Is the U.S. Losing Its Preeminence in Higher Education? *

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Abstract

Expansion of U.S. universities since World War II gained from the arrival of immigrant scientists and graduate students, the broadening of access to universities, military research, and expansion of high technology industries. Since the 1980s growth of scientific research in Europe and East Asia has exceeded that of the U.S., suggesting convergence in world science and engineering. But the slowdown of U.S. publication rates in the late 1990s is a different matter. Using a panel of U.S. universities, fields and years evidence is found of allocative inefficiency which has slowed growth in public universities and in university-fields falling into the middle and bottom 40 percent of their disciplines. This is not true of private or Top 10 universities or top 20 percent university-fields. These developments can be traced in part to slower growth in tuition and state appropriations compared to revenue growth in private universities.

I. Introduction

For over half a century U.S. universities have been leaders in research and graduate education, building on firm foundations laid down in the 19th century, and rising to new heights during the 20th century. But of late doubts have arisen concerning the standing and the prospects of higher education in the United States. This is partly because the number of countries who are intensively engaged in academic research has grown explosively, suggesting greater competition for scientific and engineering talent and greater competitiveness of foreign high technology firms. But besides, there is evidence of slowdown in growth of financial resources and productivity that seem to have particularly affected U.S. public universities[1]. I address these issues here.

I begin by reviewing evidence on the expansion of research in leading U.S. universities during World War II and during the Cold War and afterwards. Then I turn to an overview of the U.S. contribution to world scientific output over the past quarter century. In presenting this material I argue for absolute measures of U.S. scientific output relative to the inputs that it requires. Finally, in the longest part of the paper, I use a panel of U.S. universities to search for factors affecting research output. Underlying this discussion is the hypothesis that to date many of the challenges facing U.S. universities are domestic and have little to do with international diffusion of science and technology.

The rest of the paper is arranged as follows. Sections II and III discuss the recent history of U.S. universities. Section II begins with the 1930s. Afterwards it discusses implications for U.S. science and engineering of events leading up to the war and the immediate postwar period.

[1] See Ehrenberg (2006) and the articles and references cited therein, and Adams and Clemmons (2006, forthcoming 2009).

Section III discusses world scientific output since the 1980s. These sections set the stage for a study of causal factors underlying trends in U.S. academic research in Sections IV and V. Section IV introduces panel data covering 110 top U.S. universities from 1981-1999. Then, in Section V, I present panel regressions where research is the dependent variable. The empirical work concludes with an econometric analysis of academic wage structure. In Section VI, I draw tentative conclusions and implications for the future of U.S. academic research.

II. U.S. Universities Since World War II: A Brief History

A. Pre-War Setting

Prior to World War II, federal R&D was located in the military (Mowery and Rosenberg, 1989, pages 92 ff.). The exception was agricultural research, conducted in the land-grant colleges founded by the Morrill Act of 1862 and co-located with state experiment stations established by the Hatch Act of 1887 (Huffman and Evenson, 1993, Ch. 1)[2].

The first reasonably comprehensive statistical evidence on university R&D derives from research balance sheets of universities in 1935-1936. The data are contained in **Research—A National Resource, Volume I** (National Resources Committee, 1938, Section 6)[3]. A survey of sixty universities yielded total research expenditures of 50 million $. Of this, 16 million were earmarked for experiment stations, much of this funded by the Department of Agriculture[4]. Of the remaining 34 million, 17 derived from endowment, 8 million from foundations, 4 from gifts,

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[2] A case can be made that the favorable conditions set by the early U.S. patent system, and discussed in Khan (2005), were complementary to the establishment of practical universities focused on the agricultural and mechanical arts, the very type envisaged by the Morrill Act.

[3] Individual evidence on university R&D exists before 1935-1936. The University of Chicago conducted an internal survey of research costs in 1929-1930 and the University of California undertook a survey in 1928-1929. But these data lack the breadth of the National Resources Committee survey.

[4] In 1940 federal R&D expenditures were 74 million $, of which 29 million $, or 39%, consisted of Department of Agriculture R&D (Mowery and Rosenberg, 1998, p. 27). In 1940 agricultural research assumed a much larger role in the federal government and universities than it does today.

2 from contract research, and 2 from state government. The federal government's main role in academic research was its support for agriculture.

The Bush report, which argued for creation of a National Science Foundation, contains estimates of research expenditure by sector from the 1930s through World War II (Bush, 1945, p. 86). The data limit the definition of research to natural science[5]. Using the figure of 50 million $ reported in National Resources Committee (1938) as a basis, this yields 25 million $ for natural science research in 1936. From survey data on research faculty, this figure is extrapolated backward to 1930 and forward to 1942 to arrive at natural science R&D for universities. This is the university series shown in Figure 1[6].

The above summarizes the prewar setting for U.S. universities. Events surrounding World War II supported expansion of university R&D in three ways. First, prior to the war, immigration of scientists from Europe significantly increased the science and engineering work force. Second, during the war, a sharp rise in defense research increased demand for scientists and engineers. The Cold War institutionalized this change[7]. Third, after the war, the GI Bill supported college education for returning soldiers. This produced a post-war spike in enrollments and in demand for faculty. We quantify these factors below.

B. The Intellectual Migration from Europe, 1933-1944

The supply of highly skilled scientists to the United States increased as a result of the flight from Hitler's Europe, but by how much and in what proportion? The main statistical source is Davie (1947) who directed data collection for the Committee for the Study of Recent

[5] In these early data natural science covers the biological, mathematical, and physical sciences, plus engineering.
[6] Industrial R&D statistics are obtained by multiplying industrial researchers by R&D per worker of 4,000 $. See **Research—A National Resource, Volume II** (National Resources Planning Board, 1941, Section IV).
[7] By an increase in demand we mean throughout a shift to the right of the demand curve for scientists and engineers.

Immigration from Europe[8]. Using the criterion of "refugee, arrival from Europe as place of last residence", the statistics of immigration and naturalization yielded 22,842 refugees in the professions during 1933-1944. The refugees were assigned to relatively detailed occupations: 507 were chemists, 2,471 engineers, 3,415 professors and teachers, and 1,907 were "scientists or literary persons." The National Resources Committee, using **American Men of Science**, 6th Edition (1938), estimated that in 1938, 28,000 U.S. men and women were researchers in the natural sciences, and that 22,000 more were in the humanities and social sciences (National Resources Committee, 1938, p. 171) for a total of 50,000 across all sectors of the economy[9]. Thus, while the intellectual migration from Europe during the 1930s was small by modern standards it was large for the time. Put another way, if half the refugees were engaged in research—not excessive, given their occupations—then this constitutes an increase of 4,000 persons on a base of 50,000, or 8%. And since they specialized in natural science and engineering, then the increase could be almost 4,000 on a base of 28,000, or 14%[10].

There is reason to think that this understates growth at the highest levels of research. Table 1 illustrates[11]. Twelve refugees had won a Nobel Prize by 1947, the most prestigious international award[12]. Using a sample collected by Davie (1947) of 707 refugees who served on university faculties in Europe, 203 persons were accounted distinguished in their disciplines, of which 181 were in natural science. To assess the meaning of this, turn to Table 2, which compiles U.S.-resident Nobel Prize winners by decade. The number of foreign born is shown in

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[8] Fermi (1971) recounts individual biographies of this wave of immigrants by detailed occupation, including scientists and engineers by their separate specialties. Her time period, 1930-1941, is earlier than that of Davie (1947), whose time frame is the one that I adopt.
[9] The Committee judged that of the existing stock of 50,000 researchers, 5,000 or 10% were in the first rank.
[10] Following the usage of Bush (1945) and Davie (1947), in this section natural science refers to biology, medicine, mathematics and statistics, and engineering, in addition to chemistry and physics.
[11] The data are compiled from Appendix C of Davie (1947).
[12] The Fields Medal in mathematics dates from 1936 and competes with the Abel and Wolf prizes. Other awards of distinction, such as the National Medal of Science in the U.S., are national in scope.

parentheses for each subject area, except for the sum across areas, which is shown as column two[13]. Noting that 23 prizes had been won by U.S. residents by 1940, with none foreign-born except for a single award, we conclude that the intellectual migration from Europe increased resident Nobel Prize winners by 50% with several more prizes to follow[14].

Table 2 also shows that major improvements in U.S. universities were underway by the 1930s. Across areas the number of native-born prizes rises from one to 17 per decade during 1901-1940. If one excludes economics prizes—since these did not exist until 1969—the total of 17 prizes for the 1930s is half the native-born total per decade during 1971-2007.

C. Increase in Federal R&D During World War II

Besides the increase in supply of highly skilled scientists and engineers before the war, the increase in military R&D during and after the war produced a sustained rise in the demand for scientists and engineers. Figures 2 and 3 illustrate[15].

Figure 1 shows R&D expressed in millions of 1958 $ in industry, government, and colleges and universities for the period 1930-1944. The data are reported on a biennial basis[16]. They clearly show that federal R&D spending rises from less than 200 million in 1940 to over 1.2 billion by 1944.

[13] In this table science Nobel Prizes include chemistry, physics, and physiology or medicine.
[14] The one foreign-born award belongs to Albert A. Michelson, for the Michelson-Morley experiment on the invariance of the speed of light.
[15] The data on federal R&D are of higher quality during this period than the data on academic and industrial R&D, because they derive from annual cost accounts. All the data are crude compared with the present day.
[16] To convert current into constant $I have used the implicit GDP deflator with 1958 set to 1.0. This chart, as I have noted, derives from Bush (1945, p. 86).

