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Public and Private Universities: Unequal Sources of Regional Innovation?

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Abstract

Public universities occupy a unique place in the research and development system of the United States due to their state-controlled missions, sources of funding, and administrative structures. State governments support public university research, which benefits local industry and stimulates innovation-based economic development. This paper examines the geographic distribution of university patent citations over the years 1975 to 2000 to test if public university research spillovers are more likely to be localized at the state level as compared to those of private universities. I find little evidence in support of this hypothesis, but a positive association between the quality of academic research and localization of resulting spillovers. Public universities should emphasize research quality as a means of fulfilling their regional innovation commitments.

Keywords: economic development; patents; public universities; regional innovation

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INTRODUCTION

Universities play a crucial role in the research and development system of the United States. Knowledge generated in universities spills over to other parties engaged in innovation, and this benefit enhances industries located close to universities (Audretsch & Feldman, 1996; Jaffe, 1989). University research "spillovers" not only complement the innovation capabilities of proximate firms but also create concentrations of skilled labor and augment the economic competitiveness of regions (Porter, 1990). Hence, state governments seek to support their universities in locally relevant research activities with a strong economic development motive (Eisinger, 1988; Feller, 1992).

In this context, the historical view of U.S. academic research as mostly "basic" and unaffected by regional compulsions appears misplaced. A number of today's public universities were established by the Morrill Land Grant Act of 1862 with a specific mandate to conduct locally useful research in agriculture and the "mechanic arts".[1] Since then, public universities have been pivotal in the development of various regional industries and technological competencies (Rosenberg & Nelson, 1994). Given the immediate economic potential of their applied research, land grant institutions were also among the first universities to confront the issue of ownership of government-funded research results (Mowery & Sampat, 2001a).[2] Following the example of the Wisconsin Alumni Research Foundation, established by the University of Wisconsin in 1925, several public universities set up separate legal entities to manage their faculty's inventions on the grounds that they would protect the public interest (Apple, 1989).[3] Public universities were hence early leaders in performing locally appropriable research and in protecting their inventions with patents. In contrast, most prominent private universities of the time specialized largely in the abstract sciences or liberal arts and had ambivalent patenting policies for the greater part of the 20th Century (Mowery & Sampat, 2001b).[4]

State legislatures have always exercised a degree of control over public university resources and research. This is reflected in the traditional sensitivity of public universities to local industrial and technology missions. However, among other developments over the last three decades, states' emphasis on technology-based economic development has contributed to a renewed commitment of public university research towards regional goals (Feller, 1997).

Despite this uniqueness in the past and present objectives of public universities, little is known about the nature of their research and the geographic distribution of their beneficiaries in comparison to private universities. This paper attempts to fill the void by investigating the patent and citation records of public and private universities spanning the years from 1975 through 2000. The following section premises the study by reviewing the role of research universities in regional innovation, as well as state government support for public institutions. The next section describes university patents, citations, and underlying trends. Subsequently I use patent data to test the hypothesis that spillovers from public university research are more likely to be captured within the state of their origin as compared to private universities. Quality of research and breadth of patents are tested as alternative explanations for localization of university spillovers. The concluding section discusses implications to economic development policies concerning universities and regional innovation.

UNIVERSITIES AND THEIR ROLE IN REGIONAL INNOVATION

Economic theory considers university research a “public good” because its outcomes are freely accessible for all parties. Knowledge created in universities are positive externalities, called “spillovers”, since the benefits of university investment in research spills over to external agents (industry or entrepreneurs) who do not pay a price for it. This happens when university-based researchers divulge the details of their research in conferences, publications, and patent applications, or even more importantly in their formal and informal interactions with other interested parties located in their vicinity. Companies situated around universities can hence introduce innovations at a faster rate than rival firms located elsewhere and are more competitive (Feldman, 1999; Jaffe, 1989).

Patent and citation studies have empirically tested the presence, extent, and spatial concentration of university research spillovers by studying the geography of citations to patents. Henderson, Jaffe, and Trajtenberg (1998) for example, in work that guides the empirical approach employed by this paper, find evidence for the localization of knowledge spillovers from university research at the Metropolitan Statistical Area -level from the location of patent citations to U.S. university inventions. Similarly, Hicks, Olivastro, and Hamilton (2001) report that a disproportionate number of scientific papers cited by patents of U.S. inventors belong to research institutions located in the same state as the inventors.

Several qualitative studies have also articulated the role of universities in the success of high-technology clusters like Silicon Valley in California, Route 128 in Massachusetts, and the Research Triangle Park of North Carolina (Saxenian, 1994). As in these examples, universities are expected to stimulate economic development by transferring knowledge to collocated industries, as well as by encouraging new business formation in university-centered incubators and science research parks of the region (Feldman, 1994). In certain industries, firms choose to locate close to leading universities to increase the ease of interaction between their R&D departments and university-based "star scientists" (Zucker & Darby, 1997). In summary, the presence of research universities is now widely viewed as a necessary (if insufficient) condition to bring about innovation-based economic development of regions (Feldman, 1999).

States, Universities, and Regional Innovation

The 1980s marked the emergence of "entrepreneurial" states which replaced counterproductive industrial recruitment strategies with policies that fostered the formation of indigenous high technology firms (Eisinger, 1995). This changed emphasis on innovation naturally increased states' interest in universities as drivers of regional economic development. As Eisinger (1988) notes, "...the most costly and visible of the state programs designed to bear directly on the promotion of high-tech industrial development and business formulation… are the university-industry cooperative research centers and science or research parks" (p.283).

