	41	55	121	64	489
James Cook	130	6	19	0	32	36	18	10	41	9	301
La Trobe	115	9	13	0	14	118	22	22	143	15	471
Macquarie	122	19	8	0	9	3	28	45	184	10	427
Melbourne	458	26	135	24	118	539	97	50	314	56	1818
Monash	345	113	170	0	0	322	48	87	252	37	1375
Murdoch	90	8	9	0	36	20	19	20	59	9	270
New England	37	4	0	0	40	9	31	11	61	4	197
Newcastle	110	0	85	11	0	109	29	19	105	41	508
Queensland	477	76	179	17	119	458	64	61	276	19	1746
QUT	102	30	63	18	0	76	51	42	63	34	480
South Australia	35	10	75	14	0	51	29	59	40	17	328
Southern Cross	24	3	0	0	0	13	7	28	18	10	103
Sydney	431	26	124	22	81	677	66	74	324	92	1918
Tasmania	130	10	17	6	73	65	24	15	75	29	444
UNSW	314	31	254	30	0	512	18	78	188	48	1474
UTS	72	17	38	14	0	21	40	51	28	22	302
Victoria	32	7	29	0	0	24	10	31	59	7	199
Western Australia	278	12	83	7	70	324	21	51	129	11	985
Western Sydney	60	12	21	5	0	40	32	29	92	28	320
Wollongong	79	21	73	0	2	24	23	25	62	17	327

Source: The Authors' calculations.

Table 4. Actual research output and estimated research output (total and the sum of disciplines)

University	Y_i Actual	$\hat{Y}_i$ Estimated using aggregate data	$\sum_{j=1}^{m=10}\hat{Y}_{ij}$ Estimated using discipline data	$\hat{\sigma}_i = (Y_i - \hat{Y}_i)/Y_i$	$\hat{\sigma}_{d1i} = \left(Y_i - \sum_{j=1}^{m=10}\hat{Y}_{ij}\right)/Y_i$	$\hat{\sigma}_{d2i} = \left(\hat{Y}_i - \sum_{j=1}^{m=10}\hat{Y}_{ij}\right)/\hat{Y}_i$
Adelaide	1003	843	854	0.16	0.15	-0.01
ANU	1323	1507	1450	-0.14	-0.10	0.04
Australian Catholic	79	85	73	-0.08	0.07	0.13
Ballarat	59	52	46	0.13	0.23	0.12
Canberra	107	104	97	0.03	0.10	0.07
Central Qld	109	100	89	0.09	0.18	0.10
Charles Darwin	71	85	65	-0.20	0.08	0.24
Curtin	364	415	369	-0.14	-0.01	0.11
Deakin	420	326	293	0.22	0.30	0.10
Edith Cowan	197	204	184	-0.03	0.07	0.10
Flinders	457	376	351	0.18	0.23	0.07
Griffith	489	513	451	-0.05	0.08	0.12
James Cook	301	279	256	0.07	0.15	0.08
La Trobe	471	549	504	-0.17	-0.07	0.08
Macquarie	427	358	348	0.16	0.19	0.03
Melbourne	1818	1909	1790	-0.05	0.02	0.06
Monash	1375	1457	1389	-0.06	-0.01	0.05
Murdoch	270	282	262	-0.04	0.03	0.07
New England	197	232	224	-0.17	-0.13	0.03
Newcastle	508	472	442	0.07	0.13	0.06
Queensland	1746	1782	1730	-0.02	0.01	0.03
QUT	480	446	413	0.07	0.14	0.07
South Australia	328	392	357	-0.20	-0.09	0.09
Southern Cross	103	121	102	-0.18	0.01	0.16
Sydney	1918	1634	1596	0.15	0.17	0.02
Tasmania	444	420	400	0.05	0.10	0.05
UNSW	1474	1525	1533	-0.03	-0.04	-0.01
UTS	302	364	325	-0.20	-0.08	0.11
Victoria	199	205	185	-0.03	0.07	0.10
Western Australia	985	970	959	0.02	0.03	0.01
Western Sydney	320	302	264	0.06	0.17	0.13
Wollongong	327	331	326	-0.01	0.00	0.01
Mean	583	582	554	$\lvert\bar{\hat{\sigma}}\rvert = 0.10$	$\lvert\bar{\hat{\sigma}}_{d1}\rvert = 0.10$	$\lvert\bar{\hat{\sigma}}_{d2}\rvert = 0.08$

