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Science and the University: Challenges for Future Research

Paula E. Stephan*

Abstract

Scientific research has played a critical role in the life of the university for a considerable period of time, both in Europe and in the US. While much remains the same in the relationship between science and the university, considerable change has occurred in recent years. Here we outline three changes in this relationship, focusing both on the consequences for the university and on questions of research interest to those interested in higher education. The three changes are: (i) increased incentives to publish; (ii) changes in the reward system and (iii) increased reliance by governments and communities on universities and institutes as a source of economic growth. (JEL codes: I23)

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1 Increased incentives to publish

The incentive to publish in scientific journals has increased considerably in recent years, both at the system level and at the individual level. Examples of this are everywhere: the budgets of universities and departments in certain countries depend heavily on publication and citation counts. Funding for the research of individual scientists depends increasingly on the publication track record of the scientist; in certain countries bonus payments are made, based on publications.

By way of example, in the United Kingdom the ranking of departments and the allocation of department funds, undertaken by the Research Assessment Exercise, are based in part on publication and citation counts. A somewhat similar system exists in Australia and an increasing share of funding for Flemish universities is now based on research performance as evaluated through publication and citations. In the Netherlands, publications and citation counts play a key role in determining the reputation of a university, although they do not figure into the allocation of funds for the university/department. At the individual level, publication and citations play a key role in garnering research resources. For example, the publication record of the scientist plays a key role in the evaluation of

* Andrew Young School of Policy Studies, Georgia State University and NBER, University Plaza, Atlanta, GA 30303-3992, USA, e-mail: pstephan@gsu.edu. This article is based on a presentation that Stephan made at the CESifo Economic Studies on Economics of Higher Education Conference, 18–19 July 2007, San Servola, Venice. We wish to thank Bill Amis, Reinhilde Veugelers and Rick van der Ploeg for comments on an earlier draft of this article.

grant applications submitted to the National Institutes of Health in the United States (NIH), with a $29 billion budget. Likewise, and by way of example, the Flemish Science Foundation makes research awards to applicants based in part on their reputation as established through publication. Chinese researchers who place in the top half of colleagues in terms of bibliometric measures can earn three to four times the salaries of co-workers (Hicks 2007). Some Chinese institutes pay cash bonuses for publishing in *Science*, *Nature* and *Cell*.

The increased emphasis on publication affects the publication strategies of faculty, the level of competition at journals and the hiring strategy of departments. Faculty arguably are paying more attention to where they submit an article for publication, with whom they co-author and how they carve the research up into publications—or what some would call "least publishable unit" or LPU (Stephan and Levin 1992). An imminent life scientist in the US recounted to us how his European co-authors consistently aimed at the top journal *Science*, even when he felt the research did not merit publication in *Science*. Although he understood the incentive for aiming so high, he was frustrated by the lag this created between completing the research and publishing the research.

The increased emphasis on publication (and publication at top journals) has arguably increased the level of competition at journals and the demand for new journals. While the latter is well documented, the increased level of competition at journals, and how it relates to changing incentives to publish, has not been addressed to the best of our knowledge and invites investigation (see subsequently). A related consequence is that the need for referees is growing. Journals (and funding agencies) increasingly report a "shortage" of knowledgeable reviewers. Study groups at NIH (where review occurs) have reduced the amount of time they spend reviewing proposals in response to the demand from reviewers to spend less time away from their labs.

A major news article in 2004 in the US (front page headline in the *New York Times*) concerned the decline in article counts written by US scientists and engineers (Broad 2004). More recently the National Science Foundation (2007) has released a report showing how US output has fared relative to other countries (Figure 1). Hicks (2007) and others have argued that the decline relates to the changing incentive structure: US scientists now face considerably more competition than in the past as incentives to publish have grown outside the US.

