RESOLVING THE PRODUCTIVITY PUZZLE: A REVIEW OF THE DETERMINANTS OF RESEARCH PRODUCTIVITY

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1. Introduction

The purpose which underlies the measurement of performance is its improvement. Central to this purpose are the devising of appropriate performance indicators and an understanding of the major determinants of performance. The first of these has been dealt with elsewhere (Harris 1994a) and the purpose of this paper is to review a range of studies which have investigated variations in research productivity, both between individuals and between groups of researchers. Variation between individuals, it should be noted, is far greater than between groups or departments.

2. Explanations of the variation in research productivity

According to Gaston (1978.133), the enormous variation in scientific productivity, including publications, reputations and recognition, between individuals is 'one of the most difficult and perplexing problems in the sociology of science'. Gaston goes on to survey many studies which report this phenomena and, sometimes, try to provide explanations for it (1978.133ff). In particular, he reports Derek Price's (1963.43) conclusion, based on the inverse square law of Lotka (1926):

> The number of people producing n papers is proportional to $1/n^2$. For every 100 authors who produce but a single paper in a certain period, there are 25 with two, 11 with three, and so on.

Studies concerned with explaining variation in research productivity between departments are of two types: there is a sparse literature dealing with academic departments, and there is an extensive literature, emanating from the sociology of science sub-discipline, which covers U.S. science laboratories, departments and centres in the 1960s and early 1970s, and subsequently examines university departments across many disciplines.

It is useful at this point to consider the relevance of U.S. studies to the Australian context. The Australian university system is based firmly on the U.K. model and differs significantly from that of the U.S. Lecturers' salaries are fixed across universities by rank, with tenure the norm and, relative to the U.S., easy to obtain. There is also far less competition between individuals and universities than in the U.S., where institutions are also differentiated according to whether their funding is private or public in origin. In the U.K. and Australia, universities are basically funded by the central government. It is likely, therefore that U.K. studies would be the most relevant although there is only one UK study of determinants (Johnes 1988) of which I am aware.

There are two fairly recent reviews of the literature on determinants of research productivity (Fox 1983; Cresswell 1985). Both are concerned with explanations of differential productivity between individuals, rather than departments. Fox breaks up the explanations into individual-level variables (psychological characteristics, work habits and demographic characteristics, particularly age), environmental location variables (graduate school background, prestige of department/institution and other organizational variables, particularly the amount of freedom) and feedback processes (cumulative advantage and reinforcement). Cresswell covers a similar range, but gives less attention to the environmental variables.

In general, psychological variables such as 'degree of commitment to science ..., activities as a child dealing with scientific ideas and problems, ability to solve problems in general, a burning desire to be famous as a scientist [etc] ...' (Gaston 1978.66-67) are notably absent from most studies.[1] There may be several reasons for this. First, such variables are notoriously difficult to measure and their combination varies considerably between individuals. Second, Fox (1983.288) points to two shortcomings of concentrating on individual, and especially psychological, characteristics. She considers it questionable whether ability and talents are a sufficient explanation of the very wide variations in productivity because, no matter how ability is measured, ability is not as skewed as productivity.[2] In addition, personality traits are influenced by the social and organizational contexts in which they are located.

Gaston (1978.141) sums up the evidence on the correlates of scientific productivity as follows. First, there are generally small positive correlations between individual characteristic variables (e.g. age, time devoted to research, research versus teaching orientation). Second, there are small - medium correlations between variables measured by 'their connections to scientists' (e.g. the quality of their undergraduate or Ph.D. departments, eminence of Ph.D. supervisors, prestige of current department). For some of the variables, e.g. prestige of department, it is not altogether clear which precedes and which succeeds productivity, and many correlations are reduced when controls are introduced. As an overall statement, the superior productivity of scientists in high prestige departments is a consequence of their superior skills and greater motivation to do research.

A comment on motivation is in order at this point. It is generally accepted that academics are motivated to carry out research principally for the intrinsic rewards (e.g. enjoyment) rather than extrinsic rewards. Among the many studies which could be cited here are Richard Startup's longitudinal studies of one provincial U.K. University (Startup and Gruneberg 1976; Startup 1985), Pelz and Andrews' (1976) studies of U.S. science laboratories (see section 3), McKeachie's (1979) study of U.S. academics from a psychological perspective, Ingrid Moses'

1 For a discussion of the idea that exploratory behaviour in childhood is an important determinant, via 'motivational style', of adult achievement in science, see Steinkamp (1984). The underlying interest of this article is to explain gender differences in scientific productivity.

2 For example, Cole and Cole (1973.69) found a correlation of only 0.05 between measured IQ and number of papers published by their sample of 499 scientists. See also Gaston (1978.18).

(1986) study of one Australian university and the fact (see section 4.3) that research productivity is maintained after promotion or the granting of tenure.[3] Katz and Kahn (1978.405-425) suggest three possible individual motivations: rule enforcement, where individuals are required to comply or face sanctions; external rewards, which may be system-wide (e.g. payment according to length of service) or individual (e.g. payments based on merit); and internal motivation. If the first or second (system-wide) dominate, a minimum effort may be expected: if individual external rewards are important, then the structure of incentives and rewards is crucial; and if individuals are internally motivated, they may continue to research regardless of rewards.

Most studies of academics suggest that they are principally motivated by intrinsic rewards.[4] Startup's (1985) study of UK academics, for example, found that enjoyment was reported as the primary motive for research by 95.7 per cent of his respondents. Behymer, cited by Finkelstein (1984.97), found that 'intrinsic' factors, which includes interest in research and interaction with research-oriented colleagues, rather than extrinsic factors such as perceived pressure to publish, were the most salient predictors of productivity. Finkelstein (1984.97) concluded that 'it would appear that colleague climate as reflected in institutional prestige together with an individual's own orientation toward research are the prime determinants of publication activity.[5] Fiona Wood's (1990) study is of particular interest, examining the research activity of a small number of Australian academics using in-depth interviews. She found that academics explained differences in individual research productivity largely in terms of 'differences in ability, energy, creativity, motivation, ambition and self-discipline' (1990.84). They also reported that differences in fields of research within a discipline (e.g. short term versus long term, theoretical versus applied, local versus international) also explained differences in productivity between individuals.

From his review of the literature, Finkelstein (1984.98) produced a 'composite portrait' of the productive US faculty member. He/she:

1. Holds the doctorate
2. Is strongly oriented toward research
3. Began publishing early, perhaps prior to receipt of the doctorate and received 'recognition' for scholarly contributions ...
4. Is in close contact with developments in his or her field via interaction with colleagues and keeping abreast of the literature

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3 At a more theoretical level, other relevant books include Hertzberg (1973), McKeachie (1979), Andrews (1979.253-289) and Katz *et al* (1980).

