2012

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Economics Working Paper Series 2012
http://www.uow.edu.au/commerce/econ/wpapers.html

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WP 12 - 05

March 2012

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by

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Abstract

Lucas (1988) hypothesised that human capital externalities explain persistent productivity growth and become manifest via interactions between workplace colleagues. Consistent with the first part of this hypothesis, Fox and Milbourne (2006) concluded that an increase in the average level of human capital in Australian economics departments raised the research productivity of departmental members. This paper tests the robustness of this finding by using a direct, rather than a proxy, measure of human capital and confirms the existence of human capital externalities within Australian economics departments. But we go further by investigating the second part of Lucas' hypothesis. Whilst there are numerous ways in which departmental colleagues may interact, we investigate whether the externality becomes manifest via co-authorship. We find no evidence that this type of interaction significantly enhances research productivity, especially for higher quality outputs.

I Introduction

Microeconomists have long recognised that externalities affect economic efficiency. Over the last 25 years macroeconomists have also developed an interest in externalities, in particular because of their potential for explaining persistent productivity increases. For example Lucas(1988) hypothesised that, additional to the usual inputs (technology, physical and human capital), production also depends on a human capital externality, which he modelled as increasing in the average skill level of workers. Subsequently, there has been some interest in identifying and quantifying human capital externalities within workplaces.

According to this literature, positive human capital externalities within firms may emerge from the creation of a team ethos, from information sharing, from skill complementarities, and from informal on-the-job training amongst co-workers. The existence of positive human capital externalities is suggested by the clustering of highly skilled professionals (and non-professionals) in firms and by team dynamic effects in professional sport. Conversely, human capital externalities may be negative if over-qualified workers are disruptive or if an excessive variation in human capital across workers in a firm creates a skills-incompatibility problem which makes it difficult to implement training programs, increases the costs of co-ordination and communication or promotes fractionalisation within the workplace. In this latter scenario more highly skilled workers may discount the productive potential from collaborating with their less skilled colleagues.[1]

Academics typically possess high levels of human capital which are relatively easily identified and so the human capital externality hypothesised by Lucas should be measurable within academia. However the literature examining this issue is sparse.

[1] See, for example, Battu, H., *et al*. (2003) for a detailed discussion of positive and negative human capital externalities within workplaces, in this case for Great Britain.

Fox and Milbourne (1999) and Rodgers and Neri (2007) both found that the research productivity of academic economists in Australia is a function of their human capital and characteristics of their departmental environment. Additionally, and of most relevance to this study, Fox and Milbourne (2006) found evidence of a positive human capital externality within departments. The authors collected survey data from 134 academics on their human capital and other characteristics, and on the institutional environment in which they worked. Human capital data included whether the academic had a PhD, the time taken to obtain the PhD and the grade of the Honours degree. Institutional data included average teaching hours per week, average class size and the average number of research grants held per year since the first appointment.

The authors calculated various proxy measures of the human capital of the co-workers of the academics who responded to the questionnaire, all based on their lifetime research output. These included the average annual research output of the most productive individual, of the three most productive individuals and of the most productive quartile in the relevant department.[2] The authors concluded, on the basis of Tobit regressions, that the coefficient on the proxy for the average human capital in one's department was statistically significant and positive: "...there are human capital externalities so that an increase in the human capital of any individual also raises, at the margin, the productivity of others. There is some evidence to suggest that the externality is driven primarily by having a small but critical mass of researchers, rather than one outstanding individual." (p. 369).

This study seeks to test the robustness of this conclusion by using a direct, rather than a proxy, measure for the human capital of departmental co-workers.

[2] See Fox and Milbourne (1999) for details on the questionnaire used and the data thereby obtained.

Furthermore we test for the existence of a human capital externality for (nearly) all Australian academic economists rather than just a self-selected sample who responded to a survey. We also examine a different study period. In doing so, we confirm the existence of a positive human capital externality within Australian economics departments.

Finally we investigate the nature of the externality, that is, how the externality becomes manifest. Lucas (1988) conjectured that "...human capital accumulation is a *social* activity, involving *groups* of people in a way that has no counterpart in the accumulation of physical capital" (p.19, italics ours), and that "The external effects...have to do with the influences people have on the productivity of others, so the *scope* of such effects must have to do with the ways various groups interact..." (p.37, italics ours). In Lucas' scenario departmental colleagues interact because they believe that such interactions are subject to increasing returns.[3] Of course workplace interactions take many forms, most of which are not directly observable. However departmental co-authorship, which may be regarded as a strong form of workplace interaction, is both observable and measurable. Indeed in at least one department of which we are aware research incentive schemes have been established to encourage such collaboration. Hence a second objective of this study is to estimate the relationship between academic economists' research productivity, the average human capital of the academics' departmental colleagues, and the academics' propensity to co-author with departmental colleagues.

The remainder of the paper is organised as follows. In the next section we present and discuss our data. In section III we estimate an econometric model of the relationship between research productivity and a vector of human capital and other

[3] We assume that professional interactions occur for the purpose of production rather than consumption.

variables, including the propensity of each individual academic to co-author with a departmental colleague. Finally, section IV concludes.

