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The Impact of Higher Education Research and Development on Australian Gross State Product

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ABSTRACT

Recent years have seen a growing interest in research and development in Australia. The Commonwealth Government has responded through the commissioning of a number of reports. Whilst examining the current state of R&D in Australian, these reports have done little to analyse relationship between R&D and Australian output. This paper examines the impact of R&D on Australian state production between 1979 and 1999. Results indicate that both total and higher education R&D are important and significant in generating output. In particular, it is shown that particular types of research contribute more significantly to Australian output.
The Impact of Higher Education Research and Development on Australian Gross State Product.

I. Introduction

The notion that research and development (hereafter referred to as R&D) is an important and vital input into the production process has been emphasised by economists for the last 30 years. Studies by Mansfield (1972), Nadiri (1980) Griliches (1992), to name but a few, have all concluded that R&D expenditure contributes substantially to the growth of output. In theory, R&D has been defined as ‘creative work undertake on a systematic basis in order to increase the stock of knowledge – including knowledge of man, culture and society – and the use of this knowledge to devise new applications’. In practice however, ‘R&D can be conceived as a stock of accumulated knowledge from R&D expenditure, that depreciates… as new products or processes supersede old ones (Mohnen, 1990, p. 4). Furthermore, Coe and Helpman (1995, p.860) note that, ‘an economy’s productivity level depends on its cumulative R&D effort and on its effective stock of knowledge’.

Internationally, the topic of R&D and its impact on productivity has been extensively explored and documented. Reviews by Dowrick (1994) and the Industry Commission (1995) illustrate that Australian studies in this area are limited and have largely been confined to the agricultural and manufacturing industries. In addition to this, the majority of research which has been conducted on this topic has been in the form of case studies as opposed to empirical studies.

In Australia, R&D is conducted by a number of institutions and governing bodies including business enterprise (both by the public and private sector), general government, higher education institutions and private non-profit organisations. The focus of this paper is on R&D conducted by higher education organisations.

In recent years the Commonwealth Government has commissioned a number of reports into the current and future status of R&D in Australia. These reports have included The Virtuous Cycle – Working together for health and medical research (Health and Medical Research Strategic Review, 1999), Knowledge and Innovation: A policy statement on research and research training (Kemp, 1999), The Chance to

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1 OECD (1980)
Change (Batterham, 2000) and Backing Australia’s Ability (Commonwealth of Australia, 2001). While these reports provided a review of current funding levels for various fields of research and have proposed a number of new initiatives for the future of R&D, they have done little to analyse the current impact R&D has on Australian output.

In addition to the possible impact of R&D, numerous other factors affect the performance of the Australian economic landscape such as business cycles, government policies, regulatory reform, world economic conditions etc. Ideally one would like to account for all of these factors such that the regression results provide the truest reflection of the impact on various variables on the Australian output. However, data and measurement issues prevent the vast majority of such factors being accounted for directly. One such factor to be considered in this paper is the effect of industrial relations and deregulation on Australia’s production process. Unions and industrial relations issues in general have been a key feature of the industrial landscape in Australia. For example, the Australian Council of Trade Unions (ACTU) has had a significant impact on economic and social policy in Australia, both through its own actions and through its links with the Australian Labour Party (Brambles, 2001 and Briggs, 2001). Another area of interest in the Australian context is the impact of deregulation of the financial systems on the production process. This has been an extensive process, involving the complete floating of the Australian dollar in 1983 and the removal of most forms of exchange rate controls, the deregulation of the banking sector and the injection of greater competition in banking and financial services. Furthermore, deregulation of other markets and privatisation of a number of government corporations have enhanced the process.

This paper’s main aim is to examine the impact of higher education R&D on Australia’s productivity through a panel data set of six states between 1979 to 1999. The results indicate that both total R&D and higher education R&D have a positive and statistically significant affect on output. In analysing the impact of higher education R&D further, R&D was segmented into the four various types: pure, strategic, applied and experimental. The results indicate that some types of R&D
have a greater impact on Australia’s Gross State Product\(^2\) than others. In particular, pure and applied R&D are shown to have a positive and statistically significant impact on output.

This paper is set out as follows. Section II provides a review of previous research in this area. Section III outlines the estimation procedure undertaken while Section IV presents the source and summary statistics for the data used in this analysis. Section V contains a discussion on the results while concluding comments are made in Section VI.