Increased reliance on reputation for the awarding of grants and department funds has also led to changes in hiring practices. The market for stars (especially just before the evaluation of departments and programs) is fierce—what one might call "just-in-time hiring". Highly cited scientists are routinely sought by universities and departments to

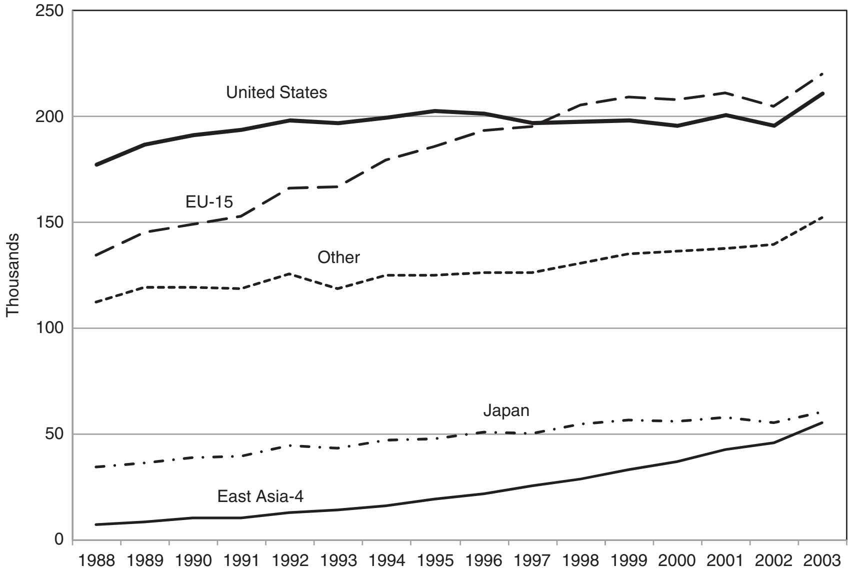

Figure 1 S&E article output (fractional counts) of major S&E publishing centers: 1988–2003. S&E = science and engineering, EU = European Union. *Notes*: Article counts are on a fractional basis, i.e. for articles with collaborating institutions from multiple publishing centers, each publishing center receives fractional credit on the basis of the proportion of its participating institutions. East Asia-4 includes China, Singapore, South Korea and Taiwan. China includes Hong Kong
Source: National Science Foundation (2007, Figure 6)

enhance their funding chances (senior faculty with strong research records have a high probability of bringing large grants, thus offsetting some of the growing costs associated with research). Moreover, such offers often are accompanied with sufficient flexibility to permit the researcher to remain in the current position while accepting a position at the new institution as well. Such strategies are not limited to the West. In recent years China has sought ‘‘trophy’’ professors, allowing them to maintain their full-time position overseas, while paying them handsomely for short working stints in China (Normile 2006).

The emphasis on stars has consequences for newer cohorts of scientists. In the US, for example, the age distribution of faculty is changing (see Figure 2, for an example of the biomedical sciences). Universities are hesitant to hire junior faculty, whose research records (and funding records) have yet to be established. Instead, they prefer senior faculty with strong research records. These same senior faculties rely on graduate

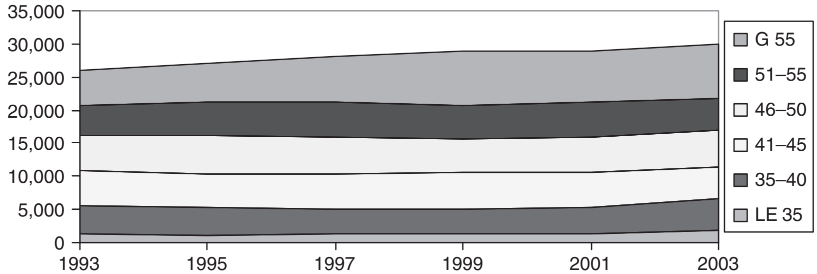

Figure 2 Tenure track biomedical faculty by age
Source: Survey of Doctorate Recipients, NSF. The use of NSF data does not imply NSF endorsement of the research methods or conclusions contained in this report

