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RESEARCH OUTPUT OF AUSTRALIAN UNIVERSITIES

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Abstract:

Research plays an important role in underpinning a country's economic and social life. Universities are at the centre of the research and human capital generating process. The aim of this paper is to explore the links between research output, research income, academic and non-academic labour and some of the characteristics of Australian universities. The results indicate that research income, academic staff and post-graduates are all positively associated with research output. There are noticeable differences across different types of universities, with the newer universities lagging in research performance.

Keywords: Research output, universities, panel data.

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Research Output of Australian Universities

1. Introduction

It is generally accepted internationally that a country's capacity to generate new knowledge is of vital importance to its economic health and living standards. The generation and transmission of knowledge through research has long been recognised as an essential requirement for a country's long-term growth and competitiveness as well as creating a capacity to solve social problems (World Bank 1998; United Kingdom 1998; Kemp 1999a, 1999b).

In Australia, the carrying out of research in the arts and sciences has long been seen as a vital function of the universities (see for instance Murray Report 1958; Martin Report 1964-65; Dawkins 1987, 1988). Today the universities play an important role in both the generation and dissemination of research. In recent years it has been estimated that the higher education sector in Australia accounts for around 27 percent of expenditure on Research and Development and 78 per cent of all expenditure on basic research (Australia, Department of Industry, Science and Tourism 1997). The Australian Government is the major provider of funds of this research activity, in 2000 contributing to higher education institutions $1.3 billion of direct funding for research. This funding provides for the training of post-graduate research students and provides universities with the basic infrastructure to carry out research, sustaining a significant proportion of Australia's basic research effort.

The aim of this paper is to explore the links between research output, labour and research inputs and some of the key characteristics of Australian universities. As research plays an important role in underpinning Australia's economic and social life, governments and universities both have a strong interest in promoting higher research output and thus, it is important to identify what impediments there may be towards achieving this objective.

2. Background

Historically Australian universities were funded for their research on the basis of their institutional status, size and course mix rather than on any specific measurement of their research output. Between 1965 and 1988 Australia possessed a 'binary' higher education sector which was divided into universities and 'colleges of advanced education' (known as CAEs). The universities were seen as having a special commitment to scholarship, research and the training of research workers and were therefore funded at a higher level than their college of advanced education counterparts. The CAEs were funded at approximately 60 per cent per student compared to the universities and concentrated purely on delivering teaching programs.

Changes in this stucture were initiated by the Minister for Employment, Education and Training (John Dawkins) in his Green and White Papers of 1987 and 1988. These changes led to the creation of a Unified National System of universities. This meant that the colleges disappeared and were replaced with much larger, multi-campus institutions. From 19 universities and 54 colleges of advanced education in 1987 the number fell to 39 universities in 1994.

The creation of the Unified National System meant that the manner in which the government funded universities for research was to change fundamentally. Instead of funding being allocated on the basis of the type of institution and its size, a Relative Funding Model was introduced. This meant that universities began to be assessed on the size and nature of their research performance and were funded accordingly. It also meant that universities were compelled to compete with each other for government research funds. Competition for research funds pre-dated 1988 to a limited degree in the sense that a limited amount of government funds had been allocated in the past for specific projects, but the bulk of research funds provided to the universities was provided as a block grant. This increase in competition for research funds put pressure on all the institutions to increase their research output, a process that was compounded by the endeavour of the universities to achieve international recognition and to build their status in Australia (Bessant 1996).

The linking of research funding to research output has meant that the Department of Employment, Education and Training (and its successor the Department of Education, Training and Youth Affairs) has had to monitor and assess research output through performance indicators and accountability arrangements in order to determine research funding allocations. This process has been a controversial one given the difficulty in assessing both the quantity and quality of academic research output.

Throughout the 1990s government funding to Australian universities was provided through three main channels. Funding to support research training was provided through university operating grants on the basis of enrolments and disciplines, as well as in the form of student fee (HECS) exemptions and student scholarships known as Australian Postgraduate Awards. The second channel was in the form of the 'Research Quantum'. This formed part of the universities' operating grant and supported the general fabric of university research and research training activities. The Research Quantum is allocated each year on the basis of a Composite Index which takes into account research inputs (private research and special government research funding) and research output (publications and award completion) components. The third manner in which funds were provided was on the basis of targeted special programmes. Examples of these include the grants of the Australian Research Council, International Researcher Exchanges, Research Fellowships, grants to special Research centres, among others. As well as these government sources, universities were funded for research and research training from private sources which includes the fees of post-graduate students.