The increasing trend of state-led efforts to direct university research towards local demands has prevailed over the last two decades. To date, technology transfer and commercialization programs to stimulate regional economic development are ubiquitous with over one thousand university-based cooperative R&D centers in the states (Reamer, Icerman, & Youtie, 2003). The phenomenal growth of university engagement in economic development activities is ascribed to a variety of reasons ranging from the low political risk associated with such investments (Eisinger, 1988) to methodological difficulties in evaluating such programs (Feller, 1992).

Whatever the reason for their popularity, the key feature of states' increased interest in universities is an emphasis on supporting research, the benefits of which are largely confined to their own citizens. State governments are increasingly acting as "brokers" in bringing local firms and universities together to benefit local constituents and, in doing so, are preferentially supporting university activities at the downstream end of the basic-applied research spectrum (Feller, 1992). Coburn and Brown (1997) note that, "state-sponsored research… places greater emphasis on activities at the downstream end of the R&D process, more typical of state activities and more productive of direct commercialization" (p. 302). Hence, to the extent that university research is affected by state-led economic development thrusts, it may be increasingly oriented towards problem-specific and locally appropriable ends (Feller, 1990).

Why does University Ownership Matter?

Ever since their inception as land grant colleges, public universities have embodied state economic development objectives.[5] By intent and example, their research has been "applied" and directed by specific industrial needs (Rosenberg & Nelson, 1994). The popular manufacturing extension program of the 1980s, set up to catalyze new technology adoption by regional industries, had its forerunner in the agricultural extension services offered originally by the land grant universities (Abelson, 1986; National Association of State Universities and Land-Grant Colleges, 1995). Public universities are now the mainstay of programs aimed at conducting research in locally relevant fields, and this is reflected in their goal statements that express a strong commitment to regional economic development.[6]

Public university missions are particularly sensitive to the influence of state-level political actors concerned with catering to the demands of local constituents (Sabloff, 1997; Martinez, 1999). State-based political, legislative, and executive bodies influence the direction of public universities at various stages. As Lombardi, Craig, Capaldi, and Gater (2002) note:

> "Every state university … is subject to the policy control of the state legislature and often to the policy objectives of the state's executive branch. Private university boards see their role as supporting their institutions; public university boards usually serve to regulate their universities on behalf of public constituencies" (p. 20).

State governments buttress their administrative control by significantly funding and directing research in public universities. While the bulk of state legislative appropriations to universities tend to be broad and general purpose, a portion is spent on research activities. The National Science Foundation (NSF) collects annual data on R&D expenditures at universities by their sources of funding. R&D expenditure is defined as actual money spent on activities organized to produce research outcomes in science and engineering fields. Since 1972, the earliest year for which NSF data is available, state government funding of public university R&D expenditures has grown about tenfold to 2.25 billion dollars in 2002. In comparison, state-financed R&D expenditures at private universities in 2002 totaled a mere $1/4 billion, an amount comparable to state funding for public universities in 1972 (National Science Foundation, 2004).[7]

FIGURE 1 HERE

In summary, states are primarily interested in orienting the research in their universities towards locally pertinent problem solving. Owing to a combination of historical factors, their sources of funding and organization structures, public universities are more likely to be the primary instruments for achieving state-specific economic development goals. If state initiatives to foster applied and locally beneficial research targeted at public universities are indeed successful, their research spillovers should be demonstrably more local as compared to that of private universities. The next section introduces university patent and citations data and explains how they can be used to examine the spatial distribution of research impacts.

AN OVERVIEW OF UNIVERSITY PATENTS AND CITATIONS

A patent grants the right to commercialize a nonobvious and nontrivial invention to its assignee. For every patent assigned, the U.S. Patent and Trademark Office (USPTO) creates a publicly available document including detailed geographic information on the assignee and references to other patents that have contributed to its development. The starting point of this analysis is the gathering of all patents granted to U.S. universities between the years 1975 and 1996. The patents are then marked as originating from either a public or a private university (a dichotomous private/public indicator, *public* is set to '1' if the patent was assigned to a state university, '0' otherwise) after dropping patents assigned to the Research Corporation.[8]

FIGURE 2 HERE

Figure 2 plots the growth in numbers of patenting universities (universities with at least one patent) and patents assigned by institutional type during the 1975 to 1996 period. The 1970s witnessed a convergence in academic patenting policies and, by the end of the decade, most public and private universities required their faculty inventions to be patented through university channels. The Bayh-Dole Act of 1980 allowed universities to claim the intellectual property rights of inventions generated from federally funded research and is widely credited with the resulting surge in patenting universities and university patents. While the trend of university patenting appears to have increased for both private and public institutions, it is particularly pronounced in the latter's case. However, there is little evidence or anecdote to suggest that public and private universities differ in their treatment of faculty inventions during the period of this study (see for example, Mowery, Nelson, Sampat, and Ziedonis, 2001 for an overview of the impacts of various policy interventions and technological developments on university patenting practices).