students and postdocs and other ‘‘temporary’’ workers to staff their faculty research labs. Richard Freeman estimates that the ratio of postdocs to tenured-faculty positions in the life sciences in the US grew from 0.54 to 0.77 between 1987 and 1999 (a 43 percent increase) (Stephan forthcoming). The increase in the number of postdoctoral positions is due to both supply and demand factors. On the supply side, there is an increased number of newly-awarded PhDs in the biomedical sciences. On the demand side, these newly-minted PhDs have been experiencing difficulty in finding tenure-track jobs as universities have reduced the ratio of tenure-track positions to non-tenure track positions. At the same time, the demand for postdoctoral positions has been augmented because of the dramatic increase in funds available to hire postdoctoral students.[1] The situation is not limited to the US. Schulze (forthcoming) shows that the number of Habilitationen in Germany grew from approximately 1,300 in 1992 to 2,300 in 2004. In terms of Habilitationen per 100 professors, this represents more than a 66 percent increase.

There is a need for systematic research into these observations. Research questions include: (i) how the composition and number of submissions to journals relates to changing incentives; (ii) how hiring patterns and associated mobility of faculty have responded to changes in incentives; (iii) the degree to which the distribution of university salaries has changed; the (iv) the degree to which the market for ‘‘dual positions’’ has increased and (v) the effects of these trends on the quality of research.

[1] Stephan and Ma (2005) find a strong negative relationship between taking a postdoc position after graduation and the demand for academic positions, as measured by the percentage change in total current fund revenue for public institutions. Demand for postdocs, especially in the life sciences, grew dramatically in the US between 1998 and 2003 when the NIH budget doubled.

2 Change in the reward system for university scientists

The earnings profile of university scientists has traditionally been relatively flat over the career. Ehrenberg (1991) for example, estimated that the average salary of a full professor in the physical and life sciences in the US was approximately 1.7 times that of an assistant professor. The shape of the profile relates arguably to monitoring problems and the need to compensate scientists for the risky nature of their work (Stephan forthcoming). The flat shape of the profile is reinforced in countries where scientists are civil-service employees.

In addition to the increase in salaries associated with increased competition, scientists increasingly have opportunities to enhance their earnings. They can do so by consulting with industry, by patenting and receiving associated royalty payments, by starting-up companies, or by serving on the advisory board of a start-up company. These changing opportunities affect the shape of the earnings profile for those who participate in these various forms of technology transfer. Given the highly skewed nature of patenting and the even more highly skewed nature of licensing and royalty revenues, these enhanced income effects are not widely experienced by the average scientist. Yet, by increasing the amount of inequality in the reward structure of science they arguably affect the fabric of scientific collaboration as well as the satisfaction that average scientists experience from their work.

Thursby and Thursby (2007), for example, find that 10.3 percent of US faculty at top universities discloses an invention to their university. While not all disclosures are patented, many are. The number of US patents assigned to universities has increased by a factor of 2.6 during the past 10 years from 1993 to 2003 (National Science Board 2006, tables 5–28). It is increasingly common for faculty to patent in Europe as well. While it is more difficult to count patents attributed to European university faculty (since more are assigned outside the university), the work of Lissoni et al. (2007) suggests that the rate at which faculty are patenting in Europe is not substantially different from that in the US.

Faculty receives royalty payments associated with these patents. While the percent that faculty receives varies across university, the amount they receive has definitely increased as royalty payments have grown. In the US, for example, between 1993 and 2003 royalty payments received by universities grew from $195 million to $867 million. In rare instances the royalty stream produced by a patent is extraordinary. For example, Emory University in July 2005 sold its royalty interests in emtricitabine, also known as Emtriva®, and used in the treatment of HIV, to Giliad Sciences, Inc. and Royalty Pharma. The University received $525 million (US). The three Emory University scientists involved received approximately 40 percent of the sale price, reflecting the university policy that was in place at the time (http://sec.edgar-online.com/2005/08/04/0001193125-05-157811/Section7.asp).