In each of the three channels through which funding for research and research training was allocated, some sort of perception of the research performance of the institutions was made by the Department or by one of its agencies. This has meant that over the course of the 1990s the need to promote research output has intensified in order to maintain the financial position of individual universities.

3. Measuring Research Output

Determining the size and quality of the research output of universities has been a controversial topic during the 1990s and early 2000s. Not only is it necessary to capture the quantity of output, but also the quality of the work must be accounted for. In determining levels of output two distinct groups have been interested in this process. The first group is government agencies in a range of countries that have aimed to determine the research output of higher education institutions in order to allocate funds towards universities. For example, in the United Kingdom, the Universities Funding Council and later the Higher Education Funding Council have undertaken research assessment exercises with the aim of determining the size and quality of research output. The other group that has addressed this problem have been academic economists that have been interested in assessing research output levels in order to use these as part of their analyses of the operational performance of higher education institutions (for a summary of some of this research see Worthington 2001).

The most straight-forward manner of determining the size of research output is to simply compile a weighted average of the various types of research publications produced by university staff. For example, Verry and Layard (1975), Verry and Davies (1976), and Madden *et al.* (1997) have all used this approach. Ying Chu and Sung Ko Li (2000) likewise used a similar publications index but broadened the definition of research output by adding contracts, patents and prizes as extra outputs. Raw data on publication numbers does detract somewhat from the quality issue. Citations have been used as a measure of research quality in a number of studies, based on the annual Social Sciences Citation Index in order to account for quality. Johnes and Taylor (1990) for instance, measure research output by using the conventional measures of publications and citation analysis and research income. De Groot *et al.* (1991) in their work on American universities incorporated a measure of both research output (bibliometric) and quality (peer review). In the United Kingdom a number of researchers have used research data based on the Government research assessment exercises that were carried out by the government and were based on peer review.[1]

One difficultly in using the publication/citation approach is that with a small number of exceptions, Australian academics tend to publish in journals which, are not widely cited in SSCI-listed journals which limits the usefulness of this measure in the Australian case.

An alternative to using some weighted-index of publications is to use external research finance attracted by a university as a proxy for research output. This approach has been used by Hashimoto and Cohn (1997), Beasley (1995) and Cohn *et al.* (1989). Gillet (1987), Tomkins and Green (1988), and Cave and Kogan (1991) suggest that research grants reflect the market value of the research conducted and can therefore be considered as a proxy for output. Johnes and Johnes (1993), however, argue that grants are spent, not only on research assistance but on other facilities which are inputs into production. To include grants as both outputs and inputs, it is argued, is to double count.

4. Recent patterns in research and teaching output

In order to explore the research process in Australian universities, we use data for the 35 government universities for the period 1995 to 2000. The data is hence a panel with 210

[1] See for instance Johnes and Johnes (1993); Johnes (1995); Johnes (1996); Johnes and Johnes (1995); Glass *et al.* (1995a); Glass *et al.* (1995b); Glass *et al.* (1998), and Athanassopoulos and Shale (1997).

observations. In the period 1995 to 2000 there were 39 universities operating in Australia. Two of these were private institutions that operated outside of the Unified National System (Bond University and Notre Dame). Another (the Australian National University) was funded on a different basis to the other government universities and another was only just opened (University of the Sunshine Coast) and so have special conditions that differentiate them from the majority of universities. In this study, therefore, these four universities have been excluded.

In this paper research output is measured in two ways. The first indicator of research output is the Research Quantum. The Research Quantum is allocated on the basis of a Composite Index which in turn is based upon the research output of the universities. This makes it a fair proxy for research output. The Research Quantum figures can be deflated by the CPI in order to derive a real research output series. The second indicator is a publications index. This was constructed using data provided by the Department of Education, Training and Youth Affairs. The index was constructed using data on conference papers, book chapters, books and journal articles. We use a weighted-index of publications, with the following weights: 1 for a conference paper, 2 for a book chapter, 3 for a journal article and 4 for a book. This ranking is obviously subjective. The index can also be constructed using different weights. For example, conference papers can be given an even lower ranking, book chapters and journal articles can be equally ranked and books can be given greater weight. Such alternative weights do not change significantly the results presented below (these results are available from the authors). There are no data on quality differences in research output. Accordingly, for all research categories, research output over all years is assumed to be of the equal quality. While this is unrealistic, it is unavoidable.[2] This is a problem which most researchers of university output have experienced.