Table 1 presents the total number of patents assigned to all universities between 1975 through 1996 and the share of public universities by technology category. The distribution of public and private university patents is consistent with traditional views of their relative technological strengths (for an excellent discussion of which, see Rosenberg & Nelson, 1994). While drugs, medicine, and chemicals account for nearly 60% of all university patents, the strongest areas of public university patenting are in the traditional fields of chemicals, mechanical and agriculture. Private universities are leading patentees in the computers and communications sector.

***TABLE 1 HERE ***

To the extent that inventors manifest the results of their innovative activities by patenting, and to the extent that prior art that contributed to the development is also recorded by patents, it is argued that "knowledge flows leave a paper trail in the form of citations in patents" (Jaffe, Trajtenberg, & Henderson, 1993, p.578) . Examining the spatial distribution of citations should hence reveal the geographic regions that capture the spillovers of a patented invention.[9]

Prior to such an examination, I matched each university patent with all later patents (between the years 1975 and 2000) that cited or referenced the original patent to form unique patent-citation pairs. Observations for which both the patent and its citation originated from the same state are marked as in-state (a dichotomous variable *instcite* is set to '1' if a patent has a citation originating from the same state, '0' otherwise) after eliminating self-citations.[10]

***TABLES 2 AND 3 HERE ***

Tables 2 and 3 show patent and citation descriptives for the 10 top (by number of patents) public and private universities. Top private universities share a higher proportion of both total and in-state citations with fewer patents. The first three private universities (Massachusetts Institute of Technology, Stanford and California Institute of Technology) account for 21% of all citations and about 31% of all in-state citations. Among publics, the University of California receives 20.3% of its citations from in-state. The state of California alone hosts three of the top four patenting universities which together account for 16% of all university patents and 37.3% of all in-state citations. The following section employs regression models to understand university ownership and research quality as determinants of localization of knowledge spillovers.

ARE PUBLIC UNIVERSITY SPILLOVERS MORE LOCALIZED?

If university technology transfer and commercialization policies systematically encourage faculty to patent the results of their research, and if public university research is targeted to local innovation needs, the geographic distribution of citations to their patents should manifest the localized capture of public university knowledge spillovers.[11] This implies that controlling for other state, technology, and time dependent variables that affect the geography of spillovers, citations to a public university patent (in comparison to a private university patent) are more likely to come from within the state of its origin.

Preparatory to testing the hypothesis, I dropped patent-citation observations for which the citing patent was granted more than 10 years after the original patent, and also patents that do not have a 10-year period to accumulate citations. This minimizes "truncation bias", a problem associated with the time lag of citations due to which (a) earlier patents appear to receive more citations as compared to later ones, and (b) citations from different time periods are qualitatively different, with a potential to produce spurious estimates on explanatory variables. While this method drops patents assigned post-1990 (the latest citations in the dataset are from the year 2000) it allows the construction of consistent 10-year "windows" in which to examine citation patterns (this is standard practice in citation-based studies; Mowery et al., 2002, is an example). The mean lag-time between the original patents and their citations is 7.3 years, and the "10-year windows" capture about 80% of all citations to patents granted between 1975 and 1990. Of all public university patents and private university patents assigned during the period, 15% and 11% respectively, had not received a citation (as of the year 2000) and are excluded from the data to restrict the hypothesis tests to inventions with a record of spillovers. The final dataset has 57,897 citations to 6884 university patents, of which

55.6% of the patents and 50.2% of the citations belong to public universities. Private universities average 9 citations per patent, about 1 of which is from within its own state, while the mean public university patent earns 7.5 citations of which 0.6 citations are in-state, on average.

State, Technology, and Time Specific Effects

The spillover-localization models developed here assume that barring the effect of observed variables, a citing patent in its search for prior art is as likely to encounter a public university patent within its own state as it is to encounter a private university patent. However, several factors influence the localization of spillovers, and if they change over time and are correlated with the production of university research, then their omission will result in biased estimates. Size of a state, for example, or the volume of economic activity in states may be significant predictors of spillover-localization and be correlated with the impacts of public or private university research. To control for the unobserved effect of factors that vary from one state to the next, I included dummy variables for each of the 50 states (see Stock & Watson, 2003, p. 278-285 for a discussion elucidating the type of unobserved variables that can be controlled using state and time "fixed effects").

Universities differ in their areas of technical specialization, and different technologies can effect localization of knowledge flows in various ways. Five technology-specific dummy variables (classified on the basis of patent technology class) are included to account for this effect. It is also possible for certain states to have a concentration of industries in a particular technology, and this can increase the probability of their patents referencing public (or private) university patents in the same area. As a consequence, localization may not truly reflect spillovers from university research, but rather the existing geography of technology production. The model controls for such agglomeration effects by including interaction terms between the 50 states and five technology categories. This eliminates technological differences between states as a source of identification.

Other factors (e.g., changes in university patent policies) are not specific to states or technologies, but evolve over time and moderate the relationship between universities and their research spillovers. Dummy variables for each of the 15 years in which the patents were granted, control for time variant effects. However, to be able to track changes in the impact of university ownership on localization over time, each of the year variables is interacted with the university-ownership binary variable (and named *Y75Public*, *Y76Public*… *Y90Public*).