4 See also the Williams Report (1979), Soliman *et al* (1984) and Everett and Entrekin (1987) for further evidence on the motivation of Australian academics.

5 'Colleague climate' in this study was measured by the proportion of colleagues holding a doctorate.

5. Spends more time in research, less time in teaching, and is not overly committed to administrative chores

Finkelstein concludes that while individual predispositions can be reinforced by colleague climate, both at the institutional and at the departmental levels, it is relatively impervious to the influence of other extrinsic factors.

It is important to recognise that extrinsic rewards, including promotion, positive feedback from colleagues etc, probably strengthen intrinsic motivation. Whilst it is probably true that researchers with the inner compulsion to carry out research - termed the 'sacred spark' by Cole and Cole (1973.115) - would continue to carry out research without extrinsic rewards, it is also true that positive and consistent rewards are valuable. Moses (1986) found that whilst Australian academics were 'mainly intrinsically motivated' (1986.145), around half stated that the promotion system influenced their attitudes to teaching and research. Extrinsic rewards can be intangible (e.g. positive comments by colleagues, being cited) or tangible (e.g. promotion), although Moses (1986.138) does warn of the dangers of increased competitiveness and of an over-emphasis on evaluation which can accompany extrinsic rewards.

In this paper, explanatory variables are broken up into individual, departmental and institutional levels (see Table 1). The second and third of these correspond with Fox's 'environmental location variables'. Cumulative advantage and reinforment are treated separately.

This breakup is artificial: if a person's age, gender or tenure has an influence on their productivity, a department skewed towards people of one gender, tenure or age group will therefore have different average productivity. Generally speaking, whilst an individual can do little to change some characteristics (e.g. age/gender), there are others (e.g. work habits, efforts to secure funding, field of research) over which some influence can be exercised. Individuals are influenced by the environment and the incentives provided by the their department and university although it should be noted that they can influence this environment. Some of the departmental variables are also listed under the university heading: the management style in a department may partly reflect the inherited style and the personality of the head; it may, however, be influenced by the university's ethos as to the role of heads of departments. Similarly, incentives and research funding are partly a departmental matter but are influences by university-level decisions as well. This is also true of student:staff ratios and secretarial assistance. Departments and universities have control over some variables (e.g. over size of departments) but little over others (e.g. organizational levels, insofar as these are imposed from outside). Some variables, which are difficult to classify, appear in more than one category.

Table 1: Variables explaining research performance

Individual level
- Psychological factors:
  - intelligence
  - personality
  - response to reinforcement
  - motivation
  - work habits
- Age
- Gender
- Rank
- Tenure
- Educational background
- Highest degree
- Prestige of first appointment
- Eminence of Ph.D. supervisors
- Field of research

Departmental level
- Freedom
- Management style
- Research funding
- Size of department
- Prestige of department
- Reward structure

Institutional level
- Size of university
- Public or private institution
- Management style
- Research funding
- Number of organizational levels
- Reward structure

Other
- Cumulative advantage
- Reinforcement

Two other explanations for different levels of research activity, which appear separately in the table, are cumulative advantage and reinforcement. The former occurs when strong research performance is rewarded in various ways which enhances further strong research, and vice versa. The advantage typically commences with graduation from a well regarded department/university and an eminent mentor which, irrespective of actual productivity (Long 1978.905), lead on to a post in a prestigious university with adequate resources for research and opportunities to interact with productive colleagues. Cumulative advantage has been linked to the 'Matthew Effect' identified by Merton (1968), which states that those who are already well off shall be given more, whilst those with little shall lose what little they have.[6] Merton's

6 Based on the Gospel of Matthew ch. 13, verse 12 and ch. 25, verse 29.

original emphasis, it may be noted, was more specific. He found that disproportionate credit was given to the eminent scientist in cases of joint authorship or collaboration, and in cases of 'independent multiple discoveries' made by scientists of distinctly different rank (1968.443). The greater recognition given to academics of greater repute can then be converted into resources to support further research.

The processes of individual self-selection and institutional social selection feed on each other, providing some individuals with relatively greater opportunities. The continued operation of this process tends to result in the formation of classes of academics ranked according to prestige in terms of perceived productivity.[7]

Cumulative advantage - in terms of the flow of resources and the prestige of departments - can be distinguished from reinforcement, although they have a common base in the Matthew Effect.[8] Reinforcement refers to feedback of various kinds, including having articles accepted for publication, being cited and being praised by colleagues; extrinsically it may occur by receiving promotion and tenure. All act as affirmations of the individual's worth and to the value of his/her research, and stimulate further productive activity. Whilst testing for the presence of reinforcement, like cumulative advantage, is difficult, a number of studies have found strong positive correlations between the number of citations received by scientists early in their career and their later productivity (e.g. Cole and Cole 1973, Blackburn *et al* 1978, Reskin 1977, 1978a and Cole and Zuckerman 1984). Direct assessment of cumulative advantage required data on the research resources available to individual academics, which is difficult to assemble. More basically, however, it is virtually impossible to control for initial differences in individual talents and motivations, known as the heterogeneity explanation of productivity differences. Results which support the importance of cumulative advantage can also be used to support the heterogeneity hypothesis.

Allison and Stewart (1974) studied cohorts of scientists to determine whether the distribution of productivity became increasingly unequal as the cohort ages, as one would expect, if cumulative advantage applied. They found strong linear increases in inequality, with respect to the number of publications and citations, for chemists, physicists and mathematicians, but not for biologists.[9] They explicitly state (1974.605) that while their results support the cumulative advantage hypothesis, it does not disconfirm the heterogeneity hypothesis. Gaston's (1978)

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7 One possible explanation of this (Long 1978; Long and McGinnis 1981) is that the 'organisational context' in which researchers work strongly influence their productivity.

8 Gaston (1978.144) suggests that reinforcement explains **why** scientists continue to be productive and that cumulative advantage explains **how** some scientists obtain the resources which lead to successful research. He further observes that whilst there can be positive reinforcement without cumulative advantage, there cannot be cumulative advantage without prior positive reinforcement.

9 They suggest (1974.605) that the 'relatively low consensus and poor communication' in biology inhibited the allocation of rewards and resources according to merit.

study of 600 U.S. and U.K. scientists discovered an almost perfect linear relationship between time and increased variability of research productivity (1978.149). How could this be explained? He found some evidence to reject the heterogeneity hypothesis, in which case cumulative advantage became a more likely explanation. In discussing reinforcement, incidentally, he found that the act of publishing and immediate, informal recognition from colleagues were more important as reinforcements than citations, which come later. This view is supported by Reskin (1977).