Table 1 traces the research output of Australian universities over this period, expressed as annual averages. Columns 2 and 3 trace the change in the real value of Research Quantum over the period studied, averaged for all universities and for the so-called ‘big seven’, respectively (University of Melbourne, University of Sydney, University of New South Wales, University of Queensland, Monash University, University of Western Australia, University of Adelaide).[3] The research output (measured either as the research quantum or

[2] For example, there is lack of citation data for Australian university research output.
[3] As noted earlier, the Australian National University is not included in this study.

the publications index) of the 'big seven' was on average between two and three times greater than that of the rest of the Australian universities.

The last column in Table 1 shows the average number of total student enrolments (post-graduate and undergraduate, full-time equivalent) in the Australian university system. Enrolments have risen steadily over the period. Table 2 presents data on the total research output of several research categories. The largest improvement in research output occurred through journal articles, followed by chapters in books.

It can be seen also from Table 1 that the Research Quantum fell steadily over the 1998-2000 period. However, in contrast to the Research Quantum, the publications index has been rising steadily. The average publication index for the big seven is about double that of the university system as whole, and has also risen steadily. The Research Quantum has been falling not because of any reduction in the research output of Australian universities but because of the fiscal restraint on the part of the Federal Government. The Research Quantum is fixed each year as a part of the Federal Government's budgetary process and then allocated proportionately on the basis of the Composite Index indicator of research performance mentioned earlier. At the same time the physical indicator of research output has been rising. This is not necessarily contradictory with the falling Research Quantum. Indeed it may be linked directly. As total research allocations are squeezed this puts pressure on universities to increase their research output even more in order to win a greater proportion of diminishing funds available. We regard the Research Quantum as an adequate measure of research output in the earlier years (such as 1995 and 1996) but not so in the later years. Hence, our preferred measure of research output over the entire period will be the publications index.

TABLE 1 ABOUT HERE

TABLE 2 ABOUT HERE

5. Modelling the research process

The literature does not offer any clear guidance on how to identify the determinants of research output. Indeed, there is a noticeable dearth of investigations on the determinants of research output. One exception is Johnes (1988) who used OLS to explore research output in

British economics departments. Johnes considered a number of potential determinants, such as the age of university staff, the staff-student ratio, the number of staff and the stock of library books.

In this paper, we draw upon two strands of theory that are relevant to the identification of the determinants of university research output. First, there is an extensive body of literature on education production functions (see, for example, Hanuschek 1986 and Cohn and Geske 1990). This literature relates education outcomes to various inputs, after introducing a number of control variables such as important differences across universities, subject mix, student characteristics and even the degree of unionisation (see, for example, Eberts and Stone 1987). This literature typically uses either a cost or production framework, usually with a Cobb-Douglas or translog specification. Second, there is a large body of literature exploring Schumpeter's (1942) hypothesis of a link between research and development and firm size. A number of arguments have been advanced in support of this hypothesis. For example, research and development requires often considerable bearing of risk and scale of activity, both of which are more easily achievable by large entities. Also, a large supply of funds is needed frequently to finance and reward research activity. The theoretical arguments and empirical investigations in this area are reviewed in Cohen and Levin (1989) and Cohen and Klepper (1996). While this literature has focussed on private sector firms, it is applicable also to university research output, as the size of a university may influence research output. For example, larger universities may have more highly developed research supporting administrative structures. Larger sized universities may also be able to attract research funds more easily. Further, there may exist complementarities between research and non-research activities, which larger universities may have an advantage over.

In this paper we combine these two strands of literature by modelling research output as a function of three inputs – research income, academic staff and non-academic staff – as well as the size of a university. This is undertaken within a translog specification allowing for interactions among the key variables. The variables, the expected associations with research output and the variable means (M) and standard deviations (SD) are as follows. Abbreviations are denoted in brackets.

ACADEMIC (A): the number of full-time equivalent academic staff. As the main input into the research process we expect a positive coefficient on this variable (M = 1114, SD = 707).