Model Estimation and Results

The model explaining the probability of an instate-citation for any patent-citation pair can be stated as:

(1)

$$\Pr(Instcite = 1 \mid X) = \alpha_0 + \beta_1 Public + \gamma_1 Y75Public + \gamma_2 Y76Public + \ldots\ldots + \gamma_{15} Y90Public + StateFixedEffects + TechFixedEffects + TimeFixedEffects + StateTechInteractionEffects$$

The model is estimated using a standard logistic transformation and the first column of TABLE 4 presents results.[12, 13]

*** TABLE 4 HERE ***

The coefficient of *Public* (0.57) indicates that the odds of a public university patent receiving a citation from its own state are only 57% as high as the odds of a private university patent netting an in-state citation, controlling for the effects of state, technology, agglomeration and time. The beta of the interaction term for the year 1990 (*Y90Public*) indicates that the odds of a public university in-state citation to that of a private university in-state citation for a 1990 patent, is 2.14 times the same parameter for the year 1975. Patents belonging to public universities assigned in the years 1977, 1982 and 1990 are more likely to have earned a citation from within their own states, as compared to public university patents from any of the other 12 years.[14] Even so, the magnitude of these interaction coefficients is not significant enough to unambiguously suggest that citations to state university patents are more likely to come from inventors within its state.

The baseline estimation hence provides evidence *against* my expectation and suggests that private universities may be associated with greater localization of their research spillovers. To better understand this puzzling result, I improved the model by considering the effects of nature and quality of academic research on the likelihood of localization in the succeeding iteration.

Does Nature of Research Impact Localization of Spillovers?

To draw attention to the fact that the success of areas like Silicon Valley and Boston's Route 128 is based not merely on the presence of universities, but on the research excellence of institutions like Stanford, University of California Berkeley, and the Massachusetts Institute of Technology might appear tautological. However, the significance of the nature and quality of research is not emphasized enough in many university-based regional economic development efforts. Indeed, apart from studies that are mostly case-based, very few systematic attempts have been made to associate the quality of academic research to localization of resulting impacts.

A recent exception is Hill and Lendel (2004) who report a significant and strong causal relation between the reputation of university doctoral programs (in science and engineering) and technology-based regional economic development (firm spin-offs and job growth). This is particularly important, because state initiatives rely primarily on "downstream" (technology transfer and commercialization) activities, but rarely attempt to improve the quality of research as a means of enhancing the utility of academic research to local industries (Feller, 1990). The hypothesis tested here is that quality of research is positively associated with the localized diffusion of university research. Two distinct measures of research quality and nature, for which means by university type are presented in Table 5, are explained below and included in the second localization model.

The National Research Council's departmental evaluations. The National Research Council's evaluation uses peer-review to evaluate the scholarly quality of about 3600 research doctorate programs in 41 fields at 274 universities (National Research Council, 1995). I matched the quality score of each university program with each of my patent-citation observation by using the technology class of university patents. As an example, for a university having a patent in the *Chemicals* technology category, the quality rating associated with either the Chemical or Chemical engineering program of that university is assigned.[15] The quality score variable (*Quality*) is coded to increase from '0' to '5', such that higher numbers along the scale denote better quality.

Generality of a patent. Inventions of high generality are characterized by their usefulness in a wide range of applications and impact innovation across several sectors

(Bresnahan & Trajtenberg, 1995). The large spillover effects of academic inventions are in part due to their high generality. Trajtenberg, Henderson, and Jaffe (2002) report that the average university patent assigned between years 1975-1980 was 15% more general than its non-university counterpart. The authors measure *generality* by the extent to which citations received by a patent are dispersed across different technology classes such that a higher dispersion of citations across several technology classes denotes broader technological impact.

Along similar lines, I use a Herfindahl-type measure, originally developed by Trajtenberg et al (2002), to construct a generality index for all university patents.[16] The index varies from ‘0’ for a patent that receives all its citations from a single technology class and approaches ‘1’ as the number and spread of citations across technology classes increase. While extant literature that relates the impact of research generality on spillover-localization is rather sparse, states prefer to support highly specific inventions based on the premise that highly generic research may not translate immediately into locally tangible benefits.[17] The average public university is associated with lower scores of quality and generality of patents.

*** TABLE 5 HERE ***

The improved model including quality of research and generality of patents as explanatory variables is stated as:

(2)

$$\Pr(Instcite = 1 \mid X) = \alpha_0 + \beta_1 Public + \gamma_1 Y75Public + \gamma_2 Y76Public + \ldots\ldots.. + \gamma_{15} Y90Public + \\ + \delta_1 Quality + \phi_1 Generality + StateFixedEffects + TechFixedEffects + TimeFixedEffects + \\ StateTechInteractionEffects$$

The second column of Table 4 presents the corresponding logistic regression estimates. Departmental quality as represented by NRC ratings is a significant predictor of localization of university research spillovers. The impact of generality of patents on the location of citations is less clear. While research of higher quality increases the localized capture of knowledge flows, highly specialized patents (or inventions of low generality) may not necessarily yield a similar benefit. Further, the significance and magnitude of university ownership drops slightly when controlling for quality of research. This suggests that some of the observed differences between the localization impacts of public and private universities can be explained by the quality of research in these universities.

DISCUSSION AND CONCLUSIONS

Research universities have a positive impact on regional innovation, and states seek to preferentially engage their public universities in the pursuit of locally appropriable research. Based on such a premise, this study examined patents and the geography of patent citations to compare the local impacts of public and private universities. Public universities, on average, appear to engage in research of lower quality (National Research Council, 1995), and produce inventions that have lesser impact (as evidenced by fewer citations per patent, and lower values of patent-generality) as compared to private universities. Further, my regression implies that public university knowledge flows are not more likely to be captured within their state boundaries (as compared to that of private universities). While this effect is mitigated for some years in the period of study, there is little in the results to conclude that public university commitment to their states is definitively reflected in the geography of their research spillovers.