II Data[4]

We identified all academics at the level of Lecturer (Level B) and above in 28 research active Australian economics departments during the period 1996-2000 and constructed a dataset of their research productivity and human capital.[5] We adjusted for publication time lags by assuming that a given publication was produced within the department stated in the affiliation if and only if the authors were members of the department two years prior to the publication year. However we classified publications as departmentally co-authored only if at least two of the co-authors appeared on one of our departmental staff lists.[6]

We counted only refereed journal publications because we are interested in research of a minimum level of quality (Neary, Mirrlees and Tirole, 2003).[7] Our major source of publications data was the on-line version of *EconLit*. This database is not without limitations (Pomfret and Wang, 2003), a major one being that articles with several authors are frequently referenced using the '*et al.*' convention. Consequently relevant articles will be missed unless the first author is included in our staff list and a supplementary search is undertaken to reveal the other authors, a practice which we followed in every case. Each of *n* authors received credit for *1/n* of the article.

[4] See Neri and Rodgers (2006) and Rodgers and Neri (2007) for more details on data sources and construction methods.
[5] We excluded the following universities because of data limitations: Charles Darwin, Charles Sturt, Swinburne University of Technology, Southern Cross and the University of Southern Queensland.
[6] In cases where a co-author had an Australian economics department affiliation but did not appear on our staff list, we assumed the person to be a student or academic from another department or research centre within the same university.
[7] This is supported by research suggesting that the returns to non-refereed publications are low, at least in other countries. See Gibson (2000) and Sauer (1988).

We calculated departmental research productivity as the weighted average of the research productivities of its members, the weights being the number of years each member was in the department from 1996 to 2000. We assumed that longer articles imply a larger research output and so we took page counts but adjusted these for differences in the mean number of words or characters per page.[8] Any meaningful measure of departmental research productivity must also take account of journal quality which is particularly relevant here because co-authorship may be more common where colleagues attempt to publish in top tier journals. However, measuring journal quality is problematic.[9]

Consequently we used two versions of our dataset on departmental research productivity. The first (which we term Q1) uses the impact factors for only the top 159 journals from Kalaitzidakis, Mamuneas and Stengos (2003). *Ipso facto*, this approach disregards publications in many other journals which are of insufficient quality. As relatively few Australian academic economists publish in top tier journals, and as we believe that an article in a refereed journal is better than no article at all, we also used the complete dataset (termed Q2) which includes a much broader range of journals based on information from Gibson (2000) and Towe and Wright (1995). Whilst there is likely to be disagreement over these journal lists and the quality relativities, any weighting scheme is to a greater or lesser extent *ad hoc*, and in any case our approach is explicit and replicable using alternate weights. Table 1 presents

[8] Our analysis is based on 'standardised' pages calculated with page-conversion factors for 391 journals provided to us by Sinha and Macri (2002). For other journals we used the average conversion factor of all 'group 4 journals' in Sinha and Macri (2002). The reference journal, with a weight of one, is the *American Economic Review*.

[9] See Neary, Mirrlees and Tirole (2003), Figure 1 for an illustrative summary of the wide range of weighting schemes used in the literature to take account of journal quality. See also Combes and Linnemer (2003), Lubrano *et al.* (2003), Axarlaglou and Theoharakis (2003), Mason, Steagall and Fabritius (1997) and Thursby (2000).

(alphabetically) our departmental data on research productivity and on the percentage of that research output that was co-authored by (at least two) departmental colleagues.

Table 1: Research Productivity and Co-authorship, 1998-2002

	Q1 Research Productivity				Q2 Research Productivity			
Depts	**Active (%)**	**Pages if active**	**Pages (all)**	**%Co-author**	**Active (%)**	**Pages if active**	**Pages (all)**	**%Co-author**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Adelaide	50	0.40	0.20	2.6	65	2.05	1.34	2.5
ADFA	28	0.05	0.01	33.4	35	0.52	0.08	29.5
ANU	83	0.80	0.66	11.8	86	2.01	1.73	14.6
Canberra	17	0.00	0.00	0.0	25	0.19	0.05	11.8
Curtin	54	0.14	0.07	12.0	82	0.97	0.77	11.6
Deakin	43	0.18	0.08	6.1	59	1.27	0.76	14.2
E.Cowan	7	0.03	0.00	0.0	13	0.64	0.08	0.0
Flinders	30	0.26	0.08	9.4	30	2.37	0.72	11.8
Griffith	21	0.03	0.01	0.0	64	0.28	0.18	8.7
JCU	19	2.68	0.50	0.0	34	5.40	1.86	0.0
LaTrobe	58	0.25	0.15	17.2	68	1.74	1.18	13.0
Macquarie	14	0.07	0.01	1.6	41	0.72	0.29	3.7
Melbourne	72	0.55	0.40	6.5	87	3.18	2.77	14.4
Monash	40	0.48	0.19	1.1	54	1.34	0.73	11.4
Murdoch	25	0.03	0.01	0.0	55	1.31	0.72	16.9
NewEng.	62	0.08	0.05	34.8	86	0.50	0.44	6.9
Newcastle	13	0.04	0.01	0.0	59	0.35	0.21	12.1
NSW	55	0.69	0.38	12.0	69	2.24	1.55	10.8
QLD	39	0.08	0.03	0.0	77	1.07	0.83	7.5
QUT	13	0.10	0.01	0.0	35	0.78	0.28	18.6
RMIT	19	0.03	0.01	22.9	30	1.08	0.32	73.9
Sydney	32	0.13	0.04	0.9	66	0.80	0.52	0.4
Tasmania	69	0.24	0.17	6.1	81	2.69	2.18	12.5
UTS	13	0.22	0.03	33.3	49	0.40	0.20	36.3
VUT	12	0.05	0.01	74.5	28	0.38	0.11	61.1
W Aust	58	1.14	0.66	0.8	70	3.08	2.15	1.3
W Sydney	29	0.08	0.02	0.0	53	0.64	0.33	2.3
W'gong	15	0.06	0.01	64.6	61	0.53	0.32	24.2
Correlation				-0.20				-0.29