II. Previous research

The first known regression analyses that linked R&D to productivity were conducted by Terleckyj (1958), Minasian (1962), Griliches (1964) and Mansfield (1965). Terleckyj (1958) used the total factor productivity (TFP)\(^3\) approach which relates R&D intensity to the rate of growth in the residual output over the labour and physical capital used in production. In assessing whether a statistically significant relationship existed between manufacturing industries and other explanatory variables, Terleckyj concluded that the intensity of research may contribute to progress in productivity.

Minasian (1962) examined the impact of R&D expenditure on the productivity of firms. Minasian’s cross-sectional study included eighteen firms in the chemical and allied products industry and five in the drug and pharmaceutical industry between 1947-57. Minasian also used the TFP approach and the results indicated that R&D expenditure was a highly significant independent variable which explained the rate of growth in productivity.

One of the earliest studies to examine the impact of agricultural research on agricultural output was conducted by Griliches (1964). This paper expanded upon earlier productivity work and covered the years 1949, 1954 and 1959, using per farm state averages as its units of observation. Using an unrestricted Cobb-Douglas

\(^2\) Gross Domestic Product or a variant of it (i.e. GNP, value added, growth rate of GDP per worker) has been used to represent productivity by numerous authors including Cuneo and Mairesse (1984), Lichtenberg (1992), Coe and Moghadam (1993) Rogers (2001, 2002).

\(^3\) The multi-factor productivity approach is a variant of the production function. In this method, growth is a function of the R&D intensity (ratio or total R&D expenditure to output). Examples of this method include Goto & Suzuki (1989), Griliches (1994) and Sterlacchini (1989).
production function Griliches concluded that public expenditure on agricultural research had a positive and significant affect on agricultural output.

Mansfield (1965) attempted to expand the growing body of literature by estimating the marginal rate of return from R&D expenditure in individual firms and manufacturing industries. Mansfield’s model assumed that the output rate of a particular firm was a function of labour, the stock of capital and the rate of expenditure on R&D. The model, tested on 10 chemical and petroleum firms and 10 manufacturing industries found that the marginal rate of return for petroleum firms averaged between 40-60 percent, while for chemical firms it was around 30 percent.

Since these early works, there has been an abundance of studies which have assessed the impact of R&D on productivity. Some of the more notable reviews are provided by Mairesse and Sassenou (1991), Nadiri (1993), the Industry Commission (1995), Mairesse and Mohnen (1994) and Mohnen (1996). Furthermore noteworthy contributions were made by Griliches (1979) and Jaffe (1986).

A review of this literature indicates that the broader issue of R&D’s impact on productivity has been explored largely via four themes/approaches being the impact on spillovers and spillovers by location, the impact on innovation and the impact on output. Each of these approaches is discussed in turn.

The impact of university research on productivity has received only scant attention in comparison to the wider attention of research and development in general. However, a review of the literature failed to find many studies which investigate or decompose university research and assess the impact of each type. The closest study found was that of Jaffe (1989). Jaffe’s analysis aimed to examine the production of corporate patents by state over time and relate this to industry and university R&D. The model included 29 U.S. states over the period 1972-1981 and incorporated a breakdown on university research by academic department being (1) drugs and medical technology, (2) chemical technology, (3) electronic, optical and nuclear technology, (4) mechanical arts and (5) all other.

Using a Cobb-Douglas specification, the first Ordinary Least Squares (OLS) regression results (including industry R&D, university R&D and population) reported statistically significant variables for all of the university research elasticities, ranging in magnitude from 0.04 for mechanical arts to 0.28 for drugs. A second regression model included a variable for total university R&D, which was only marginally
statistically significant. A third model was regressed using the Generalised Least Squares (GLS) and this produced better results for both the industry R&D and university R&D variables. Overall Jaffe found that university expenditure on drugs and medical technology produced the statistically strongest effect, while chemical technology ranked second, followed by electronic, optical and nuclear technology. Importantly, Jaffe’s study found that there was only a weak relationship between the location of the R&D spillovers and the location of the university and research laboratories and that spillovers of R&D were limited to specific research areas. Anselin, Varga and Acs (1997, 2000) later disproved the findings on the location of R&D spillovers and the location of university and research laboratories. Based on Jaffe (1989) both papers conclude that R&D spillovers were in fact affected by the location of universities and research laboratories.