Finally, as Fox (1983.296) notes, the cumulative advantage hypothesis raises the issue of the extent to which limited research resources are allocated on the basis of actual achievement versus 'ascribed characteristics unrelated to performance'. Almost certainly, resource allocations will be unequal: if they are allocated according to achievement, as opposed to other criteria, the advance of knowledge will be promoted.

3. Studies from the sociology of science

We have noted that a number of studies which bear on research productivity were carried out by sociologists examining U.S. science laboratories. Many of these studies stand in the tradition of Robert Merton, formerly Professor of Sociology at Columbia University, whose influence dates from the late 1950s. Merton's principal interest was with the recognition and reward system devised by science 'to give recognition and esteem to those who have best fulfilled their roles, to those who have made genuinely original contributions to the common stock of knowledge' (Merton 1957.640).[10] Among those researchers nurtured under Merton were Harriet Zuckerman, Diane Crane and Stephen and Jonathan Cole (*Social Stratification in Science*, 1973). Many others, including Warren Hagstrom and Gerry Gaston (*The reward system in British and American Science*, 1978), were strongly influenced by Merton and his associates.

Cole and Cole (1967) were particularly interested in the relationship between the quantity and quality of research output, and how these were related to the recognition/reward system in science. Their sample comprise 120 U.S. university physicists amongst whom, they admitted, eminent scientist were heavily over-represented. They distinguished four types of researchers

- prolific researchers (who made up 33% of their sample), who scored highly on both quantity and quality.[11]
- mass producers (12%), who scored high on quantity but low on quality.

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10 For a collection of Merton's major articles, see Merton (1973).

11 Quantity was measured by number of published papers; quality was measured by the average number of citations to the researchers of three most cited years, weighted according to their time distribution.

- perfectionists (18%), who produced relatively little, but whose production was of high quality.
- silent researchers (37%), who produced little and were cited little.

The Coles identified three types of reward in physics: honorific awards, including memberships of honorific societies 'positions in top ranked departments' and the opinions of peers. They found that research quality, as measured by citations, was consistently more highly correlated with these rewards than was research quantity. Whilst quantity and quality were certainly correlated, where there is inconsistency, as with mass producers and perfectionists, then quality was more correlated with recognition than quantity. In other words, it is significant research which matters, whether from high or low output producers.

In the mid-1960s, the theoretical base of Merton began to blend with a more practical, management-oriented approach, exemplified by the work of Donald Pelz and associates. Pelz and Andrews published *Scientists in Organisations* in 1966, which was reprinted with additions in 1976. In this book, there was a particular concern to determine how three factors - individual motivation, group structure and organizational processes - influenced the performance of scientists and engineers in R & D organizations. In the early 1960s, they studied 1300 scientists in eleven U.S. government, industrial and university laboratories. These were broken up into departments of, typically, 20 to 60 members, and further broken up into sections. Individual performance was measured in two ways: first there was a peer review (by senior people in the same laboratory) of the individuals' contribution to scientific or technical knowledge in the field and their overall usefulness in helping the organization carry out its responsibilities. Second, the number of each individual's 'scientific products' was measured, including unpublished reports, published papers and patents. Performance was assessed over the previous five years.

To summarise such a major piece of research is difficult, but some of their results are particularly relevant to this thesis. First, highly productive researchers had several specialisations rather than one only, and spent between a quarter and half their time on non-research activities;[12] the pressures of teaching and administration, it seems, acted as a stimulus to research productivity:

> Contrary to the folklore which holds that scientists perform best when in a relaxed 'academic' environment, these data suggest that a sense of time pressure can enhance several qualities of scientific performance including innovation ... [In fact] the highest performing scientists also tended to **want** large amounts of pressure. (Pelz and Andrews 1976.380, emphasis in the original)

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12 This is confirmed by Knorr *et al* (1979.69) who concluded that 'in academic settings, publication productivity peaks when about one-third of a scientist's time is spent on research'.

Second, productive researchers had several personal characteristics which may be described as an intense dedication to research and intellectual self reliance. Pelz and Andrews explored whether these two characteristics could be encouraged. They found that giving individuals more say in their research, giving rewards of various kinds and providing opportunities to associate with 'key' people all encouraged an individual's greater involvement in his/her work.[13] They noted that interest in the scientific field was a more enduring influence than career advancement within the organization or extrinsic rewards. Third, with respect to age, they found the usual result that research performance peaked in the late 30s/early 40s. However, they also found strong evidence of 'a renaissance 10 to 15 years later in the 50s' (1976.177). There was some suggestion that older researchers were better at development rather than research (1976.183), at integration rather than innovation (1976.196), and that as their wisdom increased, their flexibility decreased (1976.201). Fourth, productive researchers were strong on contact and communication with other researchers, as measured by the number of people contacted, the frequency of such contacts and the length of time involved in communicating.

A related book (Andrews 1979) presents the results of the UNESCO-sponsored study of over 11,000 scientists in 1200 research units in six European countries. Using similar methods, it reaches broadly similar conclusions to Pelz and Andrews but several additional findings may be noted. First, they found a positive and significant, albeit not very strong, relationship between a 'strength of motivation index' and productivity (Andrews 1976.250ff). The index varied more between research units than within units, and led Andrews to suggest (1979.268) that motivation be viewed as a group characteristic rather than an individual one. This result is reminiscent of Long's contention that the prestige of a department determines individual members' productivity, rather than the reverse. Somewhat at odds with this is the contribution by Knorr *et al* (1979), which concludes that variation in individual productivity is the major explanation of variation of group productivity. They therefore suggest (1979.88) that future research focuses on factors influencing individual productivity. Second, an individual's 'position' in his/her unit is crucial, where more senior positions involved supervisory roles of technical and service staff and opportunities to influence research topics and approaches. Both these increase the number of publications which he/she can claim (Knorr *et al* 1979.87). With this foundation, we now turn to examine some of the explanatory variables in more detail.

4.0 Explanatory variables

This section examines some of the more important explanatory variables in detail. These are size of department, gender, tenure and rank, prestige of department and university, and age.

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13 In discussing ways of building self reliance amongst scientists, they insist on the importance of multiple channels in recognising and rewarding achievement (1976.xxvi).

The differences in space devoted to these explanatory variables reflect not only the extent of the literature on each, but also their apparent importance and their relevance to present and future policy formation.

4.1 Size of department

The sheer size of a department is, of course, likely to be positively related to its status, particularly peer reviews,[14] because its total research output is likely to be large as well its other outputs and required inputs. For example, Hagstrom's (1971) study of the determinants of prestige rankings amongst 125 U.S. science departments found that almost a third of the variance could be explained by size.[15] Indeed, the following remarks by Jones (1988.9) concerning British universities as a whole are just as relevant to department.