The Cold War produced a sustained increase in demand for scientists and engineers, to the benefit of U.S. universities. Figure 2 shows Federal R&D in 1958 $ for the years 1947-1968[17]. Total federal R&D amounted to one billion in 1947, rising to 12 billion by 1968. Nearly all R&D expenditures were on defense, the Atomic Energy Commission, and NASA.

D. Postwar Demand for Higher Education

Mobilization produced a decline in male college enrollment and degrees awarded. But under the GI Bill this decline was succeeded by a spike not to be equaled until the 1960s. Figure 3 illustrates using data on B.A.-B.S. degrees from 1932-1960[18]. Baccalaureate degrees earned by men rise during the 1930s, then decline from a peak of 100 thousand in 1940 to a trough of 50 thousand in 1946, and finally spike to 350 thousand in 1950. The decline and recovery of degrees earned by women are slight by comparison. As accumulated demand for education diminished during the 1950s baccalaureate degrees fell for much of the decade and did not regain their 1950 peak until the 1960s.

Figure 4 shows Ph.D. degrees from 1932-1960[19]. These increase from two to almost four thousand during the 1930s, then decline to two thousand by 1946, and finally, increase to 10 thousand in 1960. Unlike baccalaureate degrees the flow of PhDs rises smoothly, reflecting long run prospects for advanced skills.

World War II and later the Cold War delivered a series of positive shocks to U.S. higher education, especially in science and engineering. Throughout the subsequent period growing demand for undergraduate and graduate education supported continued expansion.

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[17] The source of the R&D data is U.S. Department of Commerce, Bureau of the Census (1975), Part 2, series W 126, 129, 137, and 138. These are deflated by the implicit GDP deflator for government purchases of goods and services (indexed to 1958) that appears in U.S. Department of Commerce, Bureau of the Census (1975), Part 1, series E 13.

[18] The data on BA and BS degrees derive from U.S. Department of Commerce, Bureau of the Census (1975), Part 1, series H 752-754.

[19] The data on PhD degrees derive from U.S. Department of Commerce, Bureau of the Census (1975), Part 1, series H 761-763.

III. World Scientific Output Since the 1980s

Having discussed forces that led to expansion of research in U.S. universities from the 1930s on we examine the place of the U.S. in world scientific research in recent years. Figure 5 illustrates relative growth of scientific papers in the U.S. compared to the EU-15 group of European countries, East Asia, and rest of the world[20]. Clearly U.S. research output grows slowly compared to other regions, and growth is zero from 1997-2002. The EU-15 countries surpass the U.S. in total publications in 1997 and maintain this lead into the 21st century. East Asia grows more rapidly than any other region, including the EU-15, but from a small base.

Figure 6 constructs regional shares in world scientific publications over the period 1988-2005. Definitions of the regions differ slightly from Figure 5[21]. The EU-23 supersedes the EU-15 and the Asia-10 countries replace East Asia[22]. On these broader definitions Europe's share of world scientific papers surpasses that of the U.S. in 1996. The U.S. share falls from 38% to 29% during this period. The EU-23 share peaks in 1998 and then declines. All shares decline except Asia-10, with the U.S decline fastest of all.

Figures 7-9 are pie charts of regional shares in world citations in 1992, 1997, and 2003[23]. Definitions of regions revert to Figure 5: Europe is the EU-15 and East Asia is as before. The charts show an accelerating decline in the U.S. share of citations, though nowhere is this equal to that for papers. The EU-15 gain share; and the share of East Asia, while small, grows fastest. At

[20] The EU-15 consists of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. These are the EU countries before the addition of countries of Eastern Europe. East Asia consists of Japan, China, South Korea, Singapore, and Taiwan. The source of Figure 5 is Appendix Table 41, Chapter 5, National Science Board (2006).
[21] The source of these data is Appendix Table 41, Chapter 5, National Science Board (2006) and Appendix Table 34, Chapter 5, National Science Board (2008).
[22] The EU-23 countries are the EU-15 plus new member countries: Bulgaria, Cyprus, Czech Republic, Estonia, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia. The Asia-10 countries consist of East Asia (Japan, China, South Korea, Singapore, and Taiwan) plus India, Indonesia, Malaysia, Philippines, and Thailand.
[23] The data source is Appendix Table 61, Chapter 5, National Science Board (2008).

the end of the period, because of gains in Europe, 75% of citations are still received by America and Europe compared with 70% at the start.

Figure 10 depicts the U.S. share in the top 1%, top 5%, and top 10% most cited papers from 1992-2005[24]. The erosion in share takes place at all levels. While hard to see, the percentage decline is less for top 1% papers than top 5% papers. The top 1% share declines from 65% of the world total in 1992 to 55% in 2005. This is a decline of 15 percentage points (10/65). The top 5% share declines from 38% to 30%, a decline of 21 percentage points. So erosion in share is less at higher levels of citation impact.

But what does this evidence mean? Share data tell us little about welfare. Output adjusted for quality, and output relative to input, are what matter for growth and technical efficiency of an industry. Universities are no exception. If we accept this point, then all we can say is that the growth rate of U.S. scientific publications has fallen and is low relative to other regions, but we have not addressed the factors that drive this change.

Foreign competition for science and engineering students is unlikely to be responsible[25]. If it were, then skill of foreign science and engineering graduate students entering U.S. universities would have undergone serious decline in recent years. But this seems implausible given the

[24] The data source is Appendix Table 63, Chapter 5, National Science Board (2008).

[25] In the long run, arguments concerning the diffusion of science and R&D vary in their implications for welfare of advanced countries like the U.S. If technology converges in science and in industrial research, then the share of innovative products produced in advanced countries will decline. Standard models build on the theory of trade with differentiated products (Helpman and Krugman, 1986). North-South models of innovation, imitation, and trade based on this approach (Krugman, 1979; Grossman and Helpman, 1991) assume that all innovation occurs in North, while imitation primarily occurs in South. But if advanced human resources arise in South as well, then innovation is distributed across both North and South, as Freeman (2006) points out. In that case the profits from new products are also distributed across both regions, and North can lose some industries with supra-normal profits. Applying this line of reasoning to universities as a particular industry suggests that the U.S. could lose the lead in some sciences which in turn might contribute to less effective industrial research in the U.S. But countervailing forces also apply, especially if product varieties grow with the world economy. First, knowledge flows to industries in formerly advanced countries will increase, including universities, so that scientific discoveries and inventions of new products could increase. Second, the larger world economy as a result of South's entry into advanced nation status would create markets for North, including in scientific research. So it is not clear whether North gains or loses as a result of South's development.

attractiveness of employment in the U.S. The recent slowdown could derive from domestic causes. Some evidence on this point is presented by Adams and Clemmons (2006, forthcoming 2009) for labor productivity in research in public and private universities. They find that scientific papers per research faculty grow at an annual rate of 1.2% in public universities and at 2.2% in private universities. Comparable figures for five-year citations received per researcher are 6.2% in public, and 8.6% in private universities. Evidence that growth has slowed down in private universities is weaker than for public universities. We return to this issue in Section VI.

IV.Panel Data on U.S. Universities

With the objective of uncovering reasons for the slowdown in U.S. academic research, we turn to empirical work using a panel of U.S. universities. We begin by describing the data. In their raw form they consist of 2.4 million scientific papers, published during 1981-1999, that have at least one author from a set of leading U.S. universities. These "Top 110" universities account for most U.S. academic research[26].

Papers consist of articles, reviews, notes, and proceedings. The data source is Thomson-Reuters Scientific[27]. Papers follow the scientific field that Thomson assigns to the journal where they appear[28]. The classification system consists of 88 academic subfields. To link the data to the National Science Foundation's (NSF) CASPAR database, we assign each of 88 subfields to

[26] About 75% of all U.S. scientific papers are published in academic institutions and about 80% of all U.S. academic papers are published by the Top 110 represented in this paper. Thus the data used in this paper cover 60% of U.S. scientific papers during 1981-1999. While not a census they are a large sample.

[27] The journal set consists of approximately 5500 journals that were active in 1999 as well as 1600 inactive (renamed or out of print) journals that were cited by active journals.

[28] This assignment is reasonable for specialized journals because of the breadth of fields that we use. But the method produces serious errors for the one percent of journals (about 70) that fall into Thomson-Reuters's Multidisciplinary category. Thomson treats this category as part of biology because biology accounts for the largest number of its papers. Multidisciplinary journals include **Nature**, **Science**, **Proceedings of the National Academy of Sciences USA**, and **Philosophical Transactions of the Royal Society**. Wholesale assignment to biology here is clearly wrong. But to correct the problem would require article (not journal) assignments to fields. Also, some Multidisciplinary journals are primarily focused on biology. Therefore, the problem applies to less than one percent of the journals.

one of NSF's 12 main fields[29].

The data record publication year, field of the journal where a paper appears, institutional affiliation of authors, address information on city, state, and country, and author names as well as number of authors[30]. Address information is separate from author information, so that a name cannot be assigned to a location. But addresses identify universities that collaborate on a paper. We use this information to compute fractional papers among universities. For example, if a paper is written by researchers in two universities, then each university is assigned half the paper. If three share authorship, then each receives a third, and so on[31]. We accumulate the fractions by university, field, and year to form an estimate of "effective" papers produced in a university-field. By treating the data this way we avoid multiple counting of research output of U.S. universities as a whole. Likewise we compute (forward) citations received by a paper in its first five years including year of publication, and we calculate fractional five-year citations in the manner just described for papers, excluding citations from the same institution. We accumulate fractional citations by university, field, and year to form an estimate of "effective" quality-adjusted papers in a university-field[32].