This divergence between the intent and reality associated with public university research can be treated as arising from two distinct sets of factors. The first is directly related to the quality of research output in universities. A high quality invention enhances the prospect of its local use by increasing the chances of its overall use. Additionally, if research is also broad in terms of its technological impact, so much the better, since a greater range of all, but particularly local industries can benefit from the resulting spillovers. Public universities are outperformed by private universities in this regard.

The second set of factors may be due to inefficiencies in the system of public universities, distinct from the nature and quality of their inventions, which work against the successful diffusion and localization of their research spillovers. Since my research does not bear the burden of proving this aspect, it is necessary to draw from other works to speculate on the reasons why public university patents earn a smaller proportion of citations from their own states, even research quality is controlled for.

Adams and Griliches (1998) show that private universities produce more patents, publications, and citations per dollar of R&D, as compared to public universities. The lower efficiency of public university research and technology transfer efforts is attributed to the diverse objectives of public universities that do not always take the demands of the private sector into account (Thursby & Kemp, 2002). Further, public university technology transfer initiatives tend to be less flexible in licensing their faculty inventions, being sensitive to the charge that they might be “giving away” taxpayer-funded technologies that could yield substantial profits (Siegel, Waldman & Link, 2003). Hence, there is reason to believe that activities bearing on the diffusion of research are generally less efficient in public universities.

Sine, Shane, and Gregorio (2003) report the presence of a “halo effect” due to which a university’s perceived prestige and image draws customers over and above what can be explained by the actual quality of its research. Private universities are traditionally associated with notions of prestige to a greater extent than public universities. Local firms may be more likely attracted to the inventions of haloed private institutions, both in their need for real university research associations and search for prior art while preparing their patent applications. A combination of these factors can systematically undermine not merely localization, but the overall utilization of public university research, and not for want of quality.

An important if unexpected finding of this study is that public universities, despite their institutional histories and state intentions, are not necessarily greater contributors to regional innovation as compared to their private counterparts. Overemphasis on narrow and downstream technology transfer efforts -- a common feature of recent state-led economic development thrusts -- may have contributed to the lesser significance of public university inventions. University inventions are unique and valuable to industry because of the quality and breadth of research they embody. Regional innovation strategies involving universities need to bear this in mind while seeking to influence the nature of academic research.

NOTES

1. Not all state universities owe their existence to the Morrill Land Grant Act (the University of Wisconsin, for example, was set up earlier) and not all land grant universities are public (M.I.T., for instance). Cornell University is a unique example of a privately endowed institution that is also a land grant institution with several schools and departments still under the contract of New York state. However, this paper uses the terms “public university”, “state university” and “land grant university” interchangeably and as distinct from private universities.

2. The main concern driving academic patenting is represented in the American Association for the Advancement of Science (AAAS) Committee on Patents, Copyrights and Trademarks 1933 report on patent problems which quotes Hoskins and Wiles (1921): “There is at large a type of engineer commonly called a “patent pirate”, who thrives by monopolizing the practical applications of the abstract discoveries of others. The patent pirate is a menace to industry and a parasite on the community. Nothing would so hamper his activities as to have the real discoverer take out broad patents in every case.” (as cited in Mowery & Sampat, 2001a, p. 784).

3. One of the earliest debates about the appropriateness of university patenting is embedded in the history of the Wisconsin Alumni Research Foundation (WARF). In 1924, Dr. Harry Steenbock, a biochemist at the University of Wisconsin, developed a method for using ultraviolet rays to enhance the vitamin D content in food and drugs. Dr. Steenbock sought a patent for his invention, since he feared its misuse by unscrupulous merchants and was subsequently responsible for setting up the WARF to manage the university’s patents, licenses, and royalties (Apple, 1989).

4. Increasing technology commercialization activities of universities in general and the interest of private universities in applied research for patentable new technologies has significantly contributed to the narrowing of this gap over the last four decades.

5. The Morrill Land Grant Act of 1862 was, according to J.F.A. Taylor, "the charter of America's quietest revolution". There were 17,430,000 acres of land in the public domain committed to finance the land grant colleges, 30,000 acres per senator and congressman in each state. The main purposes were to make education nonexclusionary and, through research, to benefit local farmers. See Graham and Diamond (1997) for a historical account of the evolution of American research universities.

6. To test if the intent premise is true, I surveyed the objective and mission statements of nine randomly selected public universities and one purposively selected public university (Georgia Institute of Technology, the author's host institution), and ten private universities. All of the public universities mentioned furthering states' interest, while none of the private universities did. Georgia Tech's mission statement is illustrative: "to provide the state of Georgia with the scientific and technological knowledge base, innovation, and workforce it needs to shape a prosperous and sustainable future and quality of life for its citizens." (President's Office, Georgia Institute of Technology).

7. It is to be noted however, that overall state government funding for academic R&D is showing a decreasing trend. State government funding accounted for nearly 13% of public university R&D expenditures in 1970, but only 9% in 2002. The state government's role in private university R&D expenditures dropped from 3.1% to 2.2% during the same period.