Another way in which faculty can earn extra income and enhance wealth is through involvement in a start-up company. The greatest rewards to such involvement come when (and if) the company goes public. Sometimes the rewards are of staggering proportions, at least on paper. A case in point is Eric Brewer, a computer scientist at UC Berkeley, who was listed on *Fortune* magazine's list of the 40 richest Americans under 40 in October 1999 with a net worth of $800 million (US), a result of the role he played in founding a company that went public in 1998 (Wilson 2000). Edwards, Murray and Yu (2006) document that, in the event a biotechnology firm makes an initial public offering, the median value of equities held by an academic with formal ties to the company, based on the IPO's closing price, ranged from $3.4 million to $8.7 billion, depending upon the period analyzed. The incidence of being on a scientific advisory board (SAB) is non-trivial. Ding, Murray and Stewart (2006) identify 785 academic scientists who are members of one or more SABs of companies that made an initial public offering in biotechnology in the US. Stephan and Everhart (1998) find 420 university scientists working with 52 biotech firms that made an initial public offering in the early 1990s. Members of such boards generally hold equity in the firm as well as receive annual compensation for attendance at meetings.

Changes in the reward structure (and the competition associated with such a change) arguably affect access to materials and information. Walsh, Cho and Cohen (2007) find that 19 percent of material requests made by their sample were denied. Competition among researchers played a major role in refusal. The cost of providing the material also was important, as well as whether the material in question was a drug or whether the potential supplier had a history of commercial activity. Research by Blumenthal and his colleagues (1997) suggests that faculty involvement with companies can delay the speed with which faculty publishes and their willingness to talk openly about their research. Heller and Eisenberg (1998) argue that increased patenting by university faculty, and the multiple property rights associated with such patents (sometimes in the hundreds, as in the case of genes) can dampen research by requiring researchers to bargain across multiple players to gain access to foundational upstream discoveries.

There is also the question of whether the focus on patenting detracts from publishing. While the presence of time in the production function for knowledge suggests that patenting and publishing may be substitute activities, there are good reasons to argue that complementarity is more likely and that patents can be a logical outcome of research activity that is designed first and foremost with an eye to publication. The reasons for complementarity are three-fold. First, the results of research, especially research in Pasteur's Quadrant, can often be both patented and published, having a dual nature. Second, the increased opportunities that academic researchers have to work with industry may enhance productivity and encourage patenting. Third, the reward structure in academe encourages patenting as one outcome of research.

A handful of studies in recent years have examined the relationship of publishing to patenting (Agrawal and Henderson (2002); Carayol (2007); Calderini, Franzoni and Vezzulli (2007) and Stephan et al. (2007). While various methodological issues arise, such as endogeneity, most find evidence that publishing and patenting are complementary rather than substitute activities. Researchers have also examined the relationship between patenting and publishing. Azoulay, Ding and Stuart (2006), for example, examine the impact of patenting on the publication activity of university researchers working in areas related to biotechnology and find that patenting has a positive effect on publication. Markiewicz and DeMinin (2004) also find patents to have a positive and significant effect on publication production of university researchers in their sample of US scientists, as do Breschi, Lissoni and Montobbio (2007) in a study of Italian scientists.[2]

Changes in the reward structure and the competition associated with such changes can also have consequences for students (Stephan 2001). On the positive side, faculty involvement with industry can provide job opportunities, create research opportunities and influence the curriculum. But the changing nature of the reward structure can also have negative effects on students. Conflict can arise between the faculty member and the student concerning the attribution of credit for an invention. Faculty may choose to allocate less time to students as they focus increasingly on technology transfer. And peer learning can also be affected. There is considerable evidence that students learn from students (Hoxby 2000; Sacerdote 2001; Symons and Robertson 1996; Zimmerman 2003). Yet an increased emphasis on patenting can discourage peer learning. A principal investigator recounted to the author how he told an undergraduate working in his lab that, for patent purposes, she should not identify the compound they were working on. To which she reportedly replied: "Oh, I know that. In the lab I worked in last summer we didn't talk about anything."