These steps give us research "output" in a university, field and year. Following along these lines we form a panel of universities, fields and years. The panel combines papers and citations with university-field level R&D, university-field PhD students and post-doctoral students, and characteristics of doctoral programs; as well as financial characteristics of parent universities. The NSF-CASPAR database of universities, a compendium of NSF surveys, is the

[29] The twelve fields are: agriculture, astronomy, biology, chemistry, computer science, earth sciences, economics and business, engineering, mathematics and statistics, medicine, physics, and psychology.
[30] There is no limit on the number of authors. The maximum number in the sample is 210 while the mean is 2.36.
[31] The cumulative distribution of universities listed on papers is: 1 university, 79.6%; 2 universities or less, 96.8%; 3 universities or less, 98.3%; and 4 universities or less, 99.5%. It follows that the fractions assigned are almost always 1, ½, 1/3, or ¼.
[32] It is tempting to think of university-fields as departments, but this would be wrong. The same field can be practiced by more than one department and (rarely) multiple fields can be practiced within one department.

source for university R&D and graduate and post-graduate students. The HEGIS (Higher Education General Information Surveys) surveys of the U.S. Department of Education provide financial data at the university level on tuition revenues, state appropriations (for public universities), endowments, auxiliary revenues from fees, and total revenues. The National Research Council (NRC) 1993 Survey of Doctoral Programs (NRC, 1995) includes rankings of PhD programs which we use to stratify departments by relative standing[33].

Besides the classification of universities into private and public we include an indicator of Top 10 University. These were chosen on the basis of top 10 citation impact per paper in 21 fields during 1981-1993. Universities ranked in the top 10 most frequently were considered a Top 10 University. They include eight private schools: Harvard, Yale, Chicago, MIT, Stanford, Princeton, Cornell, and California Institute of Technology. The two public universities are Berkeley and the University of Washington.

We consider only leading departments in the Top 110. Their number depends on field size: we include the top 25 universities in astronomy and the top 50 universities in agriculture, chemistry, computer science, economics and business, earth sciences, mathematics and statistics, physics, and psychology. Last, we include the top 75 universities in biology, medicine, and engineering. Summing across fields, and accounting for the fact that 48 formal schools of agriculture exist, the panel data consist of 648 top university-fields per year. Our purpose in breaking out few individual schools in small fields and more in large fields is to avoid empty cells for universities in which fields are small or non-existent[34]. The result is a panel that contains papers and citations received for 648 university-fields in 12 main sciences during 1981-

[33] NRC ranks are not available for agriculture and medicine. For these fields we sort universities by their 1998 R&D and assign a rank of 1 to the university with the largest R&D and so on, in descending order.
[34] The size of the remainder of the top 110 equals an average university-field in the individual top 25, 50, or 75 schools. This reflects the positive skew of academic R&D. For more on this see Adams and Griliches (1998).

1999, implying a total of 12,312 observations before exclusions due to lags and missing values. For some regressions we stratify the data into top 20 percent, middle 40 percent, and bottom 40 percent university-fields. A field that contains 50 of these has 10 in the top 20 percent, 20 in the middle percent, and 20 more in the bottom 40 percent.

Table 3 contains descriptive statistics consisting of means, standard deviations, minima, and maxima. The groups are all, private, public, and top10 universities. The last three are principal groups in the empirical work.

We begin with research output. Mean (fractional) papers in all universities are 177 per university-field and year. They are slightly larger in private schools and 25% larger in Top 10 schools. The data indicate considerable variation, especially in private schools. The field with the most papers is in a private, Top 10 university. Five-year (fractional) citations received, or citation-weighted papers, exhibit more variation. The mean is 520 per university, field and year. This is 33% higher in private schools, 17% lower in public schools and 79% higher in Top 10 schools. Again the maximum occurs in a private, Top 10 university.

For comparison we report numbers of faculty. This is available only at the university level: its purpose here is to measure size of work force[35]. The average school employs slightly more than 1,200 faculty; private schools employ 800; and public schools employ 1,500. A smaller number of faculty in private schools produce about the same papers but more appreciably more citation-weighted papers than faculty in public schools. And fewer Top 10 faculty produce more papers and many more citations than public school faculty. This is slightly tricky because we are comparing total faculty in universities with papers and citations in university-fields. But it goes through at the university level (Adams and Clemmons, 2006 and forthcoming 2009).

[35] The data include untenured as well as tenure track faculty. In the Top 110 about 90% are tenure track according to HEGIS. Note that data on faculty by university and field have not been collected since 1985.

Research & Development (R&D) stock, an indicator of lagged resources entering into research, is the depreciated sum of lagged R&D in a university-field over the previous 8 years[36]. The depreciation rate is 15%; underlying R&D flows are expressed in millions of '92 dollars. R&D stock in field i, university j, at time t is

$$(1) \qquad R\,\&\,D\;Stock_{ijt} = \sum_{\tau=1}^{8} (0.85)^{\tau} r_{ij,t-\tau}$$

Mean R&D stock is about 80 million; its mean is slightly larger in Top 10 schools. Research output varies more than R&D and private and Top 10 universities produce more research than expected given their R&D stocks.

Financial statistics of tuition, state appropriations, and endowment follow. They derive from HEGIS[37]. All these resources could be used to hire more and higher quality faculty. For example, tuition in private universities might be used to cover start-up packages for assistant professors in science and engineering (Ehrenberg, Rizzo, and Jakubson, 2005). Financial variables could determine research output through choice of labor quality, allocation of time to research, and the purchase of equipment. Not surprisingly, while they have smaller enrollments, private and Top 10 schools have larger tuition revenues and larger (non-tax) endowments. State appropriations capture the tax endowments of public universities. For convenience we construct the following measure of revenue support in university j for use in the regressions:

$$(2) \qquad \text{Revenue}_{j,t} = \text{Tuition}_{j,t-1} + \text{Public} * \text{State Appropriations}_{j,\,t\text{-}1}$$

In private universities revenue is tuition since Public equals zero. But in public universities it is tuition plus state appropriations. This assumes that appropriations substitute for tuition in public

[36] I chose an 8-year lagged stock because the NSF CASPAR R&D data begin in 1973 and papers begin in 1981. It is the maximum length of stock available.

[37] One problem with the financial variables is that they are not available for the late 1990s. Their use costs an appreciable part of the data set.

universities. While we lack a history of revenue we lag (2) by one year to approximate lagged resources. We treat endowment separately from revenue since it is a stock and since it may be earmarked for different uses.

We use the moving average of the stock of graduate students over the previous three years to capture the role of research assistants in research:

(3) $$\text{Graduate Students}_{ij,\,t} = 0.333 * \sum_{\tau=1}^{3} \text{Students}_{ij,\,t-\tau}$$

Table 3 shows that public universities utilize more graduate students. But numbers of faculty and undergraduate students are also larger, conceivably requiring graduate students to serve more as teaching assistants. And besides, large public university programs in engineering include masters as well as PhD students. For all these reasons (3) is likely to be a noisy indicator of research assistance though it is the best we have.

As one indicator of financial duress we use the ratio of auxiliary/total revenues from HEGIS. Auxiliary revenues are defined as fee-for-service charges to students, faculty, or staff. Examples are fees for residence halls, food services, intercollegiate athletics, student unions, stores, and movie theaters[38]. We divide auxiliary by total revenues to abstract from size of university. The mean of this variable is 0.10 but it reaches a maximum of 0.30.

To explain the motivation for the auxiliary/total revenue ratio, suppose that tuition is price-controlled in a public university. One example is a state that provides guaranteed tuition. Controls exist because the state must pick up tuition were the price cap to be lifted. State appropriations place the same burden on taxpayers as lifting the tuition price cap (Rizzo, 2006). Fees are a substitute for tuition in this setting. Likewise, private universities with small endowments and gifts could rely on fees to finance their operations. If these examples are

[38] Hospital revenues are separate from auxiliary revenues.

representative then the ratio of auxiliary/total revenues may indicate financial duress.

Tables 4 and 5 present evidence on this issue. Where 1 is the rank of the school with the lowest auxiliary/total revenue ratio, Table 4 shows that public universities rank highest, and Top 10 universities rank lowest[39]. Top private universities have more resources per student. One would expect them to rely less on fees-for-service.

Table 5 reports correlations among auxiliary/total revenue, enrollment/faculty, tuition plus state appropriations per student, and endowment per student. Reading the first column enrollment/faculty—a student-teacher ratio—is positively correlated with auxiliary/total revenue. Since an increase in this ratio shares limited resources, it also may indicate duress, and we accordingly include it in Table 3. If the auxiliary ratio also represents financial duress then the two indicators should be positively correlated; and they are. Tuition plus state appropriations per student, and endowment per student capture more abundant resources per student. They are the opposite of financial duress (Ehrenberg, 2002). They should both be negatively correlated with auxiliary/total revenue; and they are. We are inclined to believe that the share of auxiliary revenues indicates financial stress. And yet, it may be difficult to separate any of these duress indicators from university effects given that they are not highly trended. Let us turn to the regression analysis using the panel data that we have described.

V. Regression Findings

A. Equation Setup

Tables 6-8 present pooled OLS regressions for private, public, and Top 10 universities. By pooled we mean regressions that combine up to 12 fields for each university. This aspect of the data allows for variability for R&D stock, graduate students, and other variables within a

[39] One could implement the Wilcoxen two sample rank test to see whether the difference is significant. See Brownlee (1965).

university. In the tables we include time trend to indicate unexplained growth, but also to compare "total" regressions to "within" regressions that include university effects. If trend increases when university effects are included this indicates not only unexplained growth within universities, but also that the allocation between universities grows less efficient over time. When the reverse holds and time trend is positive and significant in the total, but not the within regression, then output growth sorts toward more productive universities.