Acs, Audretsch and Feldam (1992) provide a comment on Jaffe’s (1989) contribution and conclude that: “the knowledge created at university laboratories spills over to contribute to the generation of commercial innovations by private enterprises”. Acs, Audretsch and Feldam (1994a) examined the degree to which university and corporate R&D spillover to innovative activity at the state level. Their analysis was based on the same data set as Jaffe (1989), however instead of investigating the contribution of university R&D on corporate patents, innovations were introduced as the dependent variable. In justifying the change from patents to innovative activity, the authors noted Griliches (1990) Scherer (1983) and Mansfield (1984) as advocates of the latter.

In essence they stated that measuring the number of patent inventions was not an accurate measure of innovative output. As such, innovative activity was used as the dependent variable, measured by the number of innovations recorded in 1982 by the U.S. Small Business Administration. The paper found that substituting patent data with a measure of innovative activity generally strengthened Jaffe’s (1989) arguments and findings. In fact, unlike Jaffe (1989) the paper concluded that spillovers were infact affected by the geographic location of universities and research laboratories.

Acs, Audretsch and Feldam (1994b) examined the degree to which university and corporate R&D spillover into firms. Their analysis concluded that R&D undertaken by university laboratories spilled-over and impacted upon the innovative activity of small firms, whilst corporate R&D affected larger firms. Sarafoglou & Haynes (1996)
evaluated the contribution of academic departments in Sweden by measuring productivity. In comparing the research output of economics and business departments it was revealed that economics produced 5 times more than the latter. Anselin, Varga & Acs (2000) was an extension of their 1997 paper in which spillovers generated by universities was disaggregated at the sectoral level. The findings concluded that local university spillovers were constrained to specific industries.

The link between research and innovation was examined by Nelson (1986). A survey of research managers concluded that university research was an important source of innovation in some industries. Link & Rees (1990) compared the university based research relationship between small and large firms in an attempt to explain why small firms are more innovative. Their analysis of 209 innovating firms concluded that larger firms were in fact more active in university based research but were unable to exploit this association to the degree achievable by smaller firms. Research by Anselin, Varga and Acs (1997) utilise the knowledge-production function as established by Griliches (1979). With the number of high technology innovations as their dependent variable, the paper found a positive and statistically significant relationship between university research and innovative activity.

In recent years various authors from the Melbourne Institute of Applied and Social Research have contributed papers to a collaborative research program. Many of the earlier paper produced in the program were overview works which set the foundation for later studies.

Fenney and Rogers (2001) compared the performance of firms relative to their innovative activity. The market value of firms (i.e. dependent variable) was assumed to be equivalent to the value of tangible and intangible assets. Tangible assets consisted of balance sheet assets while intangible assets were composed of R&D expenditure, patents trade marks and designs. Following Griliches (1981) a total of three regressions were run. The coefficient values were then used to construct weights and aggregate into a single index. The study concluded that innovation lead to increased firm performance.

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4 The program is entitled ‘The Performance of Australian Enterprises: Innovation, Productivity and Profitability. The papers presented here are a sample of the various working papers generated as part of the program between 1998 and 2002. The majority of working papers utilised the enterprise database of IBIS Pty Ltd for the period 1994 to 1998.

5 Asset data and R&D expenditure variables were sourced from the IBIS Pty Ltd Enterprise database while intangible data (i.e. patents, trademarks and design application) were sourced from IP Australian
Rogers (2001) examined the importance of a set of new absorptive capability proxies in determining economic growth. Under the cross-country regression approach, the study examined the economic growth of 61 countries between 1965 and 1985. With the trend growth in GDP per worker as the dependent variable, Roger added each of the absorptive capacity proxies (20 in total) individually to the baseline regression. The absorptive capacity proxies were grouped under 5 main categories which comprised students studying abroad, telecommunications (i.e. main telephone lines per population) publications (i.e. periodicals published), patents (per thousand worker) and trade data (i.e. imports/export variables). Rogers refrained from assessing the economic impact of the results due to correlation concerns. However, from a theory prospective, the overall results tended to suggest that absorptive capabilities (e.g. patents etc) affected the determination of economic growth.

Rodgers (2002) analysed how innovative activity affected firm profitability in a sample of Australian firms. The study examined innovative activity from 1994 to 1998. Net profit before tax to total revenue was chosen as the dependent variable. In addition to this year dummies were included to capture any macroeconomic trends along with market share, the square of market share and capital intensity. In assessing the impact of innovative activity, the proxy for K (i.e. stock of intangible assets) were R&D, patents and trade mark activity. In essence the regressions revealed that patenting activity was never significantly associated with market value implying that either patent applications were a poor proxy for innovative activity or more important that the stock market failed to recognise such value.