Column 2 of Table 1 shows the percentage of academics, department by department, with some Q1 publications during the study period. Because many academics in many departments did not publish at all, we present in Column 3 the Q1 research productivities of the subset of academics in each department who had positive publications. Column 4 contains departmental Q1 research productivities for all academics, which range from a minimum of zero to a maximum of 0.66 pages per person year. Whilst for all departments the productivity figures are much higher for the research active than for all members, in some cases by as much as sevenfold (e.g. Macquarie and UTS), the data nevertheless highlight the fact that the large majority of Australian academic economists have low research productivity by international standards during the study period. Column 5 of Table 1 contains the proportions of the departmental Q1 outputs that were co-authored with departmental colleagues and the range is again very wide, from a minimum of zero percent to a maximum of 74.5%.

Columns 6-9 of Table 1 contain the corresponding data for Q2 publications. Departments are more productive in terms of Q2 publications, with productivity of the research-active ranging from 0.19 to 5.40 pages per person per year (Column 7) and that of all members ranging from 0.05 to 2.77 (Column 8). Finally Column 9 contains the respective proportions co-authored by colleagues, the range being very similar to that for Q1 productivity.

Table 1 makes clear the fact that research productivity, whether measured for a restricted or a much broader collection of journals, was low on average across all departments and was driven in most departments by a relatively small group of active researchers. These data also suggest that attitudes or traditions towards co-authoring with colleagues within departments varied greatly. In some departments, as much as

75% of all journal articles were authored by departmental colleagues. In other departments, such collaboration was simply non-existent.

Of particular interest to us is whether departmental co-authorship, which can be regarded as a (strong) form of workplace collaboration, is positively related to research productivity. The last row of Columns 5 and 9 in Table 1 contains the simple correlation coefficients between, respectively, Q1 and Q2 departmental research productivities and the relevant proportions co-authored. In both cases there is a weak negative correlation between these two variables. Thus the research externalities identified by Fox and Milbourne are not manifest via co-authorship between departmental colleagues, at least not in simple correlations based on department-level data. In the next section we investigate this hypothesis using partial correlations based on data at the level of the individual.

III A model of research productivity

In this section we investigate the existence and nature of the human capital externality identified by Fox and Milbourne (2006) by estimating a model of the determinants of research productivity using data for individual academics. As a substantial proportion of academic economists in our data set have zero publications, we use a Tobit (Type I) model which allows for corner solutions. Equation (1) states the hypothesis that research output is related to human capital, research experience, a human capital externality, and some control variables as follows.

$$\log(output) = \max [lower\ limit,\ \beta_0 + \beta_1 phd1 + \beta_2 phd2 + \beta_3 phd3 + \beta_4 exp + \beta_5 (phd1*exp) + \beta_6 (phd2*exp) + \beta_7 gender + \beta_8 prof + \beta_9 aspro + \beta_{10} resuni + \beta_{11} size + \gamma_0 externality + \gamma_1 controls + u] \quad (1)$$

The *lower limit* is set just below the logarithm of the smallest positive research output in the data set (see Cameron and Trevedi, 2009, Section 16.4.2).[10] The dependent variable is the logarithm of research output because, unlike research output itself, the logarithm is approximately normally distributed over strictly positive output values (see Appendix 1). The error term, *u*, represents unobservable influences on *output* and is, by assumption, independent of the explanatory variables and Normal$(0,\sigma^2)$

Human capital is represented by three dummy variables, *phd1*, *phd2* and *phd3*, which equal one if, in the first year between 1996 and 2000 that the individual was employed in a given department, he or she had a PhD from an institution ranked 1-50, 51-150 or ≥151, respectively (in descending order of quality).[11] Experience, *exp*, is the number of years between when the PhD was conferred and the last year between 1996 and 2000 that the individual was employed in the given economics department. Individuals without a PhD have *exp* set equal to zero; they constitute the benchmark category to which others are compared. The two interaction terms allow experience to have a differential effect on research output, depending on the quality of the PhD.

Several control variables are also included in the model. The binary variable *gender*, which equals one if female, controls for any productivity differences between male and female academic economists. Two binary variables attempt to control for research ability and ambition to climb the academic ladder: *prof*, which equals one if the individual was a professor when first observed in the department, and *aspro* which equals one if the individual was an associate professor when first observed and was

[10] The Tobit I model assumes that each explanatory variable has the same effect on the probability of publishing as on the (log of the) number of pages published, given some publications were achieved. We checked this following the procedure suggested by Wooldridge (2009, p.595). A Probit model with the same explanatory variables was estimated and found to have coefficients with the same sign and of approximately the same magnitude as those of the Tobit I model.