The regressions follow three formats. In the regressions y_{ijt} is the logarithm of research output (papers or citations) in field i, university j, at time t, x_{ijt} consists of logarithms of R&D stock and stock of graduate students; z_{jt} is a set of financial variables (revenue and endowment in logarithms; auxiliary/total revenue, and enrollment/faculty), and D_i stands for a vector of field dummies[40]. Then the "total" equation is:

(4) $$y_{ijt} = \alpha + \beta_0 t + \beta_x' x_{ijt} + \delta_i' D_i + e_j + u_{ijt}$$

While university variables z_{jt} are omitted from (4), we include the z_{jt} below:

(4') $$y_{ijt} = \alpha + \beta_0 t + \beta_x' x_{ijt} + \gamma_z' z_{jt} + \delta_i' D_i + e_j + u_{ijt}$$

In (4) and (4′), e_j is a university error component that may be correlated with the right hand variables, while u_{ijt} is a transitory component that is assumed to be uncorrelated both over time and with the right hand variables. The "within" equation is

(5) $$y_{ijt} = \alpha + \beta_0 t + \beta_x' x_{ijt} + \gamma_z' z_{jt} + \delta_i' D_i + \delta_j' D_j + u_{ijt}$$

In (5) the vector of university dummies D_j absorbs the university error component.

[40] In experimental regressions I included shares of full and associate professors to capture aging effects. The shares were dropped from the regressions because they were not robust. Unlike individual regressions for productivity of scientists (Stephan and Levin, 1991, 1992) where aging has significantly negative effects, at the university and field level these effects are insignificant. One plausible explanation for the difference is that selective pressures favoring more productive researchers and resulting in promotion to full professor counteract individual effects of aging.

B. Pooled Regressions: Private Universities

Table 6 reports estimates for private universities of equations (4), (4′) and (5). In 6.1, trend, R&D stock and the stock of graduate students are highly significant. Together they explain most of the variation in papers[41]. The elasticity of R&D stock is 0.42, that of graduate students 0.16. It follows that an expansion of R&D and graduate students of 10 percent results in 5.8 percent more papers in private universities. Following (4′), equation 6.2 adds financial variables. Lagged tuition is linked to an increase in papers, but this is not statistically significant. The coefficient of endowment is positive and marginally significant. Auxiliary/total revenue and enrollment/faculty (financial duress) reduce research output but are insignificant. Following (5) 6.3 adds university fixed effects. Tuition revenue now enters significantly, as do the duress measures. In 6.2 and 6.3 trend becomes insignificant, so that growth of research output is completely "explained" by these regressions. The output elasticities of R&D stock and graduate students decline slightly, but remain significant.

Equations 6.4-6.6 explain five-year citations received, following the format of 6.1-6.3. While the elasticity of R&D stock increases that of graduate students declines and becomes insignificant. This suggests that for highly cited papers, the contribution of students as research assistants equals the contribution of faculty as advisors. Also, endowment is linked to an increase in citations, suggesting that private universities use endowment to buy release time and hire star faculty. As in 6.3, trend is insignificant in the "within" equation 6.6. These findings suggest that for private universities, the between university contribution to trend is positive.

C. Pooled Regressions: Public Universities

Table 7 reports results for public universities. In general elasticities of R&D stock are slightly less than for private universities. One difference, though, is the larger elasticity of the

[41] See Adams and Griliches (1998) for a related analysis.

stock of graduate students, about 0.1 higher and significant throughout. Research output rises with revenues from tuition plus state appropriations. Endowment does not contribute to research output as it did in private universities. Duress (auxiliary/total revenues; enrollment/faculty) enter with the expected negative signs. But they are not significant when university effects are included in 7.3 and 7.6.

The coefficient of trend increases in the "within" equations relative to the "total" regressions 7.2 and 7.5. It appears that resource allocation favors public universities whose output grows more slowly (Adams and Clemmons, 2006 forthcoming 2009), since trend increases when the "between" variation is taken out. Some of the trend growth in Table 7 could be due to knowledge flows from private universities, since knowledge flows are more likely to occur from highly ranked departments (Adams, Clemmons, and Stephan, 2006).

D. Pooled Regressions: Top 10 Universities

Table 8 reports estimates for Top 10 universities of (4') and (5). Since there are public universities in the Top 10 we include Public (1 if yes, 0 if no) to test for public-private differences in 8.1 and 8.3: we drop Public from 8.2 and 8.4 since it is a linear combination of fixed effects for public universities. In any event, Public is insignificant.

The most striking feature of Table 8 is the increase in the combined elasticity of R&D and graduate students. This lies in the range of 0.63-0.71: higher than before. The graduate student elasticity approaches that of R&D for the first time. One view of this finding is that graduate students in Top 10 schools are more able. Another is that they are primarily research assistants.

Most financial indicators are insignificant. In 8.1 and 8.3 revenue is associated with a decline in research implying that Top10 tuition is earmarked for teaching. Trend disappears in the within regressions, suggesting allocative efficiency in this group.

E. Regressions Stratified by Rank of University-Field

Tables 9 and 10 consider university-fields stratified by quality into top 20, middle 40, and bottom 40 percent groups as described in Section IV. Table 9 reports frequency distributions of university-fields by private, public, and Top 10 universities. It shows that top 20 and middle 40 percent account for the majority of private school observations. Public school observations cluster in the middle and bottom 40 percent; and nearly all observations for the Top 10 are in the top 20 and middle 40 percent. It turns out that within groups, university-fields are higher ranked in private and Top 10 universities. A top 20 percent university-field in a private school is higher ranked on average than one in a public school. But in lumping together public schools, it is important to remember the wide variation in quality of fields within these institutions.

Table 10 reports estimates of (4′) and (5). Results for the top 20, middle 40, and bottom 40 percent are shown in Panels A, B, and C. Because I separate university-fields into groups by rank, I call these as stratified regressions, though they are pooled across fields[42]. To focus on key variables consisting of trend, R&D, and graduate students, financial variables are omitted though these are included in the regressions.

Top 20 percent university-fields obtain more research output from R&D and graduate students than the middle or bottom 40 percent. Indeed graduate students in the bottom 40 percent fail to make a significant contribution to research. This implies that they teach and work on thesis research. This and faculty time needed for dissertation work reduce the net student contribution to zero in the bottom 40 percent.

[42] Following Section IV, top 20 percent regressions include the top five in astronomy, the top 15 in biology, medicine, and engineering, and the top 10 in all other fields. Middle 40 percent regressions include the next 10 in astronomy, the next 30 in biology, medicine, and engineering, and the next 20 in all other fields. Bottom 40 percent regressions include the bottom 10 in astronomy, the bottom 30 in biology, medicine, and engineering, and the bottom 20 in all other fields.

Trend coefficients suggest that the allocation among university-fields is not efficient below the top 20 percent. We begin with the papers regressions, moving from the top 20 through the bottom 40 percent. In the total regression 10.1, the coefficient of trend is 0.0054 and insignificant. It is indistinguishable from 0.0086 in the within regression 10.2. For the middle 40 percent the coefficient of trend is 0.0028 in 10.5 and insignificant compared with 0.0148 and significant in the within equation 10.6. For the bottom 40 percent the coefficient is 0.0088 and marginally significant in 10.9, compared with 0.0208 and significant in 10.10. We conclude that as rank declines, within estimates of trend rise and diverge from total estimates. This suggests that resource allocation is less efficient in lower ranked university-fields.

Bearing in mind that citations grow faster than papers, a similar pattern is observed for the citations regressions. For the top 20 percent the total regression 10.3 yields a significant coefficient on trend of 0.0216, compared with 0.0126 in 10.4, where it is insignificant. For the top 20 percent, resources are allocated to the most productive groups. But the reverse is true for the middle and bottom 40 percent. For the middle 40 percent the total regression (10.7) yields a trend coefficient of 0.0301 compared with 0.0439 in the within regression (10.8). For the bottom 40 percent, the coefficient is 0.0383 in the total regression (10.11), rising to 0.0509 in the within regression (10.12). Both are statistically significant. Trend coefficients in total and within regressions diverge. The latter is increasingly the larger as rank diminishes. I again conclude that allocative efficiency is less among lower ranked university-fields (Adams and Clemmons 2006, forthcoming 2009).

F. Regressions by Field of Science

We also ran separate regressions by field of science. To save space we do not report these regressions, but provide a brief summary. The results cover six fields accounting for the majority of academic R&D expenditures: biology, chemistry, engineering, mathematics and statistics, medicine, and physics. We included trend, R&D stock, the stock of graduate students, and (for biology and medicine) the lagged three-year moving average of the stock of post-doctoral students. Generally speaking, graduate students are consistently more important in the production of papers in engineering and physics. They vary in importance in biology, chemistry, and mathematics and statistics. R&D withstands inclusion of university effects and remains significant more often than graduate or postdoctoral students. Finally, R&D contributes more, and students less, to citations than to papers.