Appendices: Database

Table A1 : The average number of academic staff members (full-time equivalent) by institution and discipline during the period 2001-2004 (persons)

University	Natural and Physical Sciences	Information Technology	Engineering & Related Technologies	Architecture & Building	Agriculture, Environmental & Related Studies	Health	Education	Management & Commerce	Society & Culture	Creative Arts	Total
Adelaide	546	29	97	16	180	459	8	66	262	41	1703
ANU	1661	54	173	0	123	231	1	132	1170	172	3719
Australian Catholic	0	0	0	0	0	61	107	34	109	0	311
Ballarat	15	16	5	0	0	32	17	22	17	6	129
Canberra	38	27	4	19	0	6	26	55	98	22	297
Central Qld	39	65	33	0	0	27	47	61	81	30	383
Charles Darwin	34	13	0	0	0	17	37	7	53	14	176
Charles Sturt	40	48	0	0	33	59	47	51	78	22	379
Curtin	149	30	124	13	24	189	20	109	292	20	970
Deakin	95	72	37	21	0	171	72	100	191	54	814
Edith Cowan	35	56	20	0	0	58	102	63	126	98	557
Flinders	87	32	0	0	0	390	46	23	227	0	805
Griffith	285	64	59	9	0	58	97	128	279	115	1094
James Cook	181	19	37	0	53	125	50	43	114	39	660
La Trobe	225	29	40	0	27	312	55	99	362	39	1188
Macquarie	172	40	13	0	8	11	62	123	316	18	764
Melbourne	828	88	224	59	146	999	163	124	578	65	3274
Monash	1000	281	325	0	1	559	113	233	608	105	3225
Murdoch	203	33	7	0	69	37	33	50	118	35	585
New England	64	20	0	0	43	26	78	28	156	10	425
Newcastle	232	0	141	33	0	240	88	67	207	74	1082
Queensland	1067	220	321	72	218	945	47	175	669	39	3773
QUT	175	107	79	55	0	146	125	112	158	85	1042
RMIT	231	115	178	76	0	62	42	138	144	169	1156
South Australia	105	35	178	58	1	140	94	169	142	71	994
Southern Cross	37	14	0	0	1	29	22	60	78	16	258
Southern Qld	29	46	51	0	0	19	36	51	55	43	330
Sunshine Coast	21	0	0	0	0	0	0	31	8	15	76
Swinburne	24	55	185	0	0	4	0	113	59	36	475
Sydney	602	49	153	32	72	896	98	205	563	110	2779
Tasmania	183	45	28	18	74	168	65	43	209	58	890
UNSW	715	176	478	103	0	969	25	221	606	101	3395
UTS	146	79	85	69	0	46	79	151	83	52	790
Victoria	45	62	47	0	2	48	23	85	146	25	483
Western Australia	556	29	162	31	52	557	26	146	302	19	1878
Western Sydney	86	44	32	20	1	114	69	89	191	64	709
Wollongong	137	45	114	0	1	29	45	75	151	36	635

Source: The authors' calculation using a database purchased from DEST in December 2005 (the DEST source reference number: Staf2001.dat - Staf2004.dat).

Table A2: Annual average Expenditure on Research and Experimental Development during the period 2000-2002 ($A'000)