GENERAL (G): the number of full-time equivalent general (non-academic) staff. We expect a positive coefficient on this variable, although *a priori* we expect its contribution to be lower than that of academic staff (M = 1141, SD = 787).

RESEARCH INCOME (Y): the total value of government and non-government research income. A positive coefficient is also expected on this variable (M = 13204, SD = 16284).

ENROLMENT (E): There is much debate about the appropriate measure of firm size, with both employment and sales used in the literature for private firms. In general, sales are preferred because they are factor proportion neutral and because the use of employment tends to overstate the R&D-firm size elasticity (see Scherer, 1965 and Bound *et al.* 1984). Johnes (1988) used the number of staff as a proxy for department size. In this paper we use the total number of equivalent full-time students (post-graduate plus under-graduate) as the preferred measure of university size (ENROLMENT). Following Bound *et al*. (1984) a quadratic specification is adopted allowing for non-linear effects of university size on research output. That is, both enrolments and enrolments squared are included as explanatory variables[4] (M = 14167, SD = 7163).

POST (P): this is the number of full-time equivalent post-graduate enrolments and is included in order to explore links between post-graduate students and research performance. Some authors prefer to use the number of graduates rather than student numbers to indicate teaching output (see for instance Athanassopoulos and Shale 1997), while others prefer to use student numbers (see for instance Coelli 1996). We believe that the number of enrolments is a more accurate measure, as the use of graduates may understate actual post-graduate activity (M = 2234, SD = 1389).

MEDICAL (M): This is a dummy variable controlling for differences in universities, separating those with a medical school and those without. Unfortunately, we are unable to control for any other differences in subject mix.

CAMPUS (CA): Universities vary according to the number of campuses they administer. While this is expected to impact on the cost structure of the university, there is no reason to believe that it should have a detrimental affect on research output. This variable was measured as the number of campuses for each university. This variable may also be considered to capture in some ways the size of a university, with larger universities tending to have more campuses. We considered also a dummy variable for region. Some universities are regionally based while others are based in the main cities. As is to be expected, the region and number of campuses variables are correlated. These variables are, however, different. A university can, for example, have a number of urban campuses without any regional presence. In preliminary analysis, the regional variable was found to be statistically insignificant and accordingly was omitted from further investigation.

BIG 7 (B7): A dummy variable if the university belongs to the big seven group of universities. We expect higher levels of research output from these universities.

TIME (T): A linear time trend is included to capture any changes in productivity in the research process over time. A positive coefficient is expected.

CAE: A dummy variable taking the value of 1 if the university is a former college of advanced education and 0 otherwise. There is no prior expectation on the sign on this variable. The colleges of advanced education did not have a tradition of research, hence they should have a lower research output. However, many have orientated themselves towards research, devoting both funds and energy to establishing a research profile.

In addition to introducing the input and enrolment variables, we allow also for interactions between the various inputs. The interaction terms offer important information on the degree of complementarity or substitutability between the various inputs into the research process. The full model to be estimated is given in equation 1, although a number of versions of this were estimated also. The estimated coefficients can be used to derive a set of research output elasticities.

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[4] We considered also a cubic function, as used by Scherer (1965), as well as others. The cubic term was never statistically significant.

$$\ln R_{it} = \beta_0 + \varphi_R \ln R_{it-1} + \beta_S \ln E_{it} + \beta_{SS} \ln E_{it} \ln E_{it} + \beta_Y \ln Y_{it} + \beta_A \ln A_{it} + \beta_G \ln G_{it} + \beta_T T_{it}$$
$$+ \beta_{YY} \ln Y_{it} \ln Y_{it} + \beta_{AA} \ln A_{it} \ln A_{it} + \beta_{GG} \ln G_{it} \ln G_{it} + \beta_{YA} \ln Y_{it} \ln A_{it} + \beta_{YG} \ln Y_{it} \ln G_{it}$$
$$+ \beta_{GA} \ln G_{it} \ln A_{it} + \beta_P \ln P_{it} + \beta_{PP} \ln P_{it} \ln P_{it} + \beta_{PY} \ln P_{it} \ln Y_{it} + \beta_{PA} \ln P_{it} \ln A_{it} + \beta_{PG} \ln P_{it} \ln G_{it}$$
$$+ \beta_{B7} B7_{it} + \beta_{CAE} CAE_{it} + \beta_M M_{it} + \beta_{CA} CA_{it} + v_{it} \qquad (1)$$

where R denotes research output, E is total full-time equivalent student enrolments, Y is total research income, A is the number of full-time equivalent academic staff, G is the number of full-time equivalent general (non-academic staff), P is post-graduate enrolments, T is time, and B7, CAE, M and CA are dummy variables for the BIG 7, CAEs, MEDICAL and CAMPUS variables. ln denotes the natural logarithm, i and t index the ith university and t is the time period, and v is the error term.