G. Faculty Compensation and Wage Structure

The empirical work concludes with an analysis of faculty compensation by rank, or in other words, academic wage structure. Studying this structure should provide additional clues as to the financial condition of universities. The dependent variable is the logarithm of wages plus fringe benefits in '92 $ at the full and assistant professor ranks[43]. These are university-wide averages since HEGIS, which is their source, does not collect wage data by university-field. Since the data are an average I cannot estimate a wage equation in which wages are treated as a function of education, experience, and tenure. But faculty quality could be reflected in the following: the logarithm of university-wide R&D stock per faculty, the logarithm of tuition revenue per faculty (private schools) or tuition plus state appropriations per faculty (public schools), the logarithm of endowment per faculty, and the financial duress indicators, auxiliary/total revenue and enrollment/faculty. Faculty are lagged in constructing these right hand side variables, in order to limit division error bias. Besides the above we include trend to capture general wage growth and a cost of living indicator for whether a university is located in a large city (Consolidated Metropolitan Statistical Area). The specification is:

[43] As with the other variables, the deflator used is the GDP implicit price deflator indexed to 1992.

(6) $$\text{Log}(\text{Wage}_{jt}) = \alpha + \beta_0\, t + \beta_L \text{Large City} + \beta' \text{x}_{\text{jt}} + u_{jt}$$

These are "total" wage regressions that omit university effects because wage variation is insufficient in the within dimension.

Table 11 contains the results. The dependent variable in 11.1 and 11.4 is the logarithm of full professor compensation, in 11.2 and 11.5 it is the logarithm of assistant professor compensation; and 11.3 and 11.6 take the difference between the two.

Starting with the results for full and assistant professors, the trend coefficients show that real compensation grows at about 1.5 percent a year, but faster in private universities, especially at the assistant professor level, where it grows at 2.5 percent[44]. Location in large cities raises private school wages by 5-10 percent. Large city has no significant effect on public school compensation. This is because state institutions are rarely located in large cities. R&D stock and endowment, for full professors, lead to higher compensation in private universities. The only significant determinant of public compensation is revenue: tuition plus state appropriations.

Results for the difference in full and assistant professor compensation are shown in 11.3 and 11.6. In private universities (11.3) we see that location in a large city, tuition, and endowment increase the wage premium for senior faculty, but trend and enrollment/faculty decrease it. In public universities (11.6) endowment per faculty increases the premium while enrollment/faculty again decreases it. Overall the public wage structure appears to be flat.

VI. Discussion, Synthesis, and Conclusion

Sections II and III tell a story of rapid postwar expansion of U.S. universities. This was aided by immigrant scientists and engineers, the broadening of access to universities, a large

[44] The compensation gap between private and public universities rises at the rate of 0.8% a year. In simple regressions that include trend and intercept, I find that relative to the GDP deflator, full and assistant professor compensation grows at 2.3% per year in private universities and at 1.5% per year in public universities. Top 10 university compensation grows at 2.1% per year. These regressions have R^2s ranging from 0.3-0.4.

increase in military research, and the expansion of high technology industries. Since the 1980s we observe an expansion of academic research in Europe, but especially East Asia, that implies convergence in world science and engineering.

Most recently, in the late 1990s, we observe a slowdown of publication output in the U.S. This becomes the central puzzle of the paper, and Sections IV-V address it at length using micro panel data on universities, fields and years. The econometric analysis uncovers evidence of inefficiency in the distribution of resources among public universities, in that trend growth of output is greater within universities than it is in total. In addition, we find that Top 10 universities are more effective in utilizing R&D stock and graduate students to produce research. Top 20 percent university-fields also employ resources more effectively and without the allocative inefficiency that characterizes the middle or bottom 40 percent. And despite immigration of scientists and engineers we find that real faculty compensation rises at close to two percent per year, and that it is rises by 0.8 percent faster in private than public universities.

These are interesting facts but at this point a synthesis that combines the facts would be useful. To this end I have composed three summary tables. All are aimed at facilitating discussion of trends in university productivity and the U.S. slowdown in publication.

Table 12 presents totals of papers, citation-weighted papers, PhD degrees awarded, and R&D stock in private and public universities, for selected years. The data consist of 620 university-fields (out of 648 possible), observed over 1982-1999, for which there are no missing values. For interpretive ease I report values relative to 1982 in square brackets. In brief, the data tell us that papers expand by slightly more (slightly less) than 50 percent in private (public) universities; citations grow more than 100 percent in both groups (from 1982-1995); and PhDs grow by a third in both groups. Since citations increase with the growing ease of citation and the number of researchers, we view citation growth as an upper bound on growth of research output, and growth of papers as a lower bound. Viewed in this light, growth of research output lies between 50 and 125 percent in both sets of institutions.

This tells us about research output, but what about input? Let us examine the behavior of R&D stock, beginning with values based on the implicit GDP deflator. This grows by 105 percent (130 percent) in private (public) schools. That exceeds growth of publications (and PhDs): surely it is a formula for a slowdown in research output. But growth of R&D stock is overstated because the GDP deflator understates cost increases in universities, and overstates growth of real R&D. Table 11's evidence on rising real compensation makes this clear.

The Bureau of Economic Analysis has constructed a deflator for university R&D that helps to address this concern (Robbins and Moylan, 2007). If we calculate real R&D using the BEA deflator we find that R&D stocks in private universities grow by 72 percent, not 105 percent; and that growth in public schools is 93 percent, not 130 percent. Real R&D now grows by 70 (90) percent in private (public) universities: research output grows by 50-125 percent in both.

Even using the BEA deflator growth of real R&D is likely to be overstated. First, large inter-university grants grow in importance during this time. Since grants are not apportioned among schools in the statistics until well after 1999, R&D is increasingly over-counted. Second, an increasing amount of funding for training and support of graduate students seems to be for training and not faculty research[45]. To assess research productivity more accurately, it would be useful to separate with certainty funds for research from funds for support and training. The point is also important if universities move from institutional support of graduate students

[45] See De Figueiredo and Silverman (2006) for an analysis of the rising earmarking of grants, a clear departure from efficiency. Another factor could be a growing emphasis on commercialization, which could detract from research output. See Toole and Czarnitzki (2007) for a discussion of this issue.

towards a system that supports students from grants. To that extent, grants replace internal funds. They are not additional funds for research.

In Table 12 publication output grows faster relative to R&D input in private universities, even though R&D grows faster in public universities. And while growth of papers slows down during 1995-1999 in private universities, it stops growing in public universities. Research output does not keep up with R&D growth at the end of the 1990s in public universities. However, the growth rate of research output recovers during 2000-2005 (National Science Board, 2008, Chapter 5, Appendix Table 5-36) so the slowdown is in part temporary[46].

Table 13 constructs ratios of papers, citations, and PhD students to R&D stocks using the GDP and BEA deflators. Especially in public schools, papers per million $ decline over time. The decline is small in private universities, from 2.31 in 1982 to 2.05 in 1999, using the BEA deflator. But that adjustment does not eliminate the decline in public schools.

Citations per million $ of R&D grow, but they grow significantly faster in private universities. Using the BEA deflator PhDs per million $ decline by 50 percent in both groups of universities. In comparing productivity growth, it is useful to recall that faculty compensation rises 0.8 percent faster per year in private universities. Papers per million $ fall less and citations per million $ rise more in private schools because labor quality rises at a faster rate.

In Table 14 I record total enrollment, faculty (tenure track and non-tenure track), tuition (plus state appropriations in public universities). All are at the university level. Again values relative to 1982 are placed in square brackets. These measure size and resources over time.

[46] For all academic institutions, total scientific papers published fell from 139,168 in 1995 to 138,472 in 1999. But by 2005 this total had increased to 159,972. These are fractional papers. Numbers of scientific papers reflect year of entry into the database rather than year of publication. See National Science Board, 2008, Chapter 5, Appendix Table 5-36.

Growth in enrollments in both private and public institutions through 1997 is about 10 percent. Coupled with the fact that PhD degrees increase by one third we see that enrollment shifts towards (more costly) graduate education over time. Numbers of faculty grow by 25 percent in private universities but by eight percent in public universities. Most of the growth in private universities occurs at the end, so the effects on research will be felt in the 21st century. Tuition revenues grow by 124 percent in private universities, but tuition plus state appropriations grow at only 46 percent in public universities. This divergence in funding is obvious during the 1990s. It helps account for private-public productivity differences, especially given that wages rise more slowly in public schools. This finding is already implicit in the regressions. In total regressions for public schools (Table 7) I found that tuition plus state appropriations increases productivity, and I found evidence for financial stringency. A slowdown in revenue reduces productivity below what it would have been, through exit and reassignment to instruction. This factor is missing from the private school results (Table 6), as is evidence for stringency.

Endowments grow at the same rate in all institutions and are almost three times larger by 1996, the last year of record. But the difference in endowment per faculty remains large: 1.39 million in private versus 0.15 million in public universities.

Together, Tables 12 and 14 open up a new perspective on research productivity in universities. In Table 12 we saw that papers increased by 50 percent during this period while citations increased by 125 percent. In Table 14 we see that faculty increase by 10-25 percent, though an increasing proportion, especially in public universities, seem to be budgeted for research (Adams and Clemmons, 2006, forthcoming 2009). Papers and citations per faculty both increase. This growth is slightly less if one takes the rising proportion of research faculty into account. But growth in papers per faculty is evident, except for 1995-1999. This recalls points that I made earlier about deficiencies in the measurement of university R&D. Its growth is probably overstated. At the same time, there can be little doubt that research productivity in public universities has fallen behind.

The analysis of this section indicates that this gap can be traced to slow growth in tuition and state appropriations compared with revenue growth in private universities. At the time, research funding expands at a faster rate in public institutions. Together this tells an interesting story of state and federal policy interactions. The states during this time are subject to rising health care costs due to Medicare. In addition, some are subject to mandated equalization of K-12 education expenditures which raise costs of elementary and secondary education (Murray, Evans, and Schwab, 1998). Towards the end of the period some states commit themselves to pre-paid tuition plans that are inadequately funded (Rizzo, 2006). So growth of mostly federal research dollars is cancelled out by the slower growth of state dollars in public universities.