> Few would deny that large universities will have a greater impact in a peer review classification than small institutions and, all else being equal, it would be reprehensible if a large university failed to attract a larger research grant income than a small one. Yet such criteria have been used indiscriminately in a variety of grading exercises with little effort ... to 'normalize' ... to ensure that the results are a proper reflection of quality rather than merely of size.

It is per capita performance which matters, and whether this is likely to be greater in a large university or department than in a small one needs to be investigated rather than assumed. The 'ingrained belief in the virtues of size' may, as Jewkes *et al* (1958.246) remind us, be the result of 'shallow-thinking'. General studies reach diverse conclusions. Several classic studies of industrial research suggest that diseconomies of scale soon swamp the economies. Comanor's (1965) study of 57 U.S. pharmaceutical firms found economies of scale with respect to R & D existed for small firms, but diseconomies set in as firms grew. Part of his explanation for this was that the productivity of research personnel was inversely related to size. Schmookler's (1972) review across a wide range of industries confirmed that the efficiency of inventive activity tends to vary inversely with firm size. Reviews of industrial research experience may be found in Kamien and Schwartz (1975) and Scherer and Ross (1990, especially ch. 17).

A number of reasons suggest that department size may be positively or negatively related to research productivity. Of course, size of department may be unrelated to research productivity because research output is 'an autonomous characteristic of individuals' (Cohen 1980.46), in which case a linear relationship between the two would occur. Or it may appear to be unrelated, especially in cross section studies, because the diseconomies and economics of size balance each other out. In addition, the relationship may well be curvilinear, with research productivity rising up to a certain size of department and declining thereafter. A simple positive

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14 On this point, see Golden and Carstensen (1992b) and Meador *et al* (1992).

15 It should be admitted that Hagstrom concludes (1971.382) that 'size is an almost necessary condition for excellence in modern scientific establishments'.

correlation between number of staff and research productivity (but not, of course, total output) would suggest economics of scale. The optimal size for a department, however, depends on whether a turning point exists - whether diminishing or increasing returns to size set in and, if so, at what size. This is shown by the sign and significance of size squared in a binominal regression equation.

How might size be positively related to research productivity? First, a 'critical mass' of individuals may be necessary to provide the interaction and cross fertilisation of ideas necessary to stimulate thinking, discovery and writing. Second, at least up to some upper limit, the more members of a department, the greater the interaction, cross fertilisation and synergy. Third, economies of scale may be reaped by larger departments in terms of shared resources, both physical, as well as and human and knowledge and skills.[16] Such sharing may mean, for example, a lesser administrative burden for individual members of the department and greater access to the experience and skills of others. Fourth, specialisation in particular research fields which may be allowed or encouraged in larger departments, may lead to increased productivity. Fifth, there may be a threshold size of department which necessitates specific administrative organization and division of labour which, together with 'other synergistic effects' (Cohen 1980.46), result in higher research productivity.

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16 Economies of scope may also occur i.e. larger departments are more likely to include several researchers in one field and the presence of different fields enhances productivity. For evidence on this for Dutch universities, see Spangenberg and Schreuder (1990).

How might size be negatively related to research productivity? First, the larger the department, the more effort needs to be devoted to communication and interaction and the less time there will be for research activity proper. Second, diseconomies of scale may occur as size increases, diverting some researcher's time and effort largely to management and administration. Third, beyond a certain size, the team spirit and synergy of a small group is likely to turn negative with factions forming, problems in communication and difficulties occurring in administration. Fourth, in large departments, individuals can avoid their responsibilities with less chance of detection and correction than in small departments, which simply cannot afford unco-operative members.

Many reports and some subsequent policies (for the U.K., see Swinnerton-Dyer (1982), Advisory Board for the Research Councils (1987) and UGC (1987, 1988); for Australia, see CTEC (1986), ASTEC (1987)[17] and Dawkins (1987, 1988)) have been based on apparent rules of thumb or flawed research as regards the minimum desired size of departments and universities. The CTEC (1986) and Dawkins (1987) reports, which formed the basis of extensive amalgamations of institutions of higher education in the late 1980s, simply cross reference each other as the source of their figure of 5000 as the minimum size at which a university could be 'reasonably economic' (CTEC 1986.61).

The Dawkins (1987) report gives considerable emphasis to the reaping of economies of scale, including those in research. Consolidation of institutions (1987.30) is partly justified by the assertion that larger institutions provide greater scope to develop an effective research infrastructure and offer substantial 'efficiencies of scale'. Elsewhere, the concentration of research resources in Special Research Centres and Key Centres of Teaching and Research, which commenced with nine Centres of Excellence in 1982, is recommended in order to reduce 'inefficiencies resulting from fragmentation and duplication of research effort' (1987.67). Accordingly, the government intends to distribute general research funds to universities 'in accordance with [indentified] areas of research strength and concentration. Additional funds for research made available on a competitive basis will continue to be distributed to Key Centres of Teaching and Research and Special Research Centres, as well as through other direct programs of the ARC' (1987.68). Similar emphases appeared in CTEC (1986.146-147) and ASTEC (1987). Marsh *et al* (1992) estimated that there were some 900 research centres at Australian universities in the early 1990s. They collected basic data on 610 of these, including 91 Federal Government-funded centres comprising 26 Special Research Centres, 31 Key Centres of Teaching and Research and 34 Co-operative Research Centres.

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17 CTEC (1986.144) and ASTEC (1987.29-30) argue for greater differentiation of teaching and research loads according to individual ability.

The belief underpinning such policy directions appears to be that research output per capita will be greater, and/or will be achieved more cost effectively, in research centres than in conventional university departments which also have teaching responsibilities. There appear to be three justifications for the push for research concentration. First, there are alleged to be economies in concentrating expensive equipment in a limited number of centres. Second, there is a belief that research teams need to reach a 'critical size threshold' (ASTEC 1987.21). Third, it is contended that by bringing outstanding researchers together in one centre, there will be interaction of such quality that more and better research will result (ASTEC 1987.21-22).

In economics research, there is little need for capital equipment other than the human brain, so the economies argument does not seem particularly important. Furthermore, studies of Australian university agricultural economics (Anderson 1978) and physics departments (Campbell and Campbell 1984) suggest that departmental size and research output per capita are not related. If research centres were more productive than teaching departments, it may be because the third argument - that great minds stimulate each other to greater research output - is important. Again, however, this seems to be more relevant to science departments where joint research is more the norm than it is in economics; Cole and Zuckerman (1984.229-230) report that 76 per cent of the publications in their sample of U.S. scientists were joint publications, whereas for Australian economists' publications between 1984 and 1988, for example, the proportion was about one third (Harris 1990).