University	Natural and Physical Sciences	Information Technology	Engineering & Related Technologies	Architecture & Building	Agriculture, Environmental & Related Studies	Health	Education	Management & Commerce	Society & Culture	Creative Arts	Total
Adelaide	39544	2206	9989	692	21504	35878	3610	3935	12469	1054	130880
ANU	136000	11627	12116	140	5681	40379	493	21913	69202	8351	305902
Australian Catholic	439	126	9	3	112	886	2527	338	1914	415	6769
Ballarat	1663	1284	495	2	502	920	214	389	1200	138	6805
Canberra	1054	150	195	292	263	657	999	512	2148	140	6408
Central Qld	4078	606	2807	0	970	284	1897	642	1386	9	12680
Charles Darwin	3876	296	2120	69	7272	2392	1444	1553	3361	404	22786
Charles Sturt	1966	583	542	130	6350	896	900	821	2270	106	14561
Curtin	10086	5468	9549	246	2102	9991	938	2436	2428	690	43934
Deakin	5743	2496	2798	1334	1828	11288	3274	3813	9887	654	43115
Edith Cowan	1223	1288	1027	13	1398	3241	2968	1842	4662	414	18075
Flinders	14648	1155	1113	228	874	30056	2036	696	10708	874	62388
Griffith	15363	3827	5261	285	3740	13884	5838	8373	17371	5606	79548
James Cook	17812	369	3112	121	5426	3112	894	1159	2113	58	34175
La Trobe	14808	734	1027	34	1637	33803	1162	5004	12876	1816	72901
Macquarie	19969	4152	1525	193	837	1190	3034	5170	22428	406	58903
Melbourne	73306	9042	22299	2974	29264	114622	13099	16655	37241	5524	324025
Monash	33501	11331	31511	0	5747	56453	5837	13849	21936	2647	182812
Murdoch	12790	1254	5884	216	8108	1760	2636	2032	6232	138	41050
New England	8239	630	528	3	15257	1171	4847	3197	7923	528	42323
Newcastle	11133	1831	14377	1017	873	23150	4077	4386	12436	4247	77528
Queensland	102957	12444	36077	1143	24681	78550	3410	11236	25764	1803	298065
QUT	16357	5272	12334	964	1711	10787	5052	6602	11805	924	71808
RMIT	9095	7221	12441	1548	2685	4796	2419	3430	3294	1150	48079
South Australia	10146	3254	8737	1008	431	7269	3502	4621	5807	801	45575
Southern Cross	4466	253	264	7	1277	1769	721	1452	1823	613	12646
Southern Qld	2707	199	3816	0	2071	865	1356	1162	1474	514	14164
Sunshine Coast	482	34	0	0	256	203	17	66	397	3	1459
Swinburne	9848	3420	11530	211	39	3644	357	4309	6565	790	40714
Sydney	65374	4268	24186	3370	19164	112249	5764	15493	38848	8566	297282
Tasmania	20148	1405	1885	636	18123	10263	3162	2807	7634	2274	68339
UNSW	46861	11323	45874	1921	1153	74541	2114	14551	21039	4557	223934
UTS	6195	3694	9229	805	1407	5667	4220	11041	8065	1145	51466
Victoria	2528	607	4804	550	657	3086	1405	5285	4144	414	23482
Western Australia	42379	5509	21158	731	18887	55240	2235	8316	10958	1801	167215
Western Sydney	5075	1405	4120	278	4966	3874	4793	1807	10423	702	37443
Wollongong	17550	4667	13408	5	1913	6914	4228	6586	12111	1403	68785

Source: The DEST website.

Table A3: Average full-year student-teacher ratio (all students) by institution and disciplines during the period 2002-2003