I close with a final observation. All that we have seen, which covers 60 percent of scientific research in the U.S., consists of a fixed set of Top 110 institutions. If there are limits on research in these schools, because of diminishing returns to scale, then future growth will have to come from elsewhere. The challenge is one of replicating assets of top universities, if sustained growth of research is an objective. At present, growth appears to be more rapid in universities where this kind of replication remains an open question.

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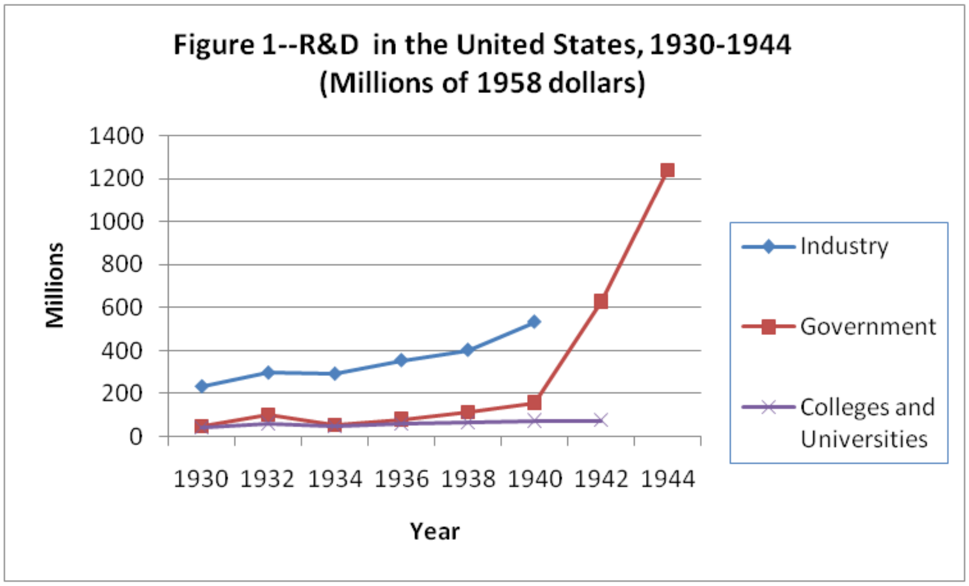


Figure 1--R&D in the United States, 1930-1944
(Millions of 1958 dollars)
Millions
1400
1200
1000
800
600
400
200
0
1930 1932 1934 1936 1938 1940 1942 1944
Year
Industry
Government
Colleges and Universities

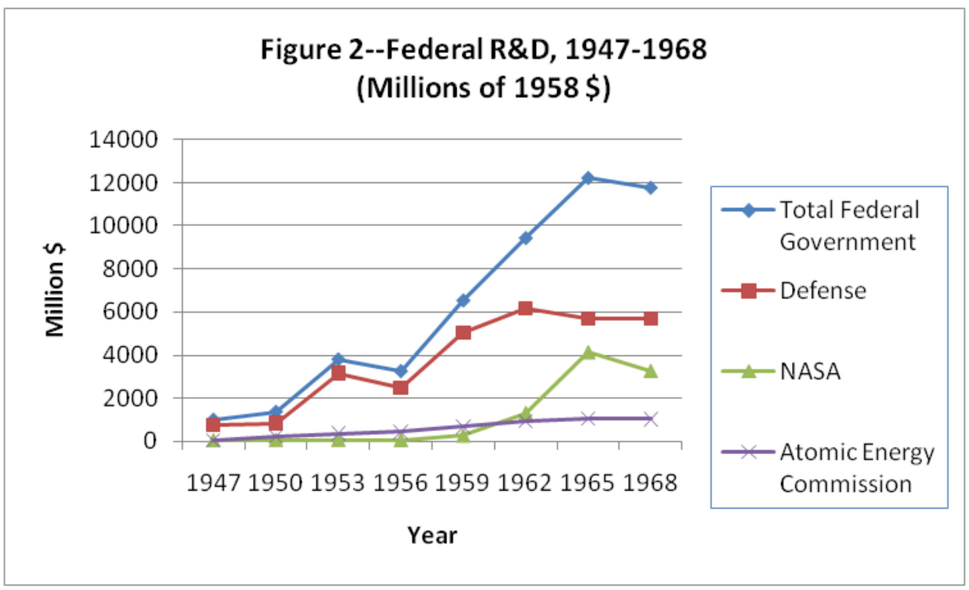


Figure 2--Federal R&D, 1947-1968
(Millions of 1958 $)
Million $
14000
12000
10000
8000
6000
4000
2000
0
1947 1950 1953 1956 1959 1962 1965 1968
Year
Total Federal Government
Defense
NASA
Atomic Energy Commission

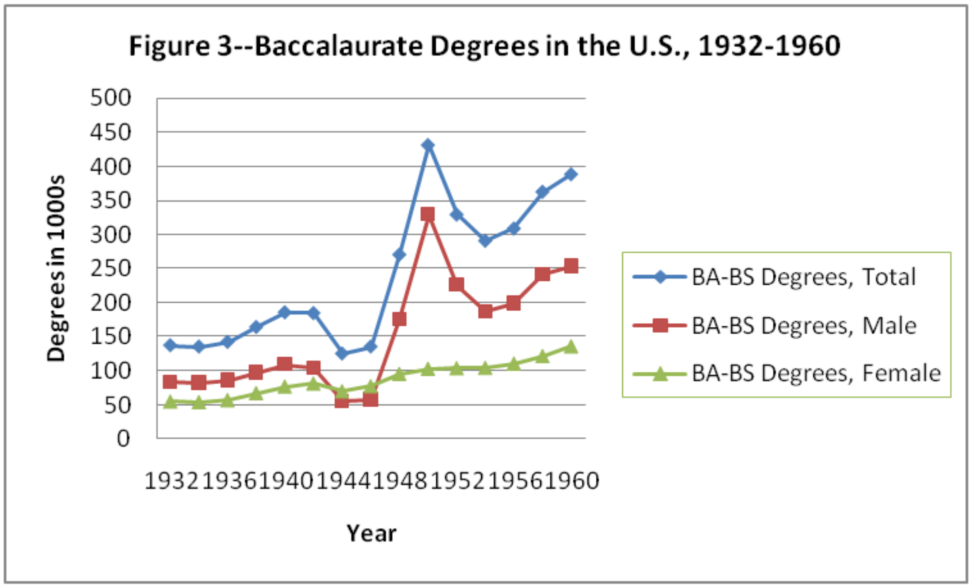


Figure 3--Baccalaurate Degrees in the U.S., 1932-1960
Degrees in 1000s
500
450
400
350
300
250
200
150
100
50
0
1932 1936 1940 1944 1948 1952 1956 1960
Year
BA-BS Degrees, Total
BA-BS Degrees, Male
BA-BS Degrees, Female

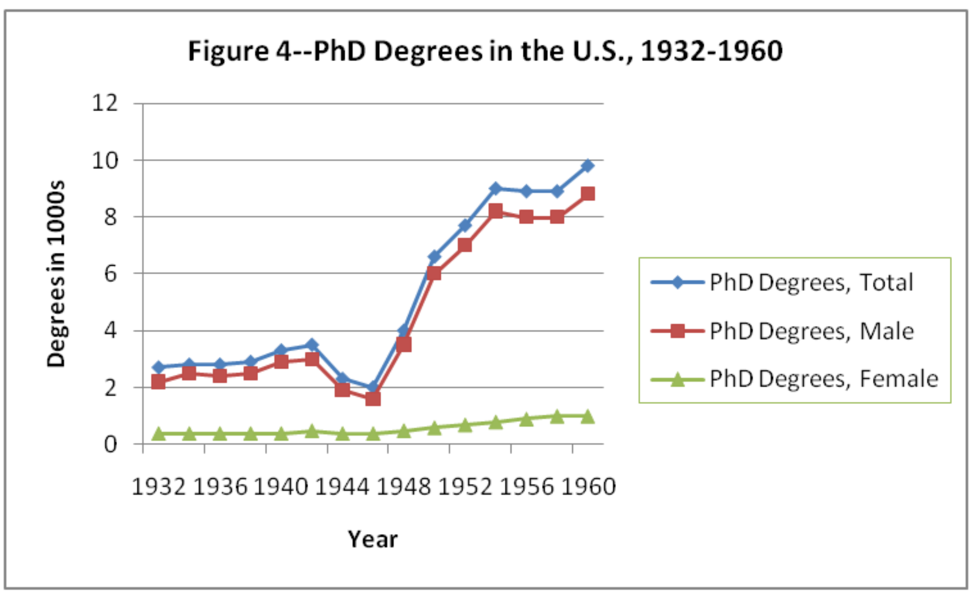


Figure 4--PhD Degrees in the U.S., 1932-1960
Degrees in 1000s
12
10
8
6
4
2
0
1932 1936 1940 1944 1948 1952 1956 1960
Year
PhD Degrees, Total
PhD Degrees, Male
PhD Degrees, Female