[11] We used the rankings of PhD granting institutions in Kalaitzidakis *et al.* (2003). See Rodgers and Neri (2007) for more details.

awarded a PhD no more than ten years earlier. The binary variable *resuni*, which equals one if the individual is employed in a research-intensive university, takes account of broad institutional differences that might affect research productivity.[12] The variable, *size*, is the average number of academics in the department during the period 1996 through 2002. It is included to control for the effect of departmental scale on research productivity and on the propensity to co-author.[13]

Two versions of the model were estimated using the method of maximum likelihood: one with productivity measured in Q1-pages per year, the other with productivity measured in Q2-pages per year. The estimated coefficients in several specifications of each version of the model, and their levels of significance are displayed in Appendix 2 . All coefficients have the expected signs and most are statistically significant. Given the nonlinear nature of the Tobit model, the average partial effects (APEs) of the explanatory variables are of more interest than the coefficients. The APEs on the expected productivity of all economists are given in Table 2 for Q1 output and Table 3 for Q2 output.[14]

With the exception of the variable *resuni*, the APEs are approximately constant across the various specifications of the model. The APEs of the three human capital variables, *phd1*, *phd2* and *phd3*, indicate that having a PhD is very important for research productivity, particularly a PhD from a top 50 university in the case of Q1 publications. For example, the APEs of *phd1*, 3.300 and 1.995 in Tables 2 and 3 (Row

[12] The research intensive universities in our study are Adelaide, ANU, Melbourne, Monash, New South Wales, Queensland, Sydney, Tasmania and Western Australia.

[13] The inclusion of the variable *size* takes account of the fact that large departments offer more opportunity for co-authoring than small departments. If productivity is inversely related to department size *ceteris paribus*, and if more co-authoring occurs in large departments than in small departments, then excluding *size* would create a downward bias in the estimated effect of co-authoring.

[14] The APEs of the explanatory variables on the productivity of those economists who have some publications are given in Appendix 2. As expected they are larger than the APEs of the explanatory variables on the productivity of all economists but are interpreted similarly.

Table 2: Average Partial Effects on the log of Q1 Research Productivity of All Academics

	Specification 1		Specification 2		Specification 3		Specification 4		Specification 5		Specification 6	
	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value
phd1	3.300	0.000	2.956	0.000	3.071	0.000	2.892	0.000	3.301	0.000	2.961	0.000
phd2	2.274	0.000	2.125	0.000	2.228	0.000	2.135	0.000	2.280	0.000	2.125	0.000
phd3	2.124	0.000	2.149	0.000	2.134	0.000	2.141	0.000	2.151	0.000	2.165	0.000
exp	-0.050	0.000	-0.053	0.000	-0.047	0.000	-0.052	0.000	-0.051	0.000	-0.054	0.000
gender	-0.537	0.020	-0.513	0.019	-0.483	0.028	-0.476	0.033	-0.526	0.025	-0.506	0.023
prof	1.595	0.000	1.672	0.000	1.560	0.000	1.655	0.000	1.624	0.000	1.693	0.000
aspro	0.840	0.129	0.769	0.125	0.792	0.129	0.752	0.132	0.848	0.125	0.770	0.123
resuni	1.173	0.001	0.217	0.522	0.583	0.081	0.103	0.729	1.343	0.000	0.348	0.350
size	-0.017	0.215	-0.024	0.035	-0.010	0.382	-0.018	0.104	-0.023	0.110	-0.028	0.020
hc1_coll			0.044	0.003			0.033	0.040			0.045	0.002
hc2_coll			0.027	0.083			0.028	0.043			0.025	0.079
hc3_coll			0.010	0.254			0.011	0.162			0.010	0.241
pub_coll					2.228	0.000	1.250	0.129				
co-author									0.007	0.438	0.006	0.473

Standard errors are cluster-robust, where the clustering is by department.

Table 3: Average Partial Effects on the log of Q2 Research Productivity of All Academics

	Specification 1		Specification 2		Specification 3		Specification 4		Specification 5		Specification 6	
	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value
phd1	1.995	0.000	1.846	0.000	1.895	0.000	1.817	0.000	1.974	0.000	1.852	0.000
phd2	1.442	0.000	1.372	0.000	1.407	0.000	1.372	0.000	1.430	0.000	1.377	0.000
phd3	1.188	0.000	1.148	0.000	1.182	0.000	1.144	0.000	1.174	0.000	1.161	0.000
exp	-0.024	0.000	-0.026	0.000	-0.022	0.001	-0.025	0.000	-0.024	0.000	-0.026	0.000
gender	-0.302	0.013	-0.281	0.015	-0.294	0.017	-0.273	0.022	-0.302	0.013	-0.274	0.019
prof	0.840	0.000	0.873	0.000	0.812	0.000	0.858	0.000	0.842	0.000	0.880	0.000
aspro	0.510	0.026	0.444	0.039	0.489	0.031	0.438	0.046	0.508	0.026	0.425	0.050
resuni	0.542	0.005	0.164	0.334	0.294	0.114	0.125	0.363	0.479	0.027	0.184	0.259
size	-0.003	0.632	-0.003	0.564	-0.001	0.870	0.000	0.957	-0.001	0.887	-0.008	0.110
hc1_coll			0.017	0.033			0.010	0.142			0.022	0.003
hc2_coll			0.015	0.086			0.016	0.027			0.019	0.022
hc3_coll			0.012	0.002			0.012	0.001			0.017	0.000
pub_coll					0.253	0.007	0.170	0.194				
co-author									-0.004	0.353	0.008	0.030

Standard errors are cluster-robust, where the clustering is by department.