It is not surprising that positive correlations occur between size and assessments of research performance involving a significant peer review component. Platt (1988) reports a number of such correlations for different disciplines based on the UGCs 1986 ratings. Much more importantly, she reports eight studies which correlated UGC ranking with research output per capita, measured by various means. Only for one discipline (economics) was there a significant correlation between UGC ratings and a measure of publications output. However, when differences in inputs were taken into account, even ths correlation became effectively zero. Platt (1988.516) felt 'obliged to conclude that the relationship between size and UGC rating is probably spurious, a methodological artifact', caused by the relationship between peer reviews and size. The 'general impression given is one of smaller departments doing as well as larger ones ... [The] evidence for larger departments being stronger in research is at best inconclusive' (Platt 1988.517).

Other U.K. research on the relationship between research productivity and size in physics, chemistry and earth science departments suggests that productivity does not vary with size. In the case of physics departments (Hicks and Skea 1989), while the large Oxford and Cambridge departments had relatively high research output per head (which was probably a function of factors other than their size), thereafter large departments were no more productive than smaller ones. Overall, size accounted for less than eight per cent of variation in research productivity between departments. A similar result was found for the other two disciplines except that the higher Oxbridge productivity was absent. Stirling (1988) provides evidence that on several citeria, even when measured on a total basis, some small U.K. chemistry departments outperform even the biggest departments.

The UGCs 1988 reviews of physics and chemistry departments in U.K. universities proposed that the smallest size for a viable research department was around 20 academic staff. A *Times Higher Educational Supplement* editorial (September 30, 1989.40) remarked that 'for all the talk of the importance of "critical mass" in science, there is little good evidence to back such a figure, or any other. And there is no convincing analysis of how the size of the critical mass might vary over time, or within or between disciplines'.

Summing up, it is difficult to be impressed by the arguments for big universities or departments as a means for promoting research productivity, a point underlined by recent U.S. research by John Jordan and his associates and critics (Jordan *et al* 1988, 1989; Meador *et al* 1992; Golden and Carstensen 1992a, 1992b). Initially using data from a number of the studies listed in Table 3 to provide their dependent variables, they found some support for the contention that research productivity in economics departments was positively associated with size; the effect diminished, however, as size increased. Specifically this was demonstrated by significant positive regression coefficients for the size variable and significant negative coefficients for size squared. A later study of 73 U.S. economics departments found similar results as did the study of 1233 Ph.D.-awarding departments in 22 other academic disciplines (Meador *et al* 1992). The idea that research productivity rises to some optimal size, and thereafter declines, was also reported by Johnes' (1988) in his study of U.K. economics departments; in this case the turning point was 56, an extremely high level.

A final comment on size is that it may distract attention from the social structure and composition of laboratories and departments. This includes 'the relative number of senior researchers, postdoctoral fellow and graduate students as well as the status differences within these groups' (Cole and Zuckerman 1984.248) which may significantly affect group and individual productivity.

4.2. Gender

Two propositions concerning the relationship of gender and research productivity are generally accepted. First, women do not publish as much as men, nor is their work cited as frequently. Cole and Zuckerman (1984) list more than 40 studies which reach this conclusion. Their own study of 526 scientists who received their doctorates in 1969/70, from six scientific fields, found that females published 57 per cent of the number of articles which males published and received 59 per cent of the citations. They did note, however, that females received very similar citations per paper published, although their most-cited publications were cited less often than those of men (1984.235). Second, women receive fewer of the traditional academic rewards of rank, tenure and salary. Where scholars part company is in explaining these propositions. On the one hand, researchers such as Jonathan Cole (1979) consider that the lesser rewards offered to women can be explained almost entirely by their lower productivity. Others (e.g. Astin 1978, 1984) criticise the idea that rewards in science are 'fair' by pointing out that equally productive males and females are not rewarded equally. Astin's most recent study was based on a survey of 7571 men and 1669 women in 1980-81.

Two questions need to be addressed: Why are women less productive than men and, even when they are equally productive, why are women rewarded and recognised less than men? We should note here that rewards and recognition include both monetary aspects, including salaries and research grants, and non-monetary aspects, including reputation, visibility invitations to serve on committees, etc. One explanation is that women may be concentrated in fields where research is less rewarded. It is generally believed, for example, that theoretical research is better rewarded than applied research. Astin (1984.274) found that academic women were concentrated in applied disciplines and fields and that this, rather than their productivity, might be an important explanation of their lesser rewards. Another explanation emphasises marriage and childbearing activities but this does not appear to be particularly influential: single women are no more productive than married women (Astin 1984; Davis and Astin 1987), although the latter start their research careers more slowly.

Much more important seems to be the influence of traditional sex roles. One aspect of this explanation is the difficulty women face in being part of the collegial system. Reskin (1978b) argues that colleagiality is an essential element in academia but that it does not easily occur between people of unequal status, as typically exists between male and female academics. Because 'scientists learn sex roles long before they learn how colleagues interact' (1978b.12), women are prone to be excluded from the informal communication networks of central importance in academia. This may lead to a circle of differential reinforcement where the lack of recognition leads to discouragement, lower productivity and back to low recognition. Cole and Zuckerman (1984) enquire into two aspects of these hypotheses. First, they find support for differential reinforcement from the fact that women are more prone than men to publish less as time passes. Second, they examined the propensity of males and females to be involved in jointly-authored publications in an effort to test the colleagiality hypothesis: they found no difference between males and females in this regard.

One implication of this understanding is that we might expect that, with increasing awareness and affirmative action, the productivity gap will be narrowing. There is evidence to support this expectation. Cole and Zuckerman's (1984) study of scientists who graduated in 1969/70 found that females made up 26 per cent of the most prolific scientists in their cohort, in terms of their publications 1968-1979; this compared with eight per cent in the 1957/58 cohort over comparable years (J. Cole 1979). They do not suggest, however, that such an explanation solves the productivity puzzle. Davis and Astin's (1987) examination of a 1980 cohort of 300 highly productive men and women academics found that men and women were equal in reputational standing.[18] In contrasting this with Jonathan Cole's (1979.129) assertion that gender differences are greatest amongst highly productive academics, they suggest that the greatly expanded scope for research on women has expanded women's opportunities for scholarly enquiry, some directly, others indirectly. This has given them access to skills and insider knowledge previously controlled by men (Davis and Astin 1987.273). In other words, their 1980 cohort has had quite different opportunities than Cole's 1969 cohort.

Even when they are recognised, however, women may respond differently to men. There is some conflicting evidence concerning the propensity of women scientists to be encouraged by recognition or discouraged by its lack. Reskin (1978a.1242) found women to be more responsive to being cited, in terms of their future productivity, than men. Cole and Zuckerman (1984.243) found women scientists to be more readily discouraged and less readily encouraged than men by different degrees of citation of their work.