A number of issues need to be addressed before presenting the results. First, the data on publications commences in 1995. However, it is unlikely that they reflect the research actually performed in 1995. Publication lags mean that it is necessary to adjust the timing of this variable. It is assumed in this paper that the publication index for year t refers to research output of year t-1. For example, the 2000 publications index is assumed to relate to the year 1999. Hence, the dependent variable is the publication index lagged one year. This means that the number of observations for estimation purposes is reduced to 175.

Second, in order to correct for the presence of serial correlation and to capture some of the dynamics of the research process, the model is estimated with one lag in the dependent variable. [5] Since the dependent variable is the publications index with one lag, then a lagged dependent variable is the publications index with two lags.

Third, there is the danger of endogeneity between post-graduate student enrolments and research output. For example, post-graduate students can be attracted to universities with large research output. It is possible post-graduate enrolments and research output cause each other. We lack a sufficient time series to investigate issues of causality, through for example,

5 An alternative approach is to include an AR(1) process. This leads to similar results as those presented in Table 3. However, the inclusion of a lagged dependent variable seems a more appropriate specification. The

Granger causality tests. However, we applied the Hausman (1978) test to explore the possibility of endogeneity. This test rejects the hypothesis of endogeneity between post-graduate enrolments and research output. We conclude that the association between post-graduate enrolments and publication index can be modelled effectively within the estimation framework outlined above. Similarly, there is no evidence of endogeneity between research income and research output.

Fourth, because of the differences in the size of the universities, heteroscedasticity is a real problem. The use of pooled least squares is not advisable in this case. Hence, the exploration of the determinants of research output using panel data was undertaken using Generalised Least Squares (GLS) with cross-section weights. This involves two steps. First, equation 1 is estimated using pooled least squares. Second, the estimated variances derived from the first step are then used to estimate feasible GLS. This is the recommended estimation procedure for panel data with heteroscedasticity (see Wooldridge 2000).

6. Results and interpretation

The parameter estimates for equation 1, as well as several variations of it, are presented in Table 3.[6] Column 1 presents the basic model with no interaction terms and no allowance for the effects of post-graduate students. In this model, research income and academic staff both have the expected positive coefficient, while general staff has a negative coefficient but this is not statistically significant. The coefficients for the enrolment variables indicate that large sized universities do not have an advantage in research. For example, when evaluated at the sample mean, the elasticity of research output with respect to enrolments is +0.12, in this basic model. This becomes –0.03 for the largest sized universities. The CAMPUS, BIG 7 and CAE variables all have expected signs.

Column 2 introduces interaction terms among research income, academic staff and general staff, but without the enrolment and post-graduate variables. The interaction terms are statistically significant indicating that they should be included in the estimation procedure. The main difference is that MEDICAL has a statistically significant negative coefficient, which is a rather unexpected and not very plausible result. General staff also has a negative

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use of SUR estimation approach is not appropriate for this data set, as the data do not meet the necessary requirements, see Beck and Katz (1995) for details.

coefficient, however, when the elasticity of research output is evaluated using all the general staff interaction terms, this elasticity is positive (+0.03).[7]

The post-graduate and post-graduate interaction variables are introduced in column 3, without the enrolment variables. The post-graduate terms are all statistically significant indicating that they should be retained. Their inclusion does however change the coefficients in other variables, with some surprising results. For example, CAMPUS now has a negative coefficient. MEDICAL now has a positive and statistically significant coefficient.

The full set of results (equation 1) are presented in column 4, which includes both the post-graduate and the enrolment variables. The sign on the input variables (top part of Table 3) are the same and in most cases the magnitude of the coefficients remain unchanged. The CAMPUS and MEDICAL variables appear to have the correct signs – with campus having a positive coefficient and medical being statistically insignificantly different from zero.