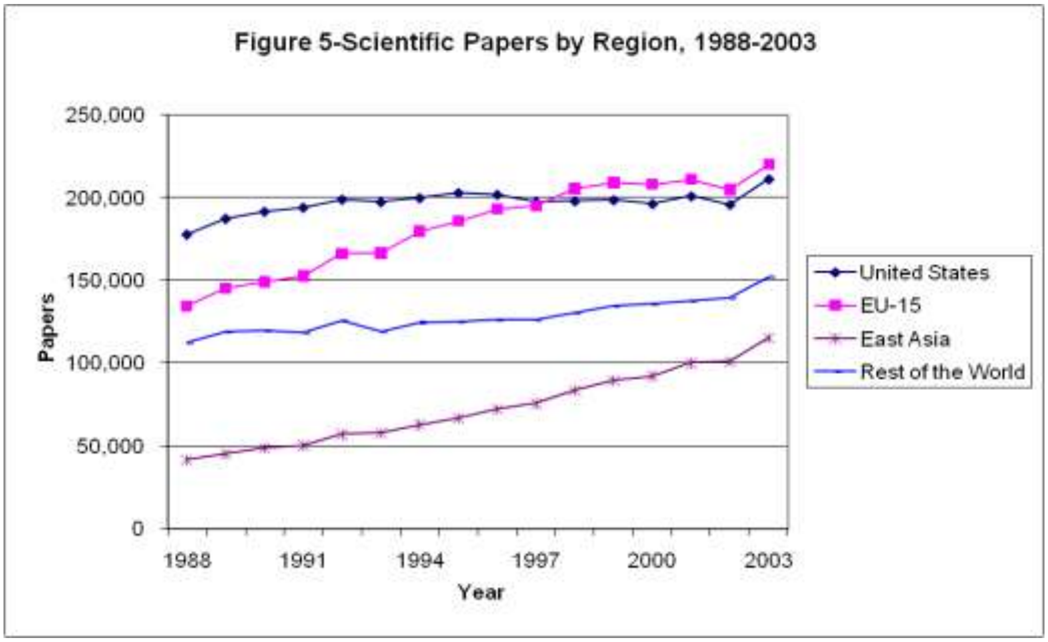


Figure 5-Scientific Papers by Region, 1988-2003
250,000
200,000
150,000
100,000
50,000
0
Papers
1988
1991
1994
1997
2000
2003
Year
United States
EU-15
East Asia
Rest of the World

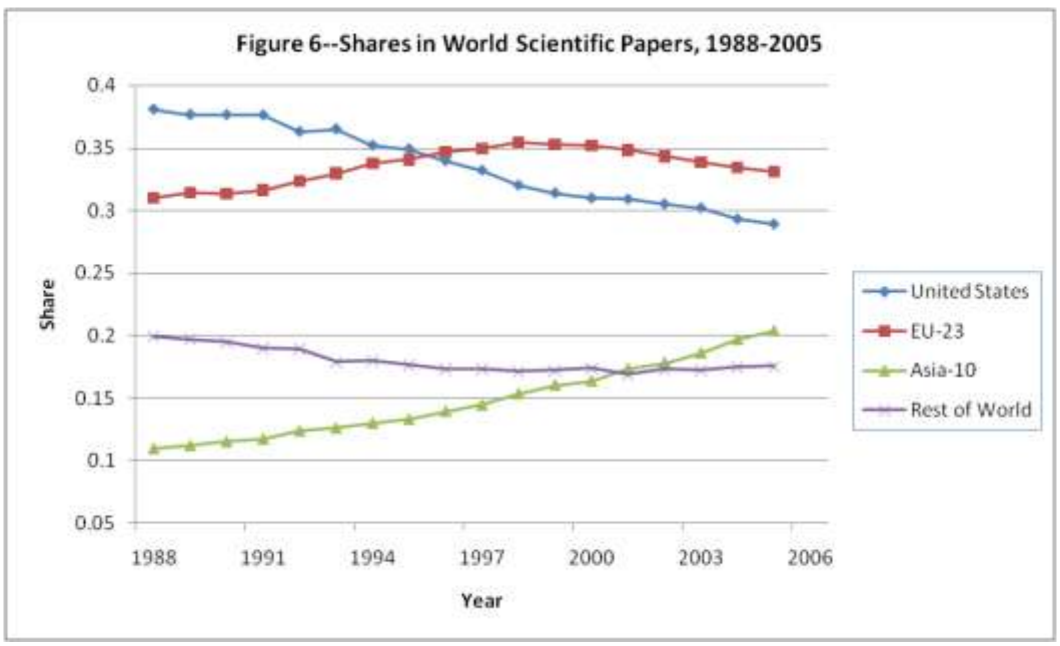


Figure 6--Shares in World Scientific Papers, 1988-2005
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Share
1988
1991
1994
1997
2000
2003
2006
Year
United States
EU-23
Asia-10
Rest of World

Figure 7--Citation Shares by Region, 1992

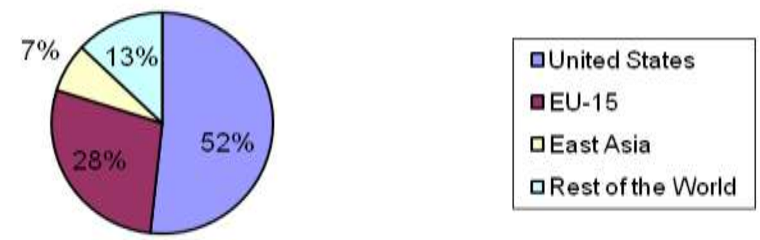


Figure 8--Citation Shares by Region, 1997

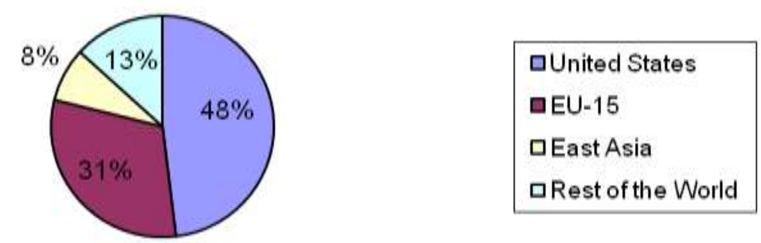
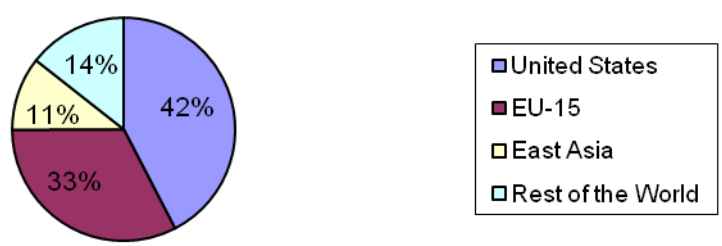


Figure 9--Citation Shares by Region, 2003



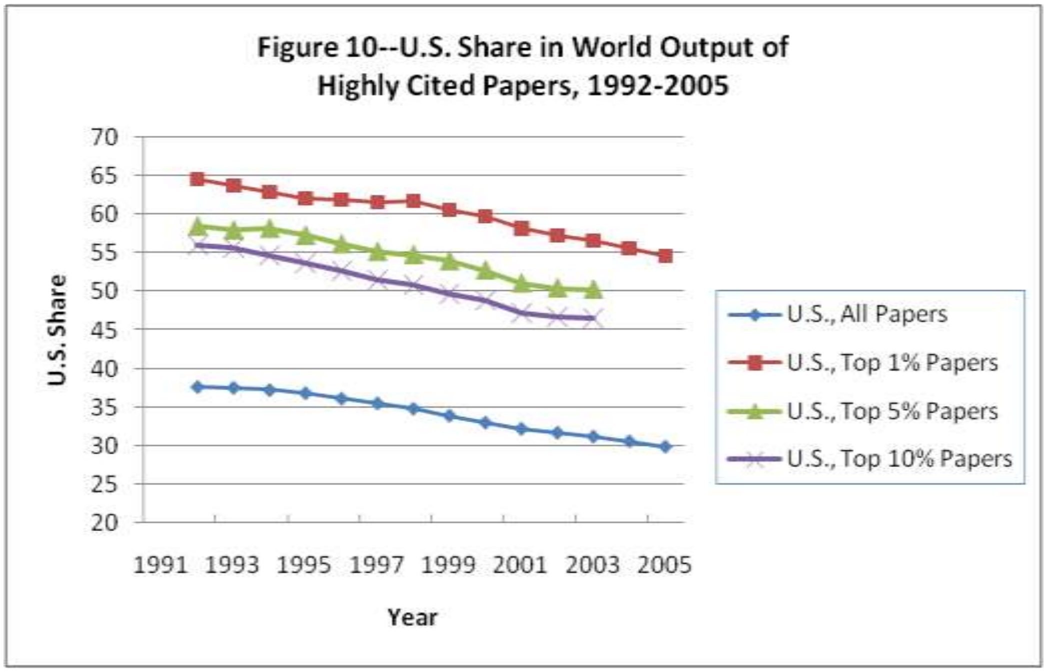


Figure 10--U.S. Share in World Output of
Highly Cited Papers, 1992-2005
70
65
60
55
50
45
40
35
30
25
20
U.S. Share
1991 1993 1995 1997 1999 2001 2003 2005
Year
U.S., All Papers
U.S., Top 1% Papers
U.S., Top 5% Papers
U.S., Top 10% Papers

Table 1—Statistics of the Intellectual Migration From Europe to the United States, 1933-1944

Field	Nobel Prize Winners [a]	Distinguished Refugees [b]	Sample of Refugee Professors [c]
Biology; Physiology or Medicine	2	72	91
Chemistry	1	28	63
Physics or Astronomy	6	40	77
Mathematics	n. a.	41	53
Literature	3	15	65
Economics	n. a.	7	60
Total	12	203	409

Notes: [a] These are Nobel Prize winners by the time of Davie (1947). [b] Distinguished Refugees are compiled by Davie (1947), pages 432-440, from **Who's Who in America** (1944-1945) and **American Men of Science** (1944). [c] Sample consists of 707 refugees who formerly were on university faculties in Europe, of which 409 were in the disciplines shown.