[2] Their research suggests that the positive effect is not due to patenting *per se* but to advantages derived by having strong links with industry.

Some of these consequences, such as access to information and cell lines, have been investigated already. Other questions remain wide open for investigation. These include changes in the shape of the earnings profile when the definition of earnings is expanded to include royalty payments, consulting fees, etc.; changes in the distribution of faculty earnings and the degree to which the process of technology transfer affects peer learning. There is also the issue, once again, as to how these trends affect the quality of research and by way of extension the accumulation of scientific knowledge.

3 Increased emphasis on universities as a source of growth

Considerable evidence exists that science is a source of economic growth (Adams 1990). There is also considerable evidence that knowledge spillovers are geographically bounded (Acs, Audretsch and Feldman 1992; Jaffe 1989). This has led governments and communities to invest in universities and programs with the expectation that they will create more Silicon Valleys and Route 128's. For example, the news from Texas in August of 2006 was that the state had decided to invest \$2.5 billion for science teaching and research in the University of Texas system. The primary focus was to build the research capacity of San Antonio, El Paso and Arlington (all cities in Texas) with the goal of turning these into the next Austin. Texas is not alone. The University of California system recently built a new campus at Merced. Many argue that a leading factor in establishing the new campus was the desire to turn the San Joaquin Valley into another Silicon Valley. Many states in the US possess biotech initiatives as do many European countries. Initiatives are underway in other areas. Singapore is one case in point.

The consequences of this increased emphasis are several: it augments the competition for stars, discussed earlier and it can create excess capacity, much like the situation where cities build sports arenas with the belief that "if we build it they will come". An emphasis on local economic development also affects the technology transfer process. Belenzon and Schankerman (2007) find, for example, that "universities with strong local development objectives generate about 30 percent less income per license". Belenzon and Schankerman also find that such universities are more likely to license to local (in-state) startup companies. Perhaps most importantly, the focus on economic development may ultimately affect the university's ability to garner resources in the future. If universities cannot deliver the level of regional economic growth that the public anticipates, especially within the time frame that states expect, the public's enthusiasm for supporting universities may diminish. Adams (1990) finds extremely long lags between research and economic growth, on the magnitude of 20–30 years.

Clearly we need more than anecdotal evidence regarding the local growth story. Granted, the importance of proximity to knowledge sources has been demonstrated in much of the work on spillovers. But this is a long way from demonstrating a relationship between knowledge production and local economic growth. There is a need to create systematic longitudinal databases to track economic development associated with local science initiatives. Questions to be analyzed include, but are not limited to, the degree to which growth is ‘‘local’’ vs. national and international and the period of time required to realize benefits.

4 Conclusion

We have identified three changes occurring in the relationship between science and the university. The three are: (i) increased incentives to publish; (ii) changes in the nature of the reward system and (iii) an increased reliance by governments and communities on universities as a source of local and regional economic growth. These changes in turn have led to changes in hiring practices, decreased opportunities for newer cohorts to engage in research, especially research directed by themselves, changes in the availability of materials and information used in research, changes in the peer learning environment, changes in publication practices, and increased expectations from the public regarding what the university can contribute to economic development.

Much of our discussion concerning the consequences of these changes has relied on anecdotal evidence. There is a need to systematically examine the relationship between these changes and some of the outcomes discussed in this article. For example, we need to know (i) the degree to which changing incentives affect submission behavior and referee behavior; (ii) how changing practices in compensation affect the shape of the earnings profile and the distribution of earnings; (iii) the degree to which faculty have become more mobile and the extent to which faculty, especially star faculty, hold dual positions; (iv) the degree to which ‘‘knowledge’’ initiatives create local economic development. Finally, and most importantly, is the need to have a clear understanding of how the three trends that we have chosen to focus on affect the quality of research and hence the accumulation of scientific knowledge.

Changes in policy are most effective when they are accompanied by research that evaluates and examines the effects of the policy. Such evaluation and examination, alas, require the systematic collection of data. A necessary step in answering these, as well as other questions is to begin the systematic collection of data.

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