1) respectively, imply that an economist with a PhD from a top 50 university has expected research productivity that is ($e^{3.300}$ =) 27 times larger in the case of Q1 publications, and ($e^{1.995}$ =) 7.4 times larger in the case of Q2 publications, than that of an economist without a PhD. These are large effects, but given the median number of Q1 pages per year is zero and the median number of Q2 pages per year is 0.041 (see Appendix 1) they are not unreasonably large.

There is a statistically significant difference between the effects of *phd1* and *phd2* and also between *phd1* and *phd3* on the production of Q1 publications. For example, compared with an economist with a PhD from an institution ranked 51-150, an economist with a PhD from a top 50 institution is predicted to have ($e^{(3.300-2.274)}$ =) 2.8 times more Q1 research output per annum. However, the difference between the effect of *phd2* and *phd3* on Q1 productivity is not statistically significant in any of the specifications of the model. On the other hand, there are no statistically significant differences among the effects of *phd1*, *phd2* and *phd3* on Q2 research productivity.

Productivity declines with the years since the PhD was awarded, by about five per cent per year in the case of Q1 publications and a little more than two per cent per year for Q2 publications. The APE of *gender* implies that the Q1 and Q2 productivity of females is about ($e^{-0.537}$ =) 0.6 and ($e^{-0.302}$ =) 0.7, respectively, that of males. The control variables, *prof* and *aspro*, indicate that academic status when first observed in the data set is directly related to productivity during the following years. Compared with other academic economists, professors are ($e^{1.595}$ =) 4.9 and ($e^{0.840}$ =) 2.3 times more productive in Q1 and Q2 publications, respectively; 'fast-track' associate professors are ($e^{0.840}$ =) 2.3 and ($e^{0.510}$=) 1.7 times more productive, although the former is not statistically significant. The size of the economics department, *size*, has no

statistically significant effect on Q2 research productivity and has a small, negative, but only marginally significant, effect on Q1 research productivity. The APE of working in a research-intensive university is highly significant in Specification 1, suggesting that academic economists at research-intensive universities produce ($e^{1.173}$ =) 3.2 times more Q1 pages per year, and ($e^{0.542}$ =) 1.7 times more Q2 pages per year, than other economists. However, in most other specifications the APE of *resuni* is much smaller and not statistically significant, the interpretation of which is explored below.

We now turn our attention to the existence of a human capital externality. Fox and Milbourne (2006) found that the research productivity of economists who responded to their survey increased with a proxy measure of the human capital of their departmental colleagues, namely their lifetime annual productivity. By contrast we use direct measures of human capital. In Tables 2 and 3, Specification 2, the externality is measured using three variables: the percentage of one's departmental colleagues who have a PhD from a top 50 university (*hc1_coll*), from a university ranked 51-150 (*hc2_coll*) and from a university of lower rank (*hc3_coll*).[15] For Q1 productivity, having colleagues with a PhD from a top 50 university creates a positive externality: a one percentage point increase in the percentage of one's colleagues with a PhD from a top 50 university increases one's own productivity by 4.4 per cent. The APE of *hc2_coll* is about half that size (2.7 per cent) and is statistically significant only at the ten per cent level. The APE of *hc3_coll* is even smaller and not statistically significant. This indicates that the externality is driven primarily by the most highly qualified subset of one's colleagues.

There is also a statistically significant positive human-capital externality in the production of Q2 research output although its size is quite small and varies little with

[15] The residual category is the proportion of one's co-workers without a PhD.

the origin of the PhD: a one percentage point increase in the percentage of one's colleagues with a PhD from a top 50 university increases one's own Q2 productivity by 1.7 per cent while the APEs of *hc2_coll* and *hc3_coll* are 1.5 per cent and 1.2 per cent, respectively. All these effects are statistically significant at the 10 per cent level and two of them are statistically significant at the 5 per cent level.

The APE of working in a research-intensive university, which is large and highly significant in Specification 1, declines substantially in size and becomes statistically non-significant once the human-capital of departmental colleagues is included in the model. This suggests that *resuni* in Specification 1 is capturing the propensity of research-intensive universities to hire well trained academics; beyond that their effect on research productivity is little different to that of other universities.

Next, we consider an alternative, indirect measure of the externality, namely, the contemporaneous, rather than lifetime, productivity of co-workers, which is measured by the variable *pub_coll*. Unlike the Fox and Milbourne (2006) analysis, the use of *pub_coll* assumes that for a research externality to exist between two academic economists, the two people must be present in the same department during the same period of time. When *pub_coll* replaces *hc1_coll*, *hc2_coll* and *hc3_coll* in Specification 2 of Tables 2 and 3 we get Specification 3. The APE of *pub_coll* on Q1 productivity is large and highly significant: a one-page increase per annum in the Q1 output of departmental colleagues is associated with a 222.8 per cent increase in the individual's Q1 productivity. Once again, to put this in perspective keep in mind that on average academics have Q1 productivity of only 0.144 pages per annum and more than 50 per cent of academics have no Q1 output at all. The APE of *pub_coll* on Q2 productivity is smaller, though still statistically significant: a one-page increase per annum in the contemporaneous Q2 output of departmental colleagues is associated

with a 25.3 per cent increase in the individual's Q2 productivity. The mean and median Q2 productivities of all academic economists in the data set are 0.807 and 0.041 pages per annum, respectively, which makes the APE of *pub_coll* a modest increase. This result implies that individuals with contemporaneously highly research-active co-workers are more productive, *ceteris paribus*, than individuals with colleagues who are less contemporaneously research active. This result also confirms the conclusion of Fox and Milbourne (2006), which is based on lifetime research output per year.