Outside of econometric studies, one of the closest and most recent papers to address the impact of the Australian higher education sector on the economy was Cabalu, Kenyon and Koshy (2000). This paper calculated the ‘market cost’ of producing university R&D. It measures the direct contribution of research to the economy and ignores the social benefits of the research.

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6 The majority of the data was sourced from UNESCO for various years between 1960 –1965. Other data sourced included the Intentional Telecommunications union database, the Economic International Data Bank, the World Industrial Property Organisation and the Penn World Table.
7 Data sourced from IBIS Pty Ltd Enterprise
8 The inclusion of these variables was justified in the basis that they are motivated by SCP studies.
Unions

As noted above, Australia’s productivity is influence by general economic conditions, one such factor being the impact of unions. Controversy surrounds the impact of unions on productivity, as well as other aspects of business such as profitability and investments. Unions may be viewed as a having ‘two-faces’. (Freeman, 1976, Freeman & Medoff, 1984). On the one hand unions are able to increase wage levels and impose employment restrictions, however unions are also able to increase productivity levels through strengthening communication between management and employees. A limited number of studies exploring the impact of unions on productivity have been conducted (Alexander & Green: 1992, Drago & Wooden: 1992, Drago, Wooden & Sloan: 1992 and Phipps and Sheen: 1994). However due to data constrains, none of these studies are comparable.

Terleckyj (1974) was one study which examined the impact of both R&D and unionisation on productivity. The data set was composed of 33 manufacturing and non-manufacturing industries between 1948-66. Terleckyj’s study reported a negative and significant correlation between productivity growth rates for the 33 industries and the relative share of industry workers who were union members. Rogers (2000) also briefly address the issue of unions. Under probit regressions, union presence was represented by a dummy variable. The results indicated that firms with unions had a higher probability of reporting to be innovative.

Deregulation

Deregulation measures are also noted above as forming part of the economic variables which influence national performance and productivity. The floating of the Australian dollar in 1983 followed by the removal of a number of regulatory measures (e.g. exchange rate controls, deregulation of the banking sector) along with the privatisation of numerous government corporations are all examples of deregulation within the Australian economy. These events have significantly impacted the structure of the economy and as such their inclusion is warranted. A review of the literature indicates that whilst the impact of deregulation on specific industries has been explored, the impact on the Australian economy has not been investigated. Industry specific

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9 Importantly this means that flow variables were used to proxy what should be stock variables.
studies include Doucouliagos & Hone (2000) who investigated the impact of deregulation on the Australian dairy processing industry and Lie, Brooks & Faff (2000) who examined deregulation within the Australian financial sector. These studies do not however explore R&D, and industrial relations issues or do they explore the impact of deregulation on Australia’s productivity.

III. Estimation Procedure

Previous research has focussed on spillovers from R&D or the location of R&D. The focus of this paper is on the actual performance outcomes of Australian university R&D, an area which until now, has been largely ignored in the literature. The analysis in this paper uses the basic Cobb-Douglas specification of the production function, relating the quantity of output to the inputs used in the production process, including R&D. In following with previous studies research capital is introduced as a third input (Terleckyj: 1974, Griliches: 1973, Coe and Moghadam: 1993).

Econometric studies that have applied this method include Coe and Helpman (1995), Griliches and Mairesse (1984) and Nadiri (1980). The production function to be estimated is expressed as:

\[
\ln(Y_i) = a + \beta_1\ln(L_i) + \beta_2\ln(K_i) + \beta_3\ln(T_i) + \beta_4\ln(P_i) + \beta_5\ln(S_i) + \beta_6\ln(A_i) + \beta_7\ln(E_i) + \beta_8\ln(U_i) + \beta_9D + u_i
\]

where \(Y\) is Gross State Product, \(L\) is employment, \(K\) is the stock of physical capital\(^{10}\), \(T\) is the stock of total R&D capital (not including the stock of higher education R&D), the stock of higher education R&D is disaggregated into four major categories: pure (P), strategic (S), applied (A) and experimental (E)\(^{11}\), \(U\) is union density, \(D\) is the deregulation variable, \(u\) is the residuals and the subscript \(i\) is an index for each state\(^{12}\). It

\(^{10}\) See Section IV for a description of the methodology used to generate stock data.

\(^{11}\) A definition of each category is provided below in Section IV.