University	Natural and Physical Sciences	Information Technology	Engineering & Related Technologies	Architecture & Building	Agriculture, Environmental & Related Studies	Health	Education	Management & Commerce	Society & Culture	Creative Arts	Total
Adelaide	13.9	18.7	18.3	19.8	11.4	9.7	20.6	31.0	25.8	7.4	17.0
ANU	17.4	15.8	11.7	0.0	15.3	7.3	0.0	31.7	20.9	7.5	18.0
Australian Catholic	0.0	0.0	0.0	0.0	0.0	13.7	21.0	25.7	16.9	0.0	18.4
Ballarat	10.0	36.8	28.9	0.0	0.0	15.6	23.1	44.5	19.9	16.2	23.0
Canberra	11.8	19.0	2.9	19.5	0.0	5.9	22.0	29.6	16.5	45.3	20.4
Central Qld	15.5	56.6	16.6	0.0	0.0	20.9	36.0	54.9	20.9	29.7	34.7
Charles Darwin	15.5	23.0	15.5	17.0	0.0	23.1	25.0	131.6	26.1	21.0	22.1
Charles Sturt	20.5	34.3	0.0	0.0	16.5	19.6	34.0	54.8	44.1	22.8	34.2
Curtin	15.5	32.2	19.3	51.8	17.3	16.7	39.9	38.0	15.9	46.4	21.3
Deakin	17.3	26.0	20.5	23.0	0.0	19.0	23.1	44.3	26.2	27.2	24.6
Edith Cowan	20.3	27.6	17.5	0.0	0.0	22.8	27.0	23.5	18.4	20.3	22.4
Flinders	17.4	18.5	0.0	0.0	0.0	12.8	21.2	25.9	21.8	0.0	18.1
Griffith	15.0	17.9	18.0	20.5	0.0	10.5	24.6	23.2	21.2	15.0	18.4
James Cook	15.5	21.2	17.2	0.0	15.0	17.9	27.7	37.4	23.0	21.1	20.8
La Trobe	13.6	15.9	14.4	0.0	12.8	19.7	25.5	29.6	21.9	27.0	19.9
Macquarie	16.8	24.0	13.6	0.0	10.9	40.1	24.2	27.5	18.5	17.1	21.0
Melbourne	15.1	20.0	19.6	22.5	11.1	13.3	24.3	29.6	24.3	13.9	18.1
Monash	14.0	16.6	16.0	0.0	0.0	14.9	24.9	27.6	21.3	25.3	19.0
Murdoch	14.2	20.4	6.6	0.0	14.2	12.8	18.9	27.9	23.1	22.1	19.2
New England	13.7	17.3	0.0	0.0	10.1	20.6	25.7	29.5	25.4	21.1	22.2
Newcastle	16.2	0.0	17.3	20.2	0.0	14.4	27.2	24.3	23.2	18.8	20.0
Queensland	22.4	18.2	17.8	20.2	19.2	12.6	2.0	24.3	23.3	20.7	19.7
QUT	19.1	27.5	20.0	20.9	0.0	16.4	27.5	36.2	29.2	20.2	24.5
RMIT	18.1	18.7	18.8	22.5	0.0	19.5	25.3	38.3	32.3	16.1	22.5
South Australia	24.1	24.6	17.0	19.9	0.0	17.0	26.1	31.7	21.7	22.9	22.9
Southern Cross	11.4	24.2	0.0	0.0	0.0	20.4	23.8	33.0	24.4	12.2	23.0
Southern Qld	14.6	25.1	19.4	0.0	0.0	17.3	13.3	35.2	30.2	19.1	21.1
Sunshine Coast	23.8	0.0	0.0	0.0	0.0	0.0	0.0	24.0	0.0	21.8	23.1
Swinburne	14.0	27.9	19.0	0.0	0.0	18.2	0.0	32.1	17.2	16.1	23.1
Sydney	15.5	17.2	16.6	22.4	6.4	13.4	12.9	24.8	22.9	12.3	17.3
Tasmania	15.2	24.5	21.0	16.4	11.6	14.7	27.2	31.9	22.5	17.5	20.5
UNSW	14.6	20.5	17.9	16.9	0.0	7.1	12.4	26.1	20.6	20.3	17.2
UTS	15.5	26.9	21.7	17.6	0.0	13.9	10.1	24.2	38.4	18.7	19.4
Victoria	11.1	21.6	15.1	0.0	5.8	8.6	23.4	27.8	21.9	22.0	19.1
Western Australia	14.7	23.1	18.2	22.0	5.4	8.2	21.8	25.6	20.3	12.1	16.4
Western Sydney	15.7	23.1	19.9	17.1	0.0	17.2	21.5	34.4	23.6	20.2	22.4
Wollongong	16.8	29.3	14.1	0.0	12.8	13.4	25.1	38.3	23.7	20.7	23.1

Source: The DEST website.

Table A4: Annual Average number of PhD Course Completions by Institution and discipline during the period 2001-2003 (persons)