In concluding, we should note that gender differences are not of great importance in explaining productivity differences:

> ... While the difference between the sexes in research output is both significant and puzzling, gender per se does not explain much of the variance in published productivity or citations. Variability between the sexes in productivity is not nearly as great as variability within each sex. (Cole and Zuckerman 1984.248)

4.3 Tenure and rank

It may be felt that the granting of tenure or promotion, far from acting as an incentive to continued or increased research activity, may act as a disincentive i.e. having achieved the

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18 As one of seven explanatory variables, gender was not significant in explaining variation in any of seven indices of reputational standing.

objective, effort may slacken. Of relevance here is the relative importance of different sources of motivation discussed earlier - rule enforcement, external rewards (system-wide), external rewards (individual) and internal.

The few studies carried out indicate that internal motivations are dominant and that researchers remain about as productive after promotion as they were before. Hedley's (1987) study of 40 Canadian academics before and after their promotion to full professorships found two patterns: previously high producers continued to be highly productive and previously low producers continued to do little research but assumed the lion's share of administration. It may be noted that if promotion were to lead to greater administrative responsibilities, the time available for research could fall. Bell and Seater (1978.610) found that tenure was not important in explaining individual variation in articles per head amongst North American university economists. The study by Bridgewater et al (1982) of 176 U.S. academic psychologists found that productivity peaked at 4.2 publications per annum prior to tenure, then fell slightly before levelling out at 3.5 publications per annum. They concluded that tenure did not retard overall publication activity but did note that the composition of publications altered: journal articles fell in relative importance and books, book chapters etc increased.

4.4 Prestige of academic department/university

A number of studies have found a moderate positive correlation between the prestige of the individual's department and his/her research productivity. Two explanations are possible: first, productive individuals may apply to prestigious departments and these are likely to select the most productive individuals; second, the prestigious department may facilitate research productivity. Long (1978) mentions two types of studies: those interested in the functioning of the academic marketplace have generally concluded that the prestige of an individual's Ph.D. granting university and the eminence of his/her mentor are more important than his/her productivity in securing prestigious posts. The other type, which stand in the Mertonian tradition, find that science is governed by 'the norm of universalism', so that rewards are based on actual contributions to knowledge. Typical of this second group is the work of Cole and Cole (1967, 1973).

Long considered previous studies methodologically deficient and used a two part longitudinal approach in his analysis of U.S. biochemists. He tested for the factors surrounding an individual's move into their first academic job, and subsequent moves between institutions. He examined, *inter alia*, changes in individual productivity following a move compared with that of non-movers. His conclusions were twofold: first, the importance of productivity in the recruiting of staff was slight, with the prestige of the applicant's Ph.D. or post-doctoral fellowship university and the eminence of his/her mentor playing major roles (1978.897). Second, the effect of the department on individual productivity was strong, showing out in citations to subsequent work rather than in number of publications. Long (1978.904-905) explored several possible explanations for the departmental effect, including the ability of prestigious departments to pick potentially productive researchers, the possibility that they might be bigger or more collaborative and that a bias in the evaluation system may be in favour of prestige departments and make papers from such departments appear superior. In a related study (Long and McGinnis 1981), similar conclusions were reached. Levels of productivity were found to depend principally on the organizational context in which people work. Braxton (1983) hypothesized that the level of publication productivity among colleagues would positively effect the productivity of individual members. Based on 50 U.S. academic chemists and 49 psychologists, his study found only modest support for the hypothesis, with such colleagial effects as did occur more likely to affect individuals with low previous research productivity. Individuals with previously high productivity were likely to continue to be productive irrespective of the publication level of their colleagues. Their research role seems to have been internalised, and they were not dependent on approval from their colleagues. Also relevant to the influence of colleagues an individual productivity is Pelz and Andrew's (1976) finding that productive researchers were much more likely to engage in a range of communication with colleagues than less productive ones.

4.5 Age

Pelz and Andrews (1976.175-176) suggest four possible links between age and research productivity: intellectual functions may decline with age; researchers may be drawn off into administrative activities; older researchers may become less motivated to carry out research; and, having specialised in one or two fields, researchers find their knowledge of other fields is obsolescent.

The classic study of productivity and age is that of Lehman (1953), who concluded that scientists made their major contributions in their late 30s and early 40s, and thereafter their contributions declined. It is important to note here (Fox 1983.289-290) that whilst Lehman was concerned with 'major contributions', most subsequent studies have taken a wider range of publications into account. Cole's (1979) study of publications in six disciplines confirmed

Lehman's result: they rose gradually with age, reached a maximum in the late 30s/early 40s, then fell off. Pelz and Andrews (1976), on the other hand, found that productivity was bi-modal: it peaked in scientists' late 30s/early 40s, went into a slump for ten to fifteen years, and then reached another peak around age 50. They suggest that 'the earlier peak represented work of a more divergent or innovative type, whereas the later peak represented work more convergent or integrative in character' (1979.196). Knorr *et al* (1979.60-63), using 'professional experience' in preference to chronological age, found that European natural science academics reached a peak after 15 to 20 years of steadily rising productivity and thereafter stagnated; technological science academics reached their productivity peak after 30 years of steady increase, and then declined. It is important to note that the precise meanings of 'stagnation' and 'decline'. The natural scientists reached a peak of seven to nine articles, over a three year period, after 16 to 20 years of professional experience; thereafter, they maintained that level. Technological scientists reached seven to nine articles after 26 to 30 years of professional experience; after 31 years they fell to six articles (1979.62). Age, it seems, really has very little impact on productivity.[19]

Pelz and Andrews (1976) found little support for the first two hypotheses - declining intellectual powers and being driven off into administration. Both they and Knorr *et al* (1979) found that productivity continued to increase steadily for the first 20 years or so of a professional career, despite increasing administrative loads and decreasing time for research.[20] Knorr *et al* (1979.63ff) suggest that age may be regarded as a proxy for occupying informal and formal supervisory roles. This includes supervising technical and service staff and having some power over what will be researched and how it will be researched. The result is that the number of publications to which scientists can lay claim increases with age as they are more able to organize their work force and marshall resources.

Pelz and Andrews (1976) did find some evidence to support the third and fourth explanations - declining motivation and obsolescent knowledge. Overall, however, the relationships of productivity with age tend to be fairly weak[21] and by no means universal. McKeachie (1983) concludes a brief review on the aging of academics with two comments.

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19 Pelz and Andrews' data are not presented in a form which allows similar analysis.

20 Knorr *et al* (1979.64) found that the average time available for research fell from around 50 to 60 per cent early in a scientists career to 30 to 40 per cent late in their career.