\(^{12}\) It is important to note that the use of output as the dependent variable has the adverse affect of creating simultaneity bias. Output may be assumed to depend on R&D stocks, however investment in R&D must to some expend depend on income levels past and present. The issue of simultaneity has been addressed by authors such as Marschak and Andrews (1994) and Olley and Pakes (1996). In essence, when confronted with a serial correlation over time, this implies that there is an unobservable variable which is a factor of both input choices and output values. Traditionally this issue is dealt with by assuming that there is a one
is logical to assume that the production process is the same across each Australian state. Hence, it is assumed that the variables of labour, capital stock, total R&D stock and higher education R&D stock will have the same coefficient in each state\textsuperscript{13}.

The regression analysis was conducted under three different estimation techniques\textsuperscript{14}. First, OLS was used. In order to test for the presence of heteroscedasticity in the residuals, White’s test (White 1980) was conducted. The results indicated that heteroscedasticity was a problem. Accordingly, the model was re-estimated using Generalised Least Squares (GLS) with cross sectional weights. GLS is recommended where cross sectional heteroscedasticity exists and where the residuals are contemporaneously uncorrelated. A third model, Seemingly Unrelated Regression (SUR) was estimated. This approach produced the preferred results. According to Beck & Katz (1995) this approach is valid when contemporaneous correlation is present and is excess of 0.50 and when the time span is at least three times greater than the number of cross sections. Both of these prior conditions are met in this analysis.

Preliminary testing of the data set was conducted and revealed the existence of serial correlation amongst the residuals of the model. In order to correct for this, each model was estimated with the addition of an AR(1) process. Equation (1) above does not include a time trend, which is usually incorporated to represent disembodied technical change. In this paper, R&D is used instead of a time trend as R&D is a better measure of technical change than a simple time counter\textsuperscript{15}.

IV. Data

The data used in this analysis was primarily sourced from the Australian Bureau of Statistics (ABS) for the six Australian states of New South Wales, Victorian, Queensland, Western Australia, South Australia and Tasmania between to one relationship between the unobserved serially correlated variable and the investment conditions affecting the observable variables. One solution hence would be to estimate a model which allowed for separate effects of R&D on output and also investment. This in turn would possibly require the inclusion of additional observable variables.

13 Similar assumptions were made by Acs, Audretsch & Feldman (1994a, 1994b), Anselin, Varga and Acs (1997), Griliches (1964) and Jaffe (1989).
14 In following with Jaffe (1986).
15 Preliminary results revealed that the inclusion of a time trend caused both the time trend and the R&D variable to become statistically insignificant. As a result the time trend was omitted from the analysis. Similar problems were encountered by Nadiri (1980).
1979\textsuperscript{16} and 1999. Due to a lack of data, the regions of Northern Territory and ACT were eliminated from the analysis. Hence, this paper constructs a panel data analysis of six states and the twenty-one year span, comprising in total of 126 observations.\textsuperscript{17} The resulting expenditure data is useful in providing an understanding of the level of funding or prominence of a particular activity. However, what is of more importance is the stock of knowledge generated by the R&D. In the absence of a stock series from the ABS, stock data\textsuperscript{18} was constructed for four variables being physical capital, total R&D, higher education R&D and the four various types of higher education R&D being pure, strategic, applied and experimental. The variables used in this regression are defined and sourced as listed below. The definitions of the variables used are as follows:

**Output**: measured as Gross State Product (GSP) and deflated into constant 1997-98 dollars using the associated Gross State Product deflator. (ABS, Cat. No 5220.0)\textsuperscript{19}

**Labour**: measured as the total number of workers employed in each state (ABS Cat. No.5242.0).

**Union density**: Trade union membership data is available in two separate ABS publications being Trade Union Members, Cat No, 6325 and Trade Union Membership, Cat No. 6323. The Australian Bureau of Statistics advises that the first listed source provides a more accurate representation of union membership figures as

\textsuperscript{16} Initial year the Australian Bureau of Statistics commenced collecting R&D expenditure data.

\textsuperscript{17} It is important to note that the Australian Bureau of Statistics provides data on R&D expenditure in Australia only biannually. In the absence of complete data, an average of the two years was taken for missing years data. Similar methodology was utilised by Olley and Pakes (1996). Rogers (2002) notes that viable alternative when confronted with unbalanced panel data is to retain the time series dimension and use fixed effects models or use a between estimator.