Table 2—Nobel Prizes Won by U.S. Residents, 1901-2007

Period	Total Laureates	Total Foreign-Born	Science [a] (Foreign-Born)	Literature (Foreign-Born)	Peace (Foreign-Born)	Economics [b] (Foreign-Born)
1901-1910	2	1	1 (1)	0	1	n. a.
1911-1920	3	0	1	0	2	n. a.
1921-1930	5	0	2	1	2	n. a.
1931-1940	13	0	9	2	2	n. a.
1941-1950	22	5	15 (5)	2	5	n. a.
1951-1960	29	7	27 (7)	1	1	n. a.
1961-1970	32	10	27 (10)	1	3	1
1971-1980	52	14	40 (7)	3 (3)	1 (1)	8 (3)
1981-1990	48	15	37 (11)	1 (1)	1 (1)	9 (2)
1991-2000	52	12	39 (9)	1	1	11 (3)
2001-2007	46	9	31 (6)	0	2	13 (3)
All Years	304	73	229 (56)	12 (4)	21 (2)	42 (11)

Notes: [a] Science Nobel Prizes include separate awards in physics, chemistry, and in physiology or medicine. [b] The Nobel prize in economics began in 1969. Thus economics prizes for the 1961-1970 decade are limited to 1969-1970. Data compiled from Nobel Archives at www.nobel.org .

**Table 3—Descriptive Statistics,
Panel of Universities, Fields, and Years**

Variable	Analytical Level	Mean	Std. Dev.	Min	Max
Papers [a]					
All Universities	University-Field	176.8	210.9	0.5	2,559.1
Private "	"	183.1	256.2	1.3	2,559.1
Public "	"	173.6	183.2	0.5	1,317.6
Top10 "	"	223.0	309.0	2.8	2,559.1
Five-Year Citations Received [a]					
All Universities	University-Field	520.1	1,078.9	0	21,954.2
Private "	"	693.8	1,518.7	0.9	21,954.2
Public "	"	430.8	743.4	0	7,710.8
Top10 "	"	929.5	1,961.3	3.0	21,954.2
Number of Faculty [b]					
All Universities	University	1,236.3	614.6	42	3,083
Private "	"	802.1	371.6	179	2,461
Public "	"	1,459.9	595.0	42	3,083
Top10 "	"	1,037.4	400.4	247	1,994
Stock of R&D (millions of '92 $) [c]					
All Universities	University-Field	79.8	109.8	0.0	1,482.9
Private "	"	79.7	113.2	0.0	854.8
Public "	"	79.8	108.1	0.2	1,482.9
Top10 "	"	92.1	124.8	0.9	725.6
Tuition Revenues (millions of '92 $) [d]					
All Universities	University	120.4	83.9	0.7	547.4
Private "	"	158.1	94.7	13.0	547.4
Public "	"	101.0	70.2	0.7	413.0
Top10 "	"	146.6	72.5	13.0	373.3
State Appropriations (millions of '92 $) [d]					
All Universities	University	155.9	132.0	0	489.7
Private "	"	11.1	30.6	0	160.8
Public "	"	230.5	97.8	23.9	489.7
Top10 "	"	73.8	118.2	0	395.3

**Table 3—Descriptive Statistics,
Panel of Universities, Fields, and Years**

Variable	Analytical Level	Mean	Std. Dev.	Min	Max
Endowment (millions of '92 $) [d]					
All Universities	University	553.9	890.7	0.013	6,553.7
Private "	"	1,118.9	1,029.4	55.3	6,553.7
Public "	"	258.7	632.7	0.013	5,089.6
Top10 "	"	1,546.8	1,311.6	123.9	6,553.7
Graduate Students [e]					
All Universities	University-Field	258.7	343.1	0.0	4,904.0
Private "	"	198.3	363.1	0.0	4,904.0
Public "	"	289.8	328.1	0.0	2,705.0
Top10 "	"	244.7	386.7	0.0	2,416.7
Auxiliary/Total Revenues [d]					
All Universities	University	0.096	0.045	0.006	0.302
Private "	"	0.077	0.040	0.006	0.245
Public "	"	0.105	0.045	0.007	0.302
Top10 "	"	0.074	0.031	0.006	0.157
Enrollment/Faculty [f]					
All Universities	University	21.5	6.4	4.8	40.1
Private "	"	16.4	4.9	6.5	28.9
Public "	"	24.1	5.4	4.8	40.1
Top10 "	"	14.9	4.6	6.5	24.3

Notes: The sources of the data are described in the text and derive from Thomson-Reuters Scientific, the CASPAR database of the National Science Foundation, and the HEGIS database of the National Center for Education Statistics. [a] Papers and citations received are fractionally assigned to universities in the manner described in the text. [b] The number of faculty is the number of tenure-track plus non-tenure track faculty. These data derive from HEGIS. [c] The stock of R&D is for a university-field. It derives from the NSF-CASPAR database of universities. [d] All the financial variables derive from HEGIS. [e] The number of lagged graduate students is for a university-field. It is an average over the previous three years. These data derive from the NSF-CASPAR database of universities. [f] The enrollment data derive from HEGIS.

Table 4—Statistics of Auxiliary/Total Revenue

University Type	Mean Rank 1982	1988	1995	Mean (St. Dev.)
Private	43.7	45.3	43.1	0.084 (0.047)
Public	56.1	55.3	56.4	0.100 (0.047)
Top10	31.9	37.2	44.6	0.072 (0.034)

Notes: Rank is 1 for the smallest value of Auxiliary/Total Revenue and rank increases with the value. Mean rank is computed for selected years shown; means and standard deviations are computed for all years.

Table 5—Correlations Among Financial Indicators (Significance Levels in Parentheses)

	Auxiliary/ Total Revenue	Enrollment/ Faculty	Tuition + State Appropriations/ Student	Endowment/ Student
Auxiliary/ Total Revenue	1.00			
Enrollment/ Faculty	0.17 (<0.0001)	1.00		
Tuition + State Appropriations/ Student	-0.41 (<0.0001)	-0.50 (<0.0001)	1.00	
Endowment/ Student	-0.25 (<0.0001)	-0.35 (<0.0001)	0.21 (<0.0001)	1.00

Notes: see text for definitions of the financial indicators.

Table 6—Pooled OLS Research Regressions: Private Universities
(Robust, Clustered S.E. in Parentheses)

Variable or Statistic	Log (Papers)			Log (5-year Citations)		
	Eq. 6.1	Eq. 6.2	Eq. 6.3	Eq. 6.4	Eq. 6.5	Eq. 6.6
Field Dummies Included	Yes	Yes	Yes	Yes	Yes	Yes
University Dummies Included	No	No	Yes	No	No	Yes
Regression Structure	Total	Total	Within	Total	Total	Within
Time Trend	0.0057*	-0.0061	-0.0070	0.0265**	0.0040	-0.0160
	(0.0026)	(0.0049)	(0.0088)	(0.0044)	(0.0069)	(0.0122)
Log (R&D Stock in mill. of ’92 $)	0.413**	0.369**	0.294**	0.563**	0.474**	0.377**
	(0.045)	(0.039)	(0.035)	(0.059)	(0.052)	(0.043)
Log (Graduate Students)	0.157**	0.127**	0.132*	0.092	0.083	0.089
	(0.049)	(0.047)	(0.055)	(0.054)	(0.057)	(0.066)
Log (Tuition Rev. in mill. of ’92 $)		0.138	0.271*		0.186	0.629**
		(0.086)	(0.128)		(0.130)	(0.213)
Log (Endowment in mill. of ’92 $)		0.102*	0.055		0.204**	0.196**
		(0.050)	(0.071)		(0.070)	(0.076)
Auxiliary/Total Rev.		-1.913	-1.857*		-1.518	-1.246
		(0.985)	(0.797)		(1.438)	(1.002)
Enrollment/Faculty		-0.015	-0.009*		-0.030*	-0.004
		(0.008)	(0.004)		(0.012)	(0.005)
Number of Observations	3,255	2,636	2,636	2,523	2,454	2,454
R-squared	0.84	0.86	0.88	0.85	0.87	0.90
Root MSE	0.471	0.448	0.407	0.641	0.597	0.536

Note: see the text for definitions of the variables.

Table 7—Pooled OLS Research Regressions: Public Universities
(Robust, Clustered S.E. in Parentheses)

Variable or Statistic	Log (Papers)			Log (5-year Citations)		
	Eq. 7.1	Eq. 7.2	Eq. 7.3	Eq. 7.4	Eq. 7.5	Eq. 7.6
Field Dummies Included	Yes	Yes	Yes	Yes	Yes	Yes
University Dummies Included	No	No	Yes	No	No	Yes
Regression Structure	Total	Total	Within	Total	Total	Within
Time Trend	0.0077**	-0.0016	0.0106**	0.0365**	0.0187**	0.0402**
	(0.0020)	(0.0027)	(0.0020)	(0.0033)	(0.0050)	(0.0030)
Log (R&D Stock in mill. of '92 $)	0.341**	0.338**	0.335**	0.416**	0.406**	0.397**
	(0.034)	(0.034)	(0.035)	(0.042)	(0.041)	(0.042)
Log (Graduate Students)	0.288**	0.215**	0.173**	0.232**	0.156**	0.127**
	(0.042)	(0.038)	(0.041)	(0.053)	(0.046)	(0.046)
Log (Tuition + State Appropriations in