8. The now defunct Research Corporation played an important role as an intermediary in the licensing and patenting tasks of U.S. universities before the 1980s when most academic institutions were loathe to engage in research commercialization activities.

9. While not all innovative activity results in patents and not all spillovers are represented by citations, several studies have validated their relevance as indicators of innovative activity (see for example, Jaffe & Trajtenberg, 2002). Jaffe et al. (1993) use citation analysis to suggest that university spillovers are geographically more diffuse than corporate patents.

10. “Self-citations” are observations for which the patent assignee cites the same patent assignee. Self-citations indicate that an assignee has built upon her prior invention and hence might not represent true spillovers of knowledge. Also, self-citations upwardly bias the count of in-state citations.

11. “Localization” here implies a concentration of the benefits of a resident university’s research within the state’s jurisdictional boundaries and not necessarily in areas of its geographic proximity.

12. The reference year is 1975, Alabama is the reference state, and chemicals are the base technology class in the estimations. Dummy variables representing these values are automatically dropped by the statistical software in reported estimations.

13. Logit coefficients are reported in exponentiated form; hence, discussed numbers are odds-ratios.

14. The model represented by equation (1) was estimated for each of the five broad technology classes (chemicals, drugs and medicine, electrical and electronics, computers

and communications, mechanical and others) separately to test if the link between university ownership and spillover localization is mediated by sectoral impacts. Results for the three categories -- chemicals, computers & communication and drugs & medicine -- were similar to the overall results (*public* was negatively associated with localization). In the category *electrical & electronics*, public universities were not statistically significantly different from private universities. In the category *mechanical and others* (comprising mostly agriculture patents), public universities were positively associated with localization, but only weakly so (at 10% significance levels).

15. The National Research Council quality ratings were calculated to yield departmental ratings to correspond to the five broad patent technological categories (chemicals, drugs and medicine, electrical and electronics, computers and communications, and mechanical and others). If a university had different ratings for its biomedicine, pharmacology, and neuroscience departments, the mean of the three departments was assigned to its patents in the Drugs and Medicine category. While an anonymous referee suggested that overall institutional quality might be a better variable, there is significant variation between broad departmental ratings for certain institutions. Emory and Johns Hopkins for instance, focus mostly on one of these technologies, a fact reflected in high scores of their *drugs and medicine* patents, but not other areas. Such intra-institutional variations are meaningfully related to the localization of research impacts and an “institutional quality” variable computed as the mean of a university’s various departments posed difficulties in weighting for departmental size and, when used in place of departmental quality, was found to be statistically insignificant in the second regression model.

16. The “generality index” for any patent ‘*i*’ is defined as: $G_i = 1 - \sum_{j=1}^{J} \left(\frac{N_{ij}}{N_i} \right)^2$ where N_i is the number of forward citations to the patent, and N_{ij} is the number of citations received from technology class “*j*”. If a patent receives 1, 3, and 6 numbers of citations from three different technology classes, then its generality is

$$1 - \left[\left(\frac{1}{10} \right)^2 + \left(\frac{3}{10} \right)^2 + \left(\frac{6}{10} \right)^2 \right] = 1 - \left(\frac{46}{100} \right) = 0.54$$

17. In simple Ordinary Least Squares regressions relating the type of university (independent variable) to the two measures of quality (NRC ratings and generality), being “public” was negatively related to quality and generality, confirming that public university patents are indeed more applied or have very narrow applicability.