\textsuperscript{18} Stock data is a more accurate measure as it takes into consideration the depreciable/obsolete nature of R&D and provides a more accurate representation of the level of R&D.

\textsuperscript{19} As noted by Rogers (1998) “output should be defined as real output produced in a set time period”. Australia’s Gross State Product (GSP) is one measure of the nation’s productivity or output level. This measurement variable was selected due to the availability of a constant data series from the ABS. The author acknowledges that GSP is influenced by a myriad of factors including general economic conditions, government policies, regulatory reforms etc. However in the absence of a consistent and complete time series (i.e. patent counts per state only goes as far back as 1980 and even then the data is only an estimate) the data appears to be a reasonable measure. Refer to footnote (2) a list of various authors to have used Gross Domestic Product or a variant.
it is based on a survey of the labour force. As data was not available for all years, a union density series was constructed by applying the ratio of trade union members to trade union statistics for missing years.

**Deregulation:** In the last two decades the Australian economy has experienced a process of deregulation in various industries through tariff reductions and industry protection. As there is no index available on deregulation in Australia, the focus of this paper is on the post 1983 period during which the majority of the deregulations were implemented. Hence, the floating of the Australian dollar and financial deregulations are accounted for through a dummy variable equivalent to zero for the years between 1979 and 1983 and one for the years 1984 to 1999.

**R&D Stock:** The stock of R&D was calculated for the variables of total R&D, higher education R&D and the four types of R&D conducted by higher education organisations being, pure strategic, applied and experimental. The stock of R&D for each of these variables was calculated using the perpetual inventory method (PIM) as used by Coe and Helpman (1995). Under the PIM, R&D capital stock in any period is a function of the value of the R&D capital stock in the previous period, less any depreciation that has occurred plus the level of R&D expenditure in the previous period\(^{20}\). The PIM also requires the calculation of an initial stock of capital which is based on the growth of R&D and the assumed rate of depreciation\(^{21}\). These calculations were conducted assuming that R&D expenditure depreciates at the rate of 10 percent per annum. According to Griliches, (1979) a rate of 10 percent was appropriate given that most private knowledge becomes obsolete after ten years. This rate was also supported by Mohnen, Nadiri and Prucha (1986) in their analysis of manufacturing sectors in the US.

\[ S_t = (1-\delta) S_{t-1} + R_{t-1} \]

where:  
- \( S_t \) = the stock of R&D capital at the beginning of the period
- \( S_{t-1} \) = the stock of R&D capital at the beginning of period \( t-1 \)
- \( R_{t-1} \) = the expenditure on R&D during the period
- \( \delta \) = the depreciation or obsolescence rate of knowledge

\[ S_0 = \frac{R_0}{(g + \delta)} \]

where:  
- \( S_0 \) = the stock of R&D capital at the beginning of the first year for which R&D expenditure data is available.
- \( R_0 \) = the expenditure on R&D during the first year for which it is available.
- \( g \) = the average annual logarithmic growth of R&D expenditures over the period for which published R&D data were available, in this case 1978-79 to 1998-99.
- \( \delta \) = the depreciation or obsolescence rate of knowledge, in this case 10 percent.
Japan and Germany and Bernstein (1989) in his analysis of inter-industry spillovers in Canada. Moreover, preliminary testing of the panel data in this analysis using depreciation rates of 8 and 15 percent did not alter results significantly. Hence, the stock series for total R&D, higher education R&D and the four various types of R&D conducted by higher education organisations are derived using a depreciation rate of 10 percent. (Expenditure figures for total R&D were extracted from ABS, Cat. No. 8111.0 whilst figures relating to higher education R&D were sourced from ABS, Cat No. 8112.0)

**Pure:** encompasses theoretical and empirical work undertaken for the fundamental advancement of knowledge.

**Strategic:** an extension of pure research and is geared towards specified broad areas with the expectation of fruitful discoveries

**Applied:** research is undertaken so as to attain knowledge relevant to a specific area.

**Experimental:** a systematic process, whereby new or improved products or processes are evolved using existing knowledge.

**Capital:** The Perpetual Inventory Method (PIM) was also used to calculate the stock of physical capital. It was assumed that the asset life of plant and equipment was 12 year while buildings would last 40 year\(^{22}\). The stock for these two variables was calculated separately and combined to represent the stock of physical capital. (Expenditure figures extracted from ABS, Cat. No. 5242.0)

Summary Statistics for the data used in this analysis is presented in Table 1.