21 See also Bayer and Dutton (1977) and Over (1982).

> First, individuals differ greatly, and these differences are likely to increase with age, so that generalizations about older faculty are generally not applicable to all individuals. Thus, in looking at faculty as a resource we should look at individual cases, not at age groups. Second, individuals have the ability to change at all ages. At one time, it was common to hear that personality, intelligence, and other basic individual characteristics were fixed by age five and human development was characterized by continuity and stability. Today, life span development research has shown that there is much less continuity in the lives of individuals than we once believed ... Individuals retain a remarkable capacity for change all though their life. (McKeachie 1983.60)

Self-reliant, internally-motivated researchers, who are active rather than passive towards their environment (Pelz and Andrews 1976.190) continue to be effective researchers as they age.

5.0 Multivariate analyses

One of the common statistical tools employed by economists is multiple regression analysis, which allows the effects of a number of explanatory variables on one dependent variable to be identified.

5.1 Studies of individual economists

I am aware of only one article which studies, albeit indirectly, the determinants of productivity among individual economists. This study (Hansen *et al* 1978) is important not only because it stands alone, but for other procedural matters. First, it makes no distinction between publications as regards type, quality, length or extent of authorship, an approach justified 'on grounds of cost, not conceptual purity' (Hansen *et al* 1978.733).[22] This assumption is akin to that of Graves *et al* (1982.1137), that 'since the relative abilities of individual faculty members at research and teaching are difficult to observe and measure, we shall assume them uniform within departments, or at least randomly distributed'. In fact, given their data source (the *Index of Economic Journals*, a stablemate of the *Journal of Economic Literature*), Hansen *et al* exclude some types of publication, including chapters in books and articles in journals not included in the *Index*. Second, in the course of investigating sources of income differences among U.S. academic economists, they tested four explanatory variables - the quality of the department in which the economist currently works, the quantity and quality of his/her formal academic training, the quality and duration of the economist's on the job research experience[23] and gender. The individual's characteristics as regards intelligence and motivation were ignored because no data were available to measure them.

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22 In one extension of their work (footnote 22, p. 737), they view one book as equal to six articles.

23 Experience was measured by years since receipt of doctorate. Both number of years and the number of years squared were employed, the latter to test for diminishing returns to experience.

The expected positive and significant results were recorded for quality of the department and years of experience and a negative (but only significant at 10 per cent) result for experience squared. An unexpected significant negative result occurred for quality of training which is explained as possibly 'reflect[ing] the omission of a quality dimension in the measurement of research output' (Hansen *et al* 1978.737). Females were less productive than males, despite the fact that they were employed at more prestigious institutions than men, on average. Overall, they found that

> 'an additional unit of research productivity yields an almost 8 per cent increase in annual earnings. [This effect] diminishes at an increasing rate with the number of publications, reaching a zero increase in earnings at 32 publications' (1978.737).

Several related studies my be mentioned here, although they are not strictly multivariate in nature. Sauer (1988) studied returns, in terms of salary, to research quality, measured largely by citations, and to single versus coauthorship amongst 140 academic economists at seven major U.S. universities. Publication of an article had an initial impact on salary which is then added to by citations. The average ten AER-equivalent-page article in the top-ranked journal increased its author's salary by 1.7 per cent in 1982. Citations over seven years added a further 2.1 per cent to salary (1988.863) making a total of $1602 in 1982 dollars. The return fell with lower journal quality: for the eightieth ranked journal (based on Liebowitz and Palmer 1984), the return was 19 per cent of that of the top journal. Coauthorship was found to be rewarded in accordance with the proportion of authorship i.e. an individual's return for an article with n authors is roughly 1/n times that of a single-authored paper.

Brennan and Teal (1991) used my 1974-83 data (Harris 1990), disaggregated to individual lecturer level, to test the extent to which Australian university economists were paid according to their research productivity. By comparing the publication points at each rank, and relating this to median salaries for these ranks, they concluded that academic pay does reflect output i.e. the costs of a publication-point is similar for each rank. However, given very large variations in individual productivity,[24] research productivity was not a good predictor of rank. These results are consistent with those of Hamermesh *et al* (1982) who studied the impact of citations on US economists' salaries, and with Johnston's (1981) study of CSIRO scientists. In the latter, over 80 per cent of salary differentials could be explained by years of post-doctoral experience, highest qualification achieved and several measures of research productivity.

24 For example, the coefficient of variation for lecturers was 176 per cent; for professors it was 135 per cent.

5.2 Studies of economics departments

Tables 2 and 3 summarise the results of the seven studies of which I am aware, the former in general terms and the latter with particular reference to the explanatory variables employed, which I have broken into eight groupings. The results are fairly mixed and some of the coefficients are very close to zero in size.[25] Typically, multiple regression is used and the variables explain about one third of the variation in research productivity. A preliminary point to note is that there are several explanatory variables - in particular average salaries, proportion of full professors and the extent of outside funding - for which there is a simultaneity problem i.e. the direction of causality could feasibly run in the opposite direction to that assumed.

Average age of lecturers could be related to research productivity positively (e.g. via greater experience) or negatively (e.g. via relatively less energy and enthusiasm). Of the three results available, one is significant and that is negative. It is relevant to note that Anderson's study is longitudinal in design, following the fortunes of one department over almost 30 years. This allows more scope for the impact of an aging department to be identified. The signs of most of the nine coefficients related to teaching and other responsibilities are as expected (i.e. more teaching etc results in less research output), but this was not the case for the U.K. study. The Australian and U.S. studies which examined the qualifications of lecturers found significant relationships of the expected sign. Size of department was significantly positively related to productivity in most studies, but after some optimal size, average productivity declines, as indicated by the negative sign reported for the size of department squared variable. Various forms of support for lecturers were usually of the expected sign, with one (secretaries per lecturer) significantly positive. Each of the three coefficients relating to rank were significant. The positive U.S. results might be explained by causality running from rank to productivity and the U.K. study hypothesises a negative relationship on the basis of greater incentives on the part of young staff and the saddling of older staff with administrative duties.

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25 Where the results of more than one equation are presented, I have attempted to present the majority result. In the case of Johnes (1988) study, I have used his 'preferred equation'. Where differences appear to exist between the coefficients and t ratios presented in the studies, and the interpretation of these, I have normally followed the former.