When *pub_coll* as well as *hc1_coll*, *hc2_coll* and *hc3_coll* are all included in the model, as in Specification 4, the APE of *pub_coll* on both Q1 and Q2 productivity is much reduced in magnitude compared with Specification 3 and is no longer statistically significant. There is evidently a positive relationship between the human capital and the research productivity of one's departmental co-workers because the APE of *hc1_coll* on both Q1 and Q2 productivity becomes smaller, and the latter is no longer significantly different from zero. However, the APEs of *hc2_coll* and *hc3_coll* on both Q1 and Q2 productivity are little changed in Specification 4 compared with Specification 2. Although these results reinforce the conclusion of Fox and Milbourne (2006) that the externality is associated with the extent to which one's departmental colleagues are research active, the direct measure of the human capital of colleagues is better able to explain research productivity than the indirect measure.

Finally, we turn to the question of whether the human-capital externality becomes manifest via co-authoring. In Tables 2 and 3, Specification 5, the variables *pub_coll*, *hc1_coll*, *hc2_coll* and *hc3_coll* in Specification 4 are replaced by the variable *co-author*, which is the percentage of each department's published pages that involve co-authoring with at least one colleague from the same department. We find no

evidence that co-authoring affects research productivity. To the contrary, the APE of co-authoring on both Q1 and Q2 publications is very small and not remotely statistically significant. The APEs of the other explanatory variables are approximately the same as in Specification 2, with the exception of *resuni*, which is larger and marginally statistically significant.

Specification 6 includes both *co-author* and the human-capital measures. The APE effect of *co-author* on Q1 productivity remains small and statistically non-significant, as it was in Specification 5. The APEs of *hc1_coll*, *hc2_coll* and *hc3_coll* on Q1 productivity retain approximately the same magnitudes and levels of significance as in Specification 2. These outcomes suggest there is little relationship between the propensity to co-author and the human capital of one's colleagues. However, the situation is a little different with respect to Q2 productivity where the APE effect of *co-author* remains small but becomes positive and statistically significant at the five per cent level. Also, the APEs of *hc1_coll*, *hc2_coll* and *hc3_coll* on Q2 productivity increase slightly and become more statistically significant in Specification 6 compared with Specification 2. This is consistent with a negative correlation between the human-capital of one's departmental colleagues and the extent of co-authoring within a department, This is the only result in support of the hypothesis that co-authorship enhances research productivity, although the effect is small, a one percentage point increase in the percentage of departmental output that is co-authored increases one's own Q2 productivity by 0.8 per cent.

IV Conclusion

This study investigated whether a human capital externality boosted the research productivity of academics in Australian economics departments from 1996 to

2000, as measured by the number of pages published per year in scholarly journals. We extended the work of Fox and Milbourne (2006) by using a direct, rather than an indirect, measure of the human capital of one's departmental colleagues. Doing so, we conclude that a one percentage point increase in the percentage of departmental colleagues with a PhD from a top 50 university increases the individual's productivity by between two and four per cent on average, depending upon the quality of the journal outlet. We also found that the contemporaneous productivity of co-workers had a large effect on the individual's productivity, which supports the Fox and Milbourne (2006) assertion that the externality is associated with the extent to which one's departmental colleagues are research active. However, once we controlled for their educational qualifications the contemporaneous productivity effect was no longer apparent.

The way in which the externality becomes manifest remains unclear but, after controlling for other factors, we find no evidence that it does so via departmental co-authoring. Whilst there may be other reasons for encouraging collaboration between colleagues, this finding casts doubt on the efficacy of departmental research incentive schemes which seek to encourage co-authorship as a way of boosting research productivity.

It is possible that co-authoring is a response to workplace conditions or personal attributes that have a negative effect on productivity and which, not being included in the model, impart a negative bias to our measure of the effect of co-authoring on productivity. On the other hand, there are mechanisms other than co-authoring that are consistent with the existence of a human capital externality. For example, there may be demonstration effects, peer pressure effects or competition to out-publish one's colleagues among academics with high levels of human capital.

Alternatively there may be a weaker form of cooperative interaction where people contribute to each other's research output without requiring 'payment' in the form of co-authorship. Sorting out these influences remains a topic for further research.

A related question, which we do not investigate here, is whether the wide disparities in co-authorship rates across departments observed in the late 1990s have persisted in the decade since 2000 when research has become increasingly important to career advancement and, if so, why such large differences exist in what might be regarded as one aspect of departmental 'tradition'.