<table>
<thead>
<tr>
<th>Table 1: Descriptive Statistics of Panel data original values, 1979-1999</th>
<th>NSW</th>
<th>QLD</th>
<th>SA</th>
<th>TAS</th>
<th>VIC</th>
<th>WA</th>
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<td><strong>Gross State Product</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>147902</td>
<td>62598</td>
<td>30519</td>
<td>9658</td>
<td>111219</td>
<td>41433</td>
</tr>
<tr>
<td>Std.Dev</td>
<td>31256</td>
<td>16618</td>
<td>5389</td>
<td>1471</td>
<td>18523</td>
<td>11985</td>
</tr>
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<td>1214</td>
<td>605</td>
<td>184</td>
<td>1890</td>
<td>693</td>
</tr>
<tr>
<td>Std.Dev</td>
<td>253</td>
<td>241</td>
<td>44</td>
<td>12</td>
<td>175</td>
<td>119</td>
</tr>
</tbody>
</table>

\(^{22}\) Bureau of Industry Economics (1995)
V. Results

A number of models were estimated using variations of Equation (i) as outlined above. Results of the regression analysis under least squares are presented in Table 2\(^{23}\). In addition to the OLS method, the regression analysis was also estimated using the Generalised Least Squares (GLS) and the Seemingly Unrelated Regression (SUR) methods. For each model the coefficient and t statistic of the relevant variables are presented. In all cases the reported standard errors are heteroscedasity consistent, while the t-statistics were tested at the 5 percent critical level.

Table 2: Least Squares Production Function Parameter Estimates for Model 1 to 3.

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coeff</td>
<td>t-stat</td>
<td>coeff</td>
</tr>
<tr>
<td>Constant</td>
<td>2.730</td>
<td>5.775</td>
<td>2.837</td>
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<td>Capital Stock</td>
<td>0.247</td>
<td>3.317</td>
<td>0.228</td>
</tr>
<tr>
<td>Labour</td>
<td>0.691</td>
<td>11.500</td>
<td>0.691</td>
</tr>
</tbody>
</table>

\(^{23}\) All of the regression analysis was performed using Eviews 3.1
Model 1 is a basic Cobb Douglas production function in which capital stock, labour and total R&D stock were found to be positive and statistically significant suggesting that as a collective variable, total R&D in Australia is an important input into the production process. Similar results were reported for Model 2 which replaced the total R&D stock variable with the stock of higher education R&D. Higher education R&D was disaggregated into the four major categories in Model 3 with the aim of highlighting which types of R&D are the most productive. The results indicate that both pure and applied stocks of R&D are closer to being statistically significant than strategic and experimental R&D.

In following with Jaffe (1986) Model 3 was re-estimated using Generalised Least Squares incorporating cross-sectional weights and also under the preferred SUR or Seemingly Unrelated Regression. Results for the Model 3, which is the complete specifications of Equation (i) are presented in Table 3. The most noticeable improvement under the GLS model was the increase in the t-statistic for total less higher education R&D from 1.436 to 1.909 thus making it significant at the 10 percent level. Further improvements were noted in the applied stock of R&D (up from 1.597 to 2.068) and the stock of experimental R&D (up from 0.863 to 1.326).

The preferred SUR model indicates that both the stock of pure R&D and applied R&D have a statistically significant impact on the Australia’s gross state product with t-statistics of 2.555 and 2.324 respectively. Union density data has a negative and statistically significant coefficient. The deregulation variable has a positive coefficient and is also statistically significant across all models.
Table 3: Results for Model 3 under the GLS and SUR

<table>
<thead>
<tr>
<th></th>
<th>GLS</th>
<th>SUR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coeff</td>
<td>t-stat</td>
</tr>
<tr>
<td>Constant</td>
<td>2.732</td>
<td>4.444</td>
</tr>
<tr>
<td>Capital Stock</td>
<td>0.239</td>
<td>3.190</td>
</tr>
<tr>
<td>Labour</td>
<td>0.649</td>
<td>12.434</td>
</tr>
<tr>
<td>Total less Higher Ed</td>
<td>0.229</td>
<td>1.909</td>
</tr>
<tr>
<td>Pure Stock</td>
<td>0.159</td>
<td>1.224</td>
</tr>
<tr>
<td>Strategic Stock</td>
<td>-0.046</td>
<td>-0.328</td>
</tr>
<tr>
<td>Applied Stock</td>
<td>0.344</td>
<td>2.068</td>
</tr>
<tr>
<td>Experimental Stock</td>
<td>0.340</td>
<td>1.326</td>
</tr>
<tr>
<td>Union Density</td>
<td>-0.045</td>
<td>-2.309</td>
</tr>
<tr>
<td>Deregulation</td>
<td>0.063</td>
<td>4.401</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.848</td>
<td>23.764</td>
</tr>
</tbody>
</table>