The problem with the results presented in column 4 is that post-graduate enrolments are correlated with total enrolments – hence the insignificant term for POST. Accordingly, the POST and POST squared terms were removed and the model was re-estimated. The final and preferred set of results are presented in column 5. The interpretation of the results and the calculation of elasticities will be based on this set of results. Most of the variables are statistically significant, although some are not, most likely because of multi-collinearity. Importantly, the interaction terms are statistically significant indicating a rather complicated set of relationships between the input and research output variables.

The research income and academic staff variables both have positive coefficients, while general staff has a negative coefficient. The research income squared term has a positive coefficient which indicates that the contributions of research income increase as the level of research income rises. This is in contrast to the labour inputs. Both the academic and the non-academic staff squared terms have a negative coefficient, suggesting that the contributions of labour inputs to research output are smaller the higher is the level of the labour input. The

[6] Eviews version 4.0 was used to derive all the estimates presented in Table 3. White's heteroscedasticity-consistent standard errors are used to calculate the t-statistics.

[7] This elasticity is calculated as: $\partial R / \partial G = \beta_G + \beta_{GG} \ln G_{it} + \beta_{YG} \ln Y_{it} + \beta_{GA} \ln A_{it}$. Note that β_{PG} is set to 0 in this set of results.

input interaction terms can be used to measure the degree of input complementarity. The negative coefficient on research income and general staff interaction term (β_{YG}=-0.26) implies substitutability in the research generation process, with the contributions of research income to research output falling as the number of general staff increases. This provides some evidence to the concerns expressed by many academics regarding the size of administration and the impact that this may have on research output. This is in sharp contrast to the complementarity that exists between research income and academic staff (β_{YA}=+0.19) – the contributions of research income to research output increase as the number of academic staff increases.

<u>TABLE 3 ABOUT HERE</u>

Table 4 lists some of the elasticities of research output with respect to inputs and enrolments. These measure the percentage change in research output arising from a one percent change in a chosen variable. Note that because of the translog specification, the elasticities are variable. The inclusion of the lagged dependent variable in the estimation procedure means that it is possible and desirable to evaluate the elasticities also in terms of long-run elasticities. These elasticities are presented in Table 5.[8] The elasticities in Tables 4 and 5 are evaluated by changing the values of the variable of interest while holding all the other variables at the mean of their respective sample. For example, in Table 4 the elasticity of research output with respect to academic labour ($\boldsymbol{\varepsilon_{academic}}=\partial R/\partial A$) is +0.28 when the sample means are used for all variables and when the minimum value in the sample is used for academic labour. If the mean of the samples is used for all variables but academic labour is evaluated at the largest value of the sample, this elasticity falls to +0.17. That is, holding all other variables constant, but increasing the number of academic staff results in a decrease in the elasticity of research output with respect to academic staff. A similar effect applies with respect to non-academic staff.

The contributions of academic labour are substantially larger than those of non-academic labour. Importantly, $\boldsymbol{\varepsilon_{general}}$ is virtually zero when employment of non-academic labour is large. This arises because nearly all the terms with general staff have a negative coefficient. The two exceptions are the general and academic staff interaction term which indicates that

[8] Long-run elasticities are derived by dividing the relevant coefficient (or set of coefficients) by 1 minus the coefficient on the lagged dependent variable.

academics and non-academics are complements to the research process, and the post-graduate and non-academics interaction term. These effects however are more than offset by the negative interaction between research income and non-academic staff (the $\beta_{YG}\ln Y_{it}\ln G_{it}$ term) and the declining contribution of general staff as the level of general staff rises ($\beta_{GG}\ln G_{it}\ln G_{it}$).

The elasticity of research output with respect to total enrolments (ε_{enrol}) is influenced by the negative quadratic term on enrolments. This means that the expansion of enrolments in individual universities has a detrimental effect on research output. As a test of Schumpeter's hypothesis, this indicates that larger sized universities do not have an advantage in research generation. Small Australian universities can be effective producers of research output. The expansion of the enrolment size of Australian universities is advocated often on the basis of cost savings. However, the results presented in this paper suggest that this expansion has a negative impact on research output.[9] Over the 1995 to 1999 period, the average number of students enrolled in Australian universities rose by approximately 16 percent. Using the long-run elasticity of –0.23 (from Table 5) implies that research output was about 4 percent lower as a result of the expansion in enrolments. The results presented in this paper indicate also that if higher enrolments are associated with an increase in the general staff ratio (general staff increases/decreases by a greater/smaller percentage than academic staff), than this will also impact negatively on research output.