University	Natural and Physical Sciences	Information Technology	Engineering & Related Technologies	Architecture & Building	Agriculture, Environmental & Related Studies	Health	Education	Management & Commerce	Society & Culture	Creative Arts	Total
Adelaide	76.3	0.0	22.7	2.7	42.0	52.0	2.0	2.7	31.3	2.7	234.3
ANU	107.3	2.0	15.0	0.0	13.0	5.7	0.0	2.7	108.0	6.0	259.7
Australian Catholic	0.0	0.0	0.0	0.0	0.0	2.3	5.0	0.0	7.3	1.3	16.0
Ballarat	2.7	2.7	0.0	0.0	0.0	2.0	1.7	1.0	7.0	2.3	19.3
Canberra	11.0	1.7	0.3	3.7	0.0	1.7	5.0	5.0	5.3	6.0	39.7
Central Qld	14.0	2.7	2.0	0.0	0.3	2.3	3.7	0.7	2.0	0.3	28.0
Charles Darwin	7.0	0.0	0.7	0.0	2.3	2.0	4.3	2.3	7.0	1.0	26.7
Charles Sturt	0.0	0.0	0.0	0.0	14.7	3.0	4.3	3.7	8.7	0.0	34.3
Curtin	22.0	2.7	11.7	2.3	3.3	24.3	31.7	12.7	35.3	8.3	154.3
Deakin	18.7	4.3	11.3	3.7	0.0	11.3	13.7	7.3	45.3	0.0	115.7
Edith Cowan	3.3	7.0	2.7	0.0	2.7	9.7	14.3	12.3	12.0	8.0	72.0
Flinders	21.7	0.7	1.7	0.0	0.0	26.3	4.7	0.3	48.3	0.0	103.7
Griffith	12.0	7.0	13.0	0.0	18.3	11.0	13.3	16.3	32.3	24.3	147.7
James Cook	45.0	1.3	4.0	2.7	8.3	4.3	8.7	1.7	13.7	4.3	94.0
La Trobe	42.0	2.3	3.3	0.0	6.7	24.7	22.3	4.0	71.3	8.3	185.0
Macquarie	35.7	4.0	1.3	0.3	4.7	0.3	8.3	9.7	50.0	5.7	120.0
Melbourne	130.3	2.7	65.3	9.7	38.7	106.7	70.3	14.7	189.3	50.3	678.0
Monash	59.0	32.7	51.0	0.0	2.3	102.7	24.0	32.0	107.3	19.7	430.7
Murdoch	18.7	1.0	2.7	0.0	8.3	7.7	9.3	11.0	33.0	5.7	97.3
New England	16.0	0.7	1.0	0.3	20.7	4.3	19.3	5.0	36.0	2.3	105.7
Newcastle	25.0	2.7	24.0	2.3	0.3	13.0	6.0	2.0	38.3	16.3	130.0
Queensland	129.0	14.0	60.7	3.3	42.7	82.3	18.0	15.0	115.7	11.3	492.0
QUT	31.0	4.0	32.0	4.7	0.0	17.0	18.0	13.3	15.7	17.7	153.3
RMIT	42.7	9.7	53.3	14.0	0.0	3.7	21.3	13.7	16.0	44.7	219.0
South Australia	8.3	1.7	29.7	3.7	1.0	14.0	11.3	45.3	9.3	7.0	131.3
Southern Cross	7.7	1.0	0.0	0.0	4.0	5.0	2.3	35.0	3.7	6.0	64.7
Southern Qld	4.0	0.7	5.3	0.0	0.0	1.3	4.3	8.0	7.0	0.3	31.0
Sunshine Coast	0.0	0.3	0.0	0.0	0.3	0.3	0.0	1.7	1.0	0.0	3.7
Swinburne	13.7	0.0	22.3	0.7	0.0	0.3	0.0	20.7	12.3	0.0	70.0
Sydney	120.3	5.7	44.7	12.0	15.0	159.0	21.3	10.3	115.0	37.7	541.0
Tasmania	48.0	1.3	9.7	1.0	27.3	8.7	7.3	4.0	18.3	12.3	138.0
UNSW	73.7	1.7	97.0	8.0	0.7	69.0	11.3	24.3	45.3	28.7	359.7
UTS	39.0	2.7	14.3	2.7	0.0	4.7	12.7	14.0	12.3	15.3	117.7
Victoria	15.0	0.3	9.7	0.0	0.0	3.7	3.7	8.7	23.7	2.0	66.7
Western Australia	66.7	2.7	22.0	1.0	22.7	46.7	28.3	13.7	51.3	3.7	258.7
Western Sydney	25.7	1.7	7.3	0.7	8.0	5.3	7.7	10.3	28.0	15.7	110.3
Wollongong	27.7	10.7	28.0	0.0	2.7	11.0	12.0	8.7	20.0	10.7	131.3

Source: The authors' calculation using a database purchased from DEST in December 2005 (the DEST source reference number OZUP-2002-2004).