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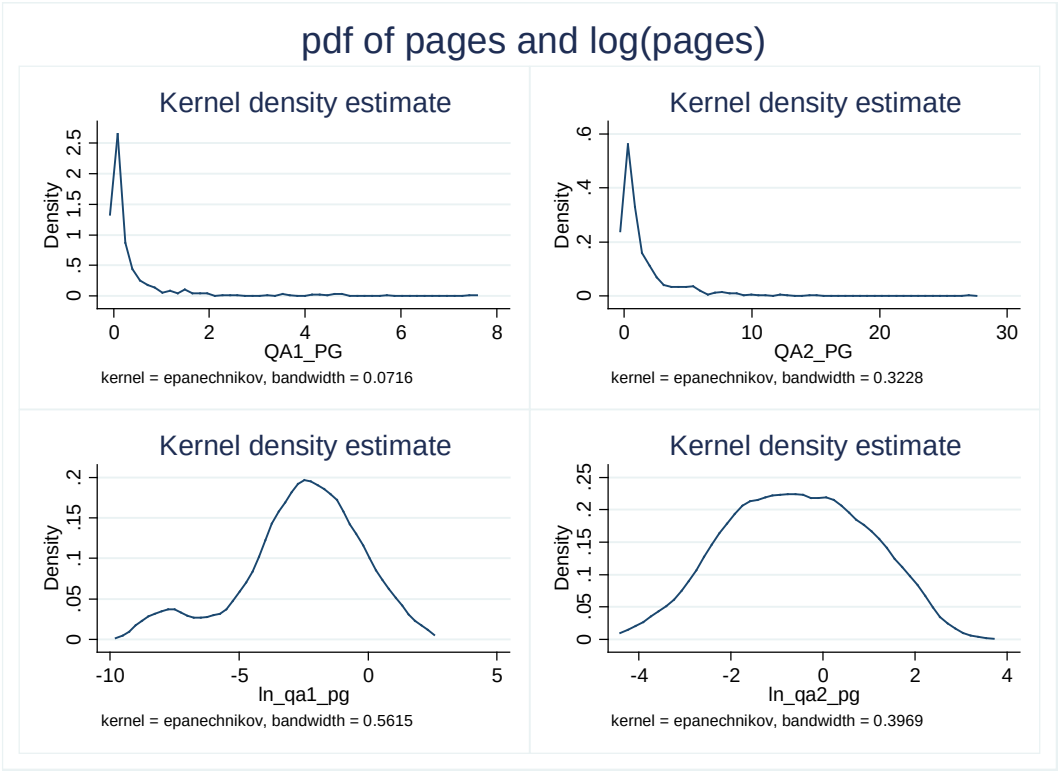
Appendix 1

Variable	Obs	Mean	S.D	Min	Max	Median	Skew-ness	Kurt-osis
Q1_pages	871	0.144	0.582	0	7.511	0	7.095	63.890
Q2_pages	871	0.807	2.009	0	27.244	0.041	5.357	48.070
ln(Q1_pg)	290	-2.586	2.298	-9.210	2.016	-1.284	-0.693	3.354
ln(Q2_pg)	451	-0.556	1.497	-4.001	3.305	-0.534	-0.013	2.326



Appendix 2

Tobit Estimation of the log of Q1 Research Productivity												
	Specification 1		Specification 2		Specification 3		Specification 4		Specification 5		Specification 6	
	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value
phd1	13.004	0.000	11.753	0.000	12.168	0.000	11.514	0.000	12.990	0.000	11.746	0.000
phd2	9.582	0.000	9.058	0.000	9.390	0.000	9.073	0.000	9.603	0.000	9.060	0.000
phd3	8.713	0.000	8.704	0.000	8.635	0.000	8.641	0.000	8.826	0.000	8.770	0.000
exp	-0.111	0.018	-0.133	0.002	-0.106	0.033	-0.129	0.005	-0.115	0.011	-0.136	0.002
*exp*phd1*	-0.161	0.026	-0.115	0.092	-0.137	0.049	-0.110	0.108	-0.154	0.030	-0.110	0.105
*exp*phd2*	-0.050	0.493	-0.047	0.508	-0.056	0.439	-0.050	0.477	-0.047	0.521	-0.045	0.529
gender	-1.867	0.031	-1.774	0.032	-1.663	0.043	-1.635	0.050	-1.825	0.038	-1.746	0.037
prof	4.534	0.000	4.697	0.000	4.422	0.000	4.647	0.000	4.603	0.000	4.744	0.000
aspro	2.602	0.085	2.396	0.087	2.452	0.090	2.343	0.095	2.625	0.081	2.399	0.086
resuni	3.814	0.001	0.712	0.528	1.905	0.092	0.336	0.732	4.348	0.000	1.142	0.359
size	-0.057	0.227	-0.078	0.039	-0.033	0.387	-0.057	0.106	-0.074	0.121	-0.092	0.022
hc1_coll			0.146	0.002			0.109	0.036			0.149	0.001
hc2_coll			0.090	0.090			0.093	0.046			0.082	0.085
hc3_coll			0.031	0.255			0.037	0.162			0.033	0.240
pub_coll					7.294	0.000	4.092	0.131				
co-author									0.024	0.436	0.021	0.473
constant	-17.678	0.000	-20.88	0.000	-18.453	0.000	-21.365	0.000	-17.827	0.000	-21.009	0.000
sigma	6.612	0.000	6.434	0.000	6.494	0.000	6.405	0.000	6.601	0.000	6.425	0.000
log-like'd	-1216.1		-1200.6		-1207.6		-1198.7		-1215.4		-1200.1	

Standard errors are cluster-robust, where the clustering is by department.