Table 2: Summary of studies of determinants of research productivity in economics

Coverage	Principal objective(s)	Principal measure(s)	Explanatory variables	Principal results	Reference
One Australian agricultural economics department, 1959-77	To measure and explain changes in per capita research output over time, using multiple regression analysis.	Prestige output (selected journals), non-book output and total output, each measured by pages per appointed lecturer per annum.	Average age. Number of courses taught per lecturer. Proportion of lecturers with Ph.D. Number of research assistants, etc per lecturer. Tutors etc per lecturer. Size of department.	Age (negative) and proportion of lecturers with a Ph.D (positive) were the only two significant explanatory variables. $R^2 = 0.48$	Anderson (1978)
The top 240 US economics departments, 1974-78	To measure and explain differences in per capita research productivity, using multiple regression analysis.	AER - equivalent pages in the top 24 journals, in total and per capita terms.	Average salary of 3 grades of lecturer, by department. Average teaching hours per week. Secretary: lecturer ratio Student: lecturer ratio Support services Teaching assistance Research assistance Location (region) Presence of Ph.D. program	Salary of full professors (positive), secretaries per lecturer (positive) and teaching hours (negative) were the three significant explanatory variables. Presence of a Ph.D program (positive) was also influential. $R^2 = 0.31\text{-}.0.48$.	Graves et al. (1982)
The top 25 US agricultural economics departments, 1980-84	To measure and explain variations in per capita research productivity, using probit analysis.	Total citations, citations based on time available for research, and citations adjusted for years of experience.	Type of university Years since highest degree Time available for research Time spent on extension Rank Highest degree lower than a Ph.D.	Time available for research and rank were positively and significantly related to the probability of having a citation, and highest degree lower than a Ph.D was significantly negatively related.	Beilock et al (1986)

The 40 UK economics departments 1980-84	To measure and explain variations in per capita research productivity.	Number of pages and number of articles in 20 top journals per capita.	Average age of department Student: staff ratio Number of staff Number of graduates p.a. Size of library Importance of external finance Ph.D. Student: staff ratio Professors: all staff ratio	Number of staff (positive), size of library (negative), and professors: all staff ratio (negative) were the significant variables. $R^2 = 0.43\text{-}0.59$	Johnes (1988)
2058 US Ph.D-awarding departments covering 23 academic disciplines, including 93 economics departments, late 1970s/early 1980s.	To determine the influence of size and form of organization on research productivity.	Number of published articles per faculty member per annum.	Size of department Size of department squared Public or private university.	Research productivity was found to be higher in private universities and to increase with size, but at a diminishing rate. $R^2 = 0.16$	Jordan et al. (1989)
1254 Ph.D-awarding departments across 23 disciplines, including 73 economics departments, late 1970s/early 1980s.	To determine the influence of size, form of organization, research support and peer ranking of scholarly achievement on research productivity.	Number of published articles per faculty member per annum.	Size of department Size of department squared Public or private university Peer ranking of scholarly achievement.	The impact of private affiliation and size plunge after controlling for research support and peer ranking. The last has a strongly significant positive coefficient. $R^2 = 0.45$	Golden and Carstensen (1992a)
1254 Ph.D-awarding departments across 23 disciplines, including 73 economics departments, late 1970s/early 1980s.	To determine the influence of size, form of organization, research support, graduate students per lecturer and size of library and research productivity.	Peer ranking of scholarly achievement.	Size of department Size of department squared Research support Graduate students per lecturer Size of university library	All explanatory variables except graduate students per lecturer were significant, and all had the expected sign. $R^2 = 0.82$.	Meador et al. (1992)

Table 3: Summary of results: explanatory variables of departmental research productivity

Explanatory variable	Anderson 1978 (Australia)	Graves et al 1982 (US)	Beilock et al 1986 (US)	Johnes 1988 (UK)	Jordan et al 1989 (US)	Golden and Carstensen 1992a (US)	Meador et al 1992 (US)
Age							
Average age of lecturers	-*			+			
Average years since completion of highest degree			+				
Time available for research vis-à-vis other responsibilities							
Number of courses offered	-						
Average teaching hours		-*					
% time spent on research			+*				
% time spent on extension			-				
Undergraduate students per lecturer		-					
Number of graduates per annum				+*			
Student:Staff ratio				+			
Graduate students							
Graduate students per lecturer				-			
Presence of Ph.D. program		+					+
Qualifications of lecturers							
% staff with Ph.D.	+*						
% staff with highest degree below Ph.D.			-*				
Size of department							
Number of lecturers	-			+*	+*		+*
Number of lecturers squared				-	-		-*
Support available to lecturers							
Research assistants per lecturer	-	-					
Tutors per lecturer	+	+					
Secretaries per lecturer		+*					
Quality of support services		+					

Table 4.3 continued

Explanatory variable	Anderson 1978 (Australia)	Graves et al 1982 (US)	Bellock et al 1986 (US)	Johnes 1988 (UK)	Jordan et al 1989 (US)	Golden and Carstensen 1992a (US)	Meador et al 1992 (US)
Rank							
% full professors			+*	-*			
% associate professors			+*				
Miscellaneous							
% university of departmental staff externally funded				-			+*
Average salary		+*					
Library stock				-			+*
Public university[1]					-	-	-*
Adjusted R^2	0.33	0.33	n.a.	0.45	0.16	0.34	0.82

Note: [1] Dummy variables were used to account for whether a university was public or private.
A negative sign means that private universities are more productive than public universities.

In summary, departmental research productivity seems to be positively influenced by lecturers' qualifications and the time available for research and, at least in the U.S., by the supporting inputs available to lecturers and being located at a private university. Size of department acts as a positive stimulus but this effect turns negative after a certain size is passed.

6.0 The determinants of research productivity: an overview

In this paper, we have examined the 'productivity puzzle' - the high degree of variation in respect of research productivity between individuals and departments - and reviewed previous research which has attempted to explain this variation. In the US, the interest in this question has been motivated by curiosity and a desire to enhance productivity. In the UK and Australia, there is an additional reason in that governments are introducing systems which will financially reward productive departments and institutions and punish unproductive ones. Apart from the desire to receive more funds or avoid cuts in funds, there is the question whether more funds will indeed result in more or better quality research by stronger research departments. It is also possible that weaker departments could increase their research performance if they had more resources.

We noted the wide range of potential determinants of research, broken up into individual, departmental and institutional factors. In addition, the influence of cumulative advantage and reinforcement was examined. Whilst individual motivation appears to be the strongest influence on research productivity, appropriate extrinsic rewards and work environments are not unimportant. The reward system in science and group/organizational processes were subjected to scrutiny by two strands of the sociology of science. Individual motivation again emerged as important but the reward and organizational environment also contributed to individual productivity. Section 4 examined selected explanatory variables - some individual, some organizational - in more detail. Size of department, gender, tenure and age were found to be of quite limited importance in explaining variations in research productivity between individuals. Section 5 considered the relatively few multivariate analyses which have been carried out. The somewhat disparate results, summarised in Table 3, suggest that lecturers' qualifications and the time available for research were both positively related to research productivity. Size of department was a positive influence up to a point but thereafter became negative. The multivariate analyses, it should be noted, do not include variables, apart from age, which measure individual characteristics. The overall conclusion from this paper is that it is individuals who carry out research, and their intrinsic motivations which principally determines productivity. It is on this point that policymakers should focus, although they can also be aware that productivity can also be influenced by extrinsic rewards and the environments in which researchers work.

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