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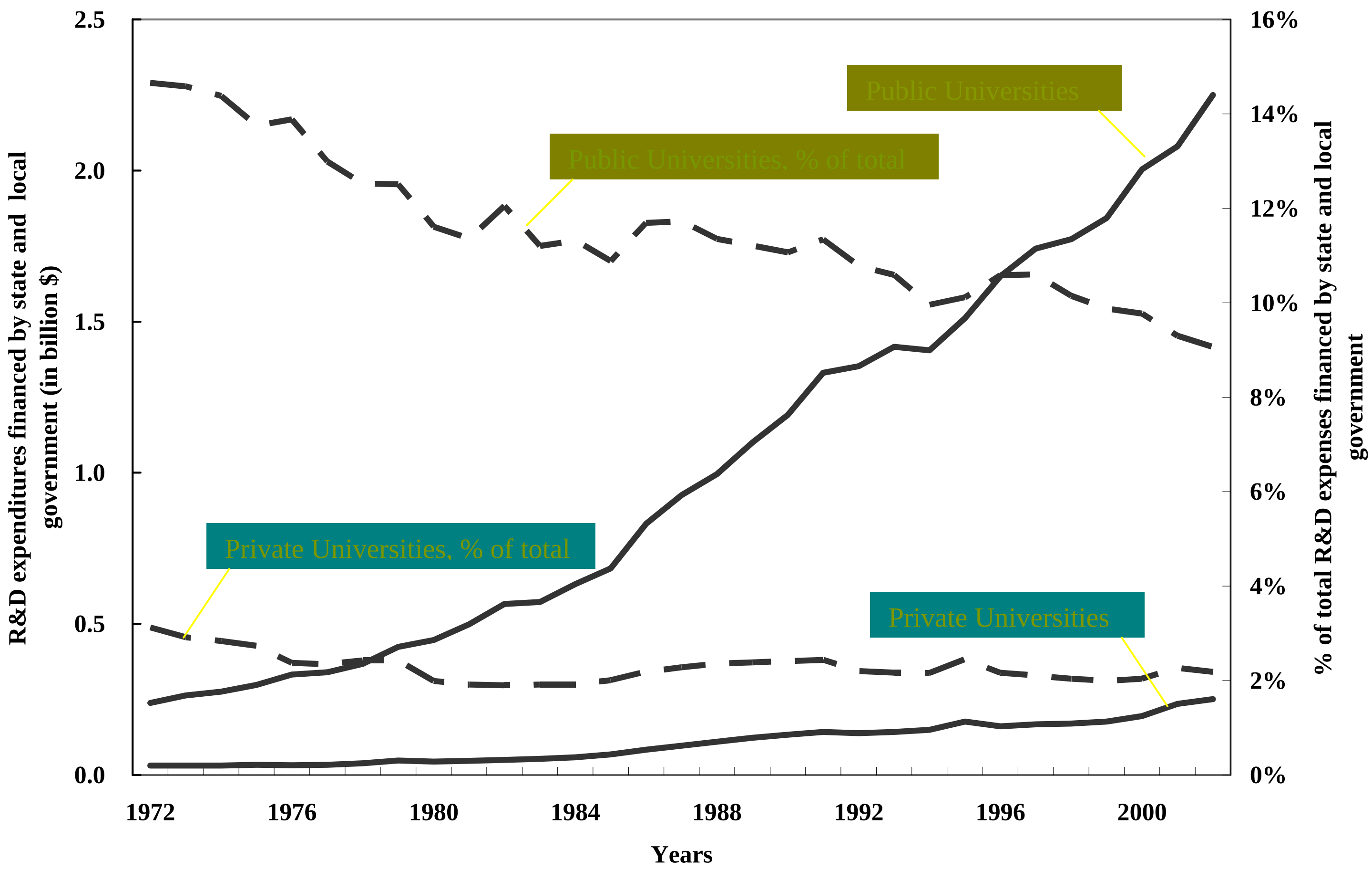

Figure 1: State government financed R&D expenditures at public and private universities, by billions of dollars, and as a percentage of total R&D expenditures (Source: National Science Foundation, Survey of academic R&D expenditures, 1972-2002).