TABLE 4 ABOUT HERE

The post-graduate interaction terms are also interesting. The post-graduate enrolments and academic staff interaction term has a negative coefficient, suggesting that the contributions of post-graduate students to research output actually fall as the number of academic staff rises, while the opposite effect holds with respect to general staff. Academics and post-graduates appear to be substitutes in the research process. An alternative way to view this is that the contributions of academic staff to research output falls as the number of post-graduate enrolments rises, presumably because of the rising burden of supervision. When evaluated at

[9] It is interesting to note that Johnes found a similar pattern for British economics departments. The coefficient on staff (his measure of size) has a positive coefficient, while staff squared has a negative coefficient.

the mean of the samples, the long-run elasticity of research output with respect to post-graduates is +0.18, rising to +0.60 for the larger sized institutions.

The dummy variable for the number of campuses is statistically significant. The size of the university in terms of number of campuses does not appear to have an adverse effect, indeed it has a very small positive impact. It is not obvious why this correlation would exist. One explanation may be that these universities have pursued with more rigour policies promoting research output. As expected the big seven universities are associated with higher research output levels, and the former colleges of advanced education produce less research output. After controlling for differences in staffing levels, research income, size and post-graduate numbers, the former CAEs are about 7 percent less productive in terms of research output than the Big 7 group of universities. The existence of a medical school has no impact on research output. Finally, the time trend indicates a solid rate of technological progress of around 3 percent per annum in the research process. This can arise through several avenues, such as greater use of new technologies, increased computing power, speedier access to library resources, etc.

7. Summary

Universities are at the centre of the research and human capital generating process, a process that has gained in importance and continues to do so. In this paper, the association between research output and university characteristics has been explored, for Australian public universities. The results indicate that research income, academic staff and post-graduates are all associated positively with research output. While general staff have a positive impact on research output, this effect is eroded rapidly as the number of non-academic staff employed rises. There are also noticeable differences across universities. The traditional and leading universities have a clear research output lead. Whatever the merits of the university amalgamation process in Australia in terms of cost savings, the research performance of the universities associated with the former colleges of advanced education is lagging. Research is necessary to investigate the factors that hinder research performance in these universities and what actions can be taken to redress this situation.

A number of policy implications can be drawn. First, the results indicate the importance of adequate funding for research purposes and the need for universities to ensure appropriate and adequate academic staffing levels. Second, the dangers of over administration seem quite clear and excessive bureaucratic attempts to raise research output may be self-defeating. Third, large universities do not to have a great advantage in terms of research output. It appears therefore that small universities will be unable to gain further advantages by increasing their size. Size might, of course, help to lower average units costs of teaching, but this may come as a costly trade-off in terms of foregone research.

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Table 1: Research output of Australian universities, annual averages.

Year	All universities Research Quantum $000 (constant prices)	Big seven Research Quantum $000 (constant prices)	Publications index	Publications index big seven	Total enrolments
1995	5012	16818	142	345	12992
1996	5060	16578	149	377	13702
1997	5118	16615	147	361	14349
1998	4934	16222	167	397	14647
1999	4919	15668	201	422	15147
2000	4668	14850	175	480	15331

Table 2: Total research output, post-graduate and under-graduate enrolments

Year	Books	Book chapters	Articles	Conference papers, etc
1995	472	2,345	12,682	4,907
1996	559	2,242	13,248	5,503
1997	358	2,140	14,070	4,008
1998	442	2,632	15,488	4,960
1999	471	2,623	16,017	5,185
2000	400	2,795	16,422	5,040

Table 3: Determinants of Research Output, Australian Universities, 1995 to 1999, (dependent variable = publications index)