The preferred sets of results are based on the SUR approach. This is recommended when there is cross-section heteroscedasticity as well as contemporaneous correlation. In this set of results, the coefficients on the labour and capital inputs and the private sector R&D all have the expected positive sign. Pure and applied university R&D also have positive coefficients. These output elasticities indicate that university R&D has a positive impact on state output. Strategic and experimental R&D appear to have no impact at all on state output.

Note that the higher education R&D has more of an impact on state productivity than the private sector. The results indicate that larger coefficients were recorded for the various types of R&D undertaken by the higher education sector (i.e. pure research and applied research) compared to R&D undertaken by the private sector (noted as the total R&D less higher education variable). Given these results, it is beneficial to briefly examine the relative share each of the four types of higher education R&D actually accounted for between 1979 and 1999. Data for selected years is presented in Table 4.

Table 4: Relative share of Higher Education R&D expenditure by type, selected years
Statistics indicate that over the 1979-1999 time period the relative share of pure R&D undertaken by the higher education section has actually decreased. To counterbalance this decline, there has been a corresponding increase in the amount of strategic and applied R&D conducted. In light of the results presented here, there is reason to suggest that higher education sectors should shift the focus away from experimental and particularly strategic research and towards pure and applied research areas, which have a positive impact on Australia’s overall productivity.

The results presented here also indicate that deregulation had a favourable impact on state output. State output is about 8 percent higher in the post deregulation period. The negative coefficient on unionisation indicates that unions in Australia had a negative impact on state output. A 1 percent increase in union density is associated with a 0.05 percent reduction in state production. This suggests that the decline in union density experienced in Australia has had a favourable impact on state production.

VI. **Concluding comments**

The importance of R&D to the production process has long been a source of considerable discussion and evaluation. Numerous international studies have highlighted its contribution to productivity and have concluded that is a source of economic growth. A review of Australia literature in this field reveals that relatively little has been written on the topic outside of agriculture and manufacturing industries. Furthermore, to date, the impact of higher education R&D on Australian productivity has been an area which has been largely ignored.
Recent years have seen a growing interest in the future of R&D in Australia, largely through the commissioning of papers by the Commonwealth Government. This paper has examined the impact of R&D and in particular that conducted by the higher education sector through a basic Cobb-Douglas production function. The results confirm that, in addition to capital and labour, R&D is an important and vital input in the production process.

Analysis of the four types of R&D conducted by higher education organisations revealed that under the preferred Seemingly Unrelated Regression estimates both pure and applied R&D were found to have a statistically significant impact. These results suggest that higher education organisations should focus towards these two types of R&D as they produce the most beneficial results and subsequently impact upon Australia’s gross state product. However, it is possible that other types of R&D, such as experimental may have payoffs, in that they may assist with applied R&D.

Statistics indicate that over the last two decades the majority of research undertaken by the higher education sector in Australia has been in the form of pure basic research. However, its relative share has decreased from over half of all research during the 1980s to just a third of total higher education research by the late 1990s. The decline in pure basic research has largely been to support increased strategic research. The relative share of strategic research during this period was reported to have experienced moderate gains. Given the positive impact these pure and strategic research have on state productivity, greater allocation of resources should be devoted to them, whilst focusing less on the other R&D types such as strategic and experimental.

The economic and institutional changes experienced by the Australia economy have received little empirical analysis. In this paper, the decline in union density was explored and it was shown that over the period studies, unionisation had a consistently negative impact on State output. Hence the decline in union density over the period has increased state output. This paper has not however examined the other effect of unions such as provision of benefits to employees, safety in workplaces etc. These issues need to be addressed and are for future research.
The impact of deregulation was explored also and it was found that the deregulation of the financial sector had a positive effect on State output. This is in line with the predictions made by macroeconomic theory.

The Australian Government has indicated that it is keen interest to accelerate investment in R&D. The results presented in this paper suggest that the focus should be directed towards R&D conducted by higher education organisations. In particular, given the positive impact these two forms of higher education R&D have on state productivity, policy makers should ensure that greater emphasis is place on pure and applied R&D.
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