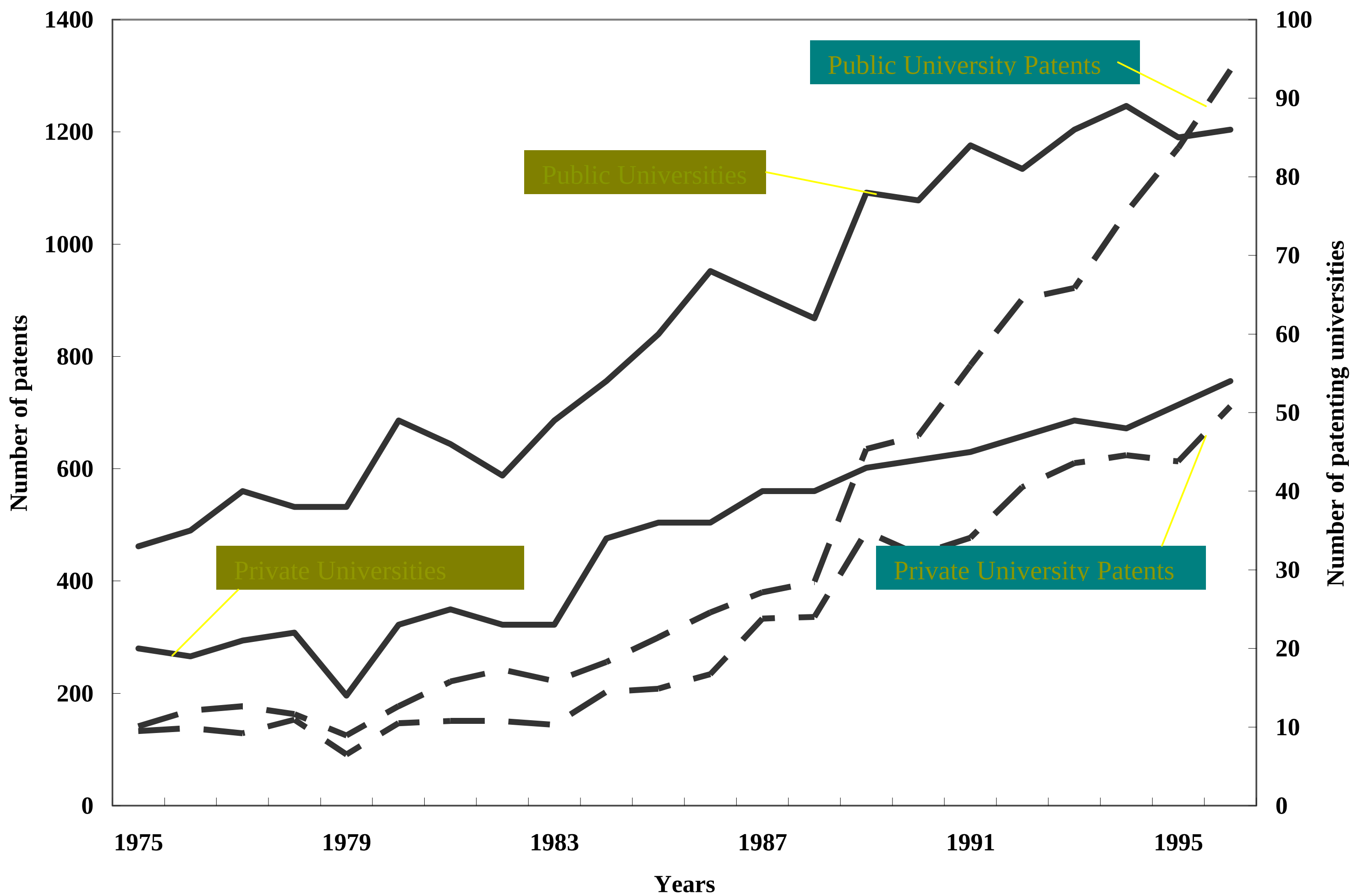

Figure 2: Number of public and private patenting universities, and patents assigned to each (1975-1996)

TABLE 1

Total number and share of public university patents by broad technology categories

	Total patents	*% Share of Publics*
Chemicals	4917	64.8
Computers & communication	1304	44.8
Drugs & medical	5839	61.5
Electrical & electronic	3433	55.1
Mechanical, other	2350	64.1
Total (1975-1996)	17843	60.3

TABLE 2

Top-10 Public Universities: share of patents, citations, and percentage of citations from their own -states (1975-1996)

Public University	*Patents*	*Share of U-Patents(%)*	*Citations*	*Share of Citations to U-patents*	*% of Cites Instate*
University of California (CA)	1549	8.7	10095	8.6	20.3
University of Texas (TX)	742	4.2	4745	4.1	9.6
University of Wisconsin (WI)	595	3.3	2954	2.5	6.2
Iowa State University (IA)	448	2.5	1672	1.4	3.7
University of Minnesota (MN)	398	2.2	2542	2.2	7.9
University of Florida (FL)	359	2.0	2144	1.8	7.9
State Univ. of New York (NY)	309	1.7	1950	1.7	11.0
University of Utah (UT)	279	1.5	1980	1.7	7.8
University of Michigan (MI)	251	1.4	1843	1.6	9.5
Purdue University (IN)	228	1.3	1568	1.3	4.9
Total, Top-10 Publics	5158	28.9	31493	26.9	

TABLE 3

Top-10 Private Universities: share of patents, citations, and percentage of citations from their own states (1975-1996)

Private University	*Patents*	*Share of U-Patents (%)*	*Citations*	*Share of Citations to U-Patents*	*% of Cites Instate*
Massachusetts Inst. of Technology (MA)	1570	8.8	13713	11.7	9.8
Stanford University (CA)	716	4.0	6871	5.9	22.1
California Institute of Technology (CA)	557	3.1	4383	3.7	20.1
Cornell University (NY)	470	2.6	3339	2.8	8.8
Johns Hopkins University (MD)	345	1.9	2678	2.2	2.7
University of Pennsylvania (PA)	246	1.4	1812	1.5	6.5
Harvard University (MA)	209	1.2	1374	1.1	11.8
Columbia University (NY)	183	1.0	1635	1.4	5.4
Duke University (NC)	170	0.9	1390	1.1	4.1
University of Southern California (CA)	165	0.9	818	0.7	21.4
Total, Top-10 Privates	4631	25.9	38013	32.5	

TABLE 4

Spillover-Localization models: Logistic regression estimates

	-1	-2
	Instcite	*Instcite*
Public	0.5689	0.5755
	[0.1547]**	[0.1567]**
Y76Public	2.2709	2.2979
	[0.8045]**	[0.8145]**
Y77Public	2.653	2.682
	[0.9160]***	[0.9266]***
Y78Public	1.5886	1.6262
	[0.5935]	[0.6078]
Y79Public	1.8916	1.8997
	[0.6727]	[0.6755]
Y80Public	1.6993	1.7239
	[0.5578]	[0.5664]
Y81Public	1.6697	1.6986
	[0.5448]	[0.5545]
Y82Public	3.0769	3.0953
	[0.9758]***	[0.9816]***
Y83Public	1.2917	1.3047
	[0.4049]	[0.4091]

TABLE 4 (continued)

Y84Public	1.9536	1.9746
	[0.5874]**	[0.5940]**
Y85Public	1.2237	1.2478
	[0.3591]	[0.3666]
Y86Public	1.6057	1.6207
	[0.4730]	[0.4780]
Y87Public	1.748	1.7596
	[0.5015]	[0.5056]**
Y88Public	1.4021	1.4197
	[0.4001]	[0.4055]
Y89Public	1.9388	1.9719
	[0.5446]**	[0.5548]**
Y90Public	2.1403	2.1955
	[0.6000]***	[0.6164]***
General		1.0383
		[0.0705]
Quality		1.0434
		[0.0208]**
Observations	55918	55918
Pseudo R2	0.07	0.08

Table 4 Notes: State, Technology, Time, & Agglomeration coefficients suppressed; Standard errors in brackets; ** significant at 5%; *** significant at 1%.

TABLE 5

Descriptives of generality and quality ratings

	Generality	*Quality*
Public University	0.42	2.96
	[0.27]	[1.05]
Private University	0.47	3.82
	[0.26]	[1.13]

Table 5 Notes: Standard deviations in brackets