Appendix 2 continued

Tobit Estimation of the log of Q2 Research Productivity												
	Specification 1		Specification 2		Specification 3		Specification 4		Specification 5		Specification 6	
	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value
phd1	5.604	0.000	5.183	0.000	5.349	0.000	5.116	0.000	5.552	0.000	5.181	0.000
phd2	4.295	0.000	4.087	0.000	4.187	0.000	4.072	0.000	4.261	0.000	4.098	0.000
phd3	3.319	0.000	3.174	0.000	3.265	0.000	3.152	0.000	3.277	0.000	3.209	0.000
exp	-0.017	0.384	-0.026	0.175	-0.015	0.468	-0.024	0.222	-0.018	0.349	-0.026	0.176
*exp*phd1*	-0.098	0.000	-0.084	0.000	-0.092	0.000	-0.084	0.001	-0.097	0.000	-0.082	0.001
*exp*phd2*	-0.053	0.024	-0.052	0.023	-0.053	0.024	-0.052	0.024	-0.054	0.024	-0.051	0.023
gender	-0.728	0.020	-0.672	0.021	-0.705	0.023	-0.650	0.029	-0.728	0.018	-0.654	0.027
prof	1.721	0.000	1.772	0.000	1.664	0.000	1.743	0.000	1.724	0.000	1.782	0.000
aspro	1.106	0.016	0.969	0.029	1.059	0.021	0.956	0.034	1.102	0.017	0.930	0.038
resuni	1.231	0.004	0.374	0.334	0.670	0.114	0.286	0.365	1.091	0.023	0.420	0.260
size	-0.008	0.633	-0.007	0.564	-0.002	0.871	-0.001	0.957	-0.003	0.887	-0.017	0.108
hc1_coll			0.038	0.027			0.023	0.139			0.050	0.002
hc2_coll			0.035	0.094			0.036	0.029			0.043	0.026
hc3_coll			0.027	0.002			0.027	0.001			0.038	0.000
pub_coll					0.581	0.007	0.390	0.190				
co-author									-0.008	0.349	0.018	0.029
constant	-6.086	0.000	-7.760	0.000	-6.428	0.000	-7.907	0.000	-5.983	0.000	-8.581	0.000
sigma	2.799	0.000	2.764	0.000	2.775	0.000	2.755	0.000	2.798	0.000	2.756	0.000
log-like'd	-1363.5		-1352.6		-1358.6		-1351.1		-1362.8		-1350.6	

Standard errors are cluster-robust, where the clustering is by department.

Appendix 3

Average Partial Effects on the log of Q1 Research Productivity of Academics with Some Publications												
	Specification 1		Specification 2		Specification 3		Specification 4		Specification 5		Specification 6	
	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value
phd1	3.836	0.000	3.351	0.000	3.528	0.000	3.268	0.000	3.827	0.000	3.351	0.000
phd2	2.417	0.000	2.231	0.000	2.371	0.000	2.250	0.000	2.416	0.000	2.226	0.000
phd3	2.212	0.000	2.260	0.000	2.241	0.000	2.255	0.000	2.240	0.000	2.275	0.000
exp	-0.063	0.000	-0.066	0.000	-0.059	0.000	-0.064	0.000	-0.064	0.000	-0.066	0.000
gender	-0.629	0.016	-0.602	0.015	-0.565	0.023	-0.558	0.027	-0.616	0.020	-0.593	0.018
prof	2.009	0.000	2.097	0.000	1.954	0.000	2.071	0.000	2.046	0.000	2.122	0.000
aspro	1.034	0.145	0.941	0.136	0.969	0.143	0.918	0.144	1.044	0.141	0.941	0.135
resuni	1.428	0.001	0.261	0.521	0.703	0.077	0.123	0.729	1.636	0.000	0.420	0.348
size	-0.021	0.209	-0.029	0.034	-0.012	0.379	-0.021	0.102	-0.027	0.105	-0.034	0.020
hc1_coll			0.053	0.004			0.040	0.043			0.054	0.002
hc2_coll			0.033	0.083			0.034	0.044			0.030	0.079
hc3_coll			0.012	0.256			0.013	0.165			0.012	0.243
pub_coll					2.664	0.000	1.497	0.128				
intra									0.009	0.439	0.008	0.473

Standard errors are cluster-robust, where the clustering is by department.

Appendix 3 continued

Average Partial Effects on the log of Q2 Research Productivity of Academics with Some Publications												
	Specification 1		Specification 2		Specification 3		Specification 4		Specification 5		Specification 6	
	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value	coeff	p-value
phd1	2.650	0.000	2.447	0.000	2.517	0.000	2.408	0.000	2.623	0.000	2.452	0.000
phd2	1.915	0.000	1.816	0.000	1.867	0.000	1.817	0.000	1.900	0.000	1.820	0.000
phd3	1.564	0.000	1.509	0.000	1.556	0.000	1.503	0.000	1.546	0.000	1.524	0.000
exp	-0.031	0.000	-0.034	0.000	-0.029	0.000	-0.033	0.000	-0.032	0.000	-0.034	0.000
gender	-0.393	0.013	-0.365	0.015	-0.381	0.016	-0.353	0.021	-0.393	0.012	-0.355	0.019
prof	1.095	0.000	1.131	0.000	1.056	0.000	1.111	0.000	1.097	0.000	1.138	0.000
aspro	0.668	0.025	0.578	0.038	0.638	0.030	0.570	0.045	0.665	0.025	0.553	0.048
resuni	0.715	0.005	0.213	0.338	0.386	0.117	0.163	0.366	0.632	0.028	0.240	0.263
size	-0.005	0.632	-0.004	0.564	-0.001	0.870	0.000	0.957	-0.001	0.887	-0.010	0.110
hc1_coll			0.022	0.032			0.013	0.141			0.029	0.003
hc2_coll			0.020	0.086			0.020	0.027			0.024	0.022
hc3_coll			0.015	0.002			0.015	0.001			0.022	0.000
pub_coll					0.329	0.007	0.221	0.194				
intra									-0.005	0.354	0.010	0.030

Standard errors are cluster-robust, where the clustering is by department.