Variable	(1)	(2)	(3)	(4)	(5)
Inputs					
RESEARCH INCOME	0.05 (4.44)***	0.10 (1.34)	-0.01 (-0.12)	0.02 (0.20)	0.09 (0.86)
ACADEMIC STAFF	0.11 (7.17)***	1.26 (4.93)***	1.94 (10.72)***	1.54 (7.18)***	1.58 (7.79)***
GENERAL STAFF	-0.02 (-1.16)	-0.03 (-0.12)	-1.91 (-8.43)***	-1.87 (-8.34)***	-1.71 (-5.94)***
RESEARCH INCOME SQUARED	-	0.01 (1.69)*	0.01 (2.91)***	0.02 (4.69)***	0.02 (5.49)***
RESEARCH INCOME * ACADEMICS	-	0.03 (1.71)*	0.12 (5.26)***	0.20 (8.53)***	0.19 (7.80)***
RESEARCH INCOME * GENERAL	-	-0.05 (-3.40)***	-0.24 (-11.49)***	-0.26 (-14.05)***	-0.26 (-13.42)***
ACADEMIC STAFF SQUARED	-	-0.15 (-4.40)***	-0.06 (-2.83)***	-0.05 (-2.39)**	-0.02 (-1.21)
GENERAL STAFF SQUARED	-	-0.01 (-8.87)***	-0.01 (-8.30)***	-0.01 (-11.91)***	-0.01 (-8.37)***
GENERAL STAFF* ACADEMIC STAFF	-	0.09 (2.44)**	0.16 (5.71)***	-0.02 (-0.61)	0.11 (3.25)***
University Size and Post-Graduates					
ENROLMENTS	1.63 (4.08)***	-	-	4.69 (7.09)***	3.86 (7.80)***
ENROLMENTS SQUARED	-0.08 (-4.06)***	-	-	-0.26 (-7.38)***	-0.21 (-7.71)***
POST	-	-	1.61 (5.40)***	0.005 (0.01)	-
POST SQUARED	-	-	-0.16 (-4.91)***	-0.15 (-3.28)***	-
POST* RESEARCH INCOME	-	-	0.09 (5.45)***	0.03 (1.53)	0.01 (1.00)
POST* ACADEMIC STAFF	-	-	-0.40 (-11.49)***	-0.29 (-9.31)***	-0.46 (-19.55)***
POST* GENERAL STAFF	-	-	0.40 (14.16)***	0.60 (18.49)***	0.45 (17.03)***
Other Characteristics					
TIME	0.01 (4.23)***	0.01 (6.13)***	0.03 (22.04)***	0.03 (31.60)***	0.03 (28.37)***
CAMPUS	0.007 (3.61)***	0.008 (4.61)***	-0.002 (-2.47)**	0.004 (3.23)***	0.003 (2.33)**
BIG 7	0.11 (7.59)***	0.13 (8.07)***	0.05 (3.63)***	0.04 (1.49)	0.07 (3.91)***
CAE	-0.05 (-3.80)***	-0.03 (-2.70)***	-0.07 (-5.87)***	-0.05 (-4.10)***	-0.04 (-3.40)***
MEDICAL	-0.02 (-1.37)	-0.02 (-1.76)*	0.05 (3.57)***	0.01 (0.61)	0.00 (0.09)
PUBLICATIONS LAGGED	0.79 (31.76)***	0.78 (31.69)***	0.67 (23.54)***	0.64 (24.01)***	0.66 (24.07)***

CONSTANT	-8.00 (-4.15)***	-4.35 (-5.50)***	-5.83 (-6.14)***	-20.64 (-11.43)***	-17.75 (-8.92)***
Adj R-squared	0.92	0.92	0.92	0.92	0.92
Sample size	175	175	175	175	175

Figures is brackets are t-statistics. *, **, *** indicates statistical significance at the 10, 5 and 1, percent levels, respectively.

Table 4: Short-run Elasticities of Research Output, Australian Universities, 1995 to 1999

Elasticity	Smallest	Sample Mean	Largest
ε_{enrol}	+0.56	-0.08	-0.48
$\varepsilon_{resincome}$	-0.07	+0.10	+0.19
$\varepsilon_{academic}$	+0.28	+0.23	+0.17
$\varepsilon_{general}$	+0.07	+0.04	+0.01

Table 5: Long-run Elasticities of Research Output, Australian Universities, 1995 to 1999

Elasticity	Smallest	Sample Mean	Largest
ε_{enrol}	+1.64	-0.23	-1.42
$\varepsilon_{resincome}$	-0.20	+0.28	+0.57
$\varepsilon_{academic}$	+0.83	+0.67	+0.51
$\varepsilon_{general}$	+0.20	+0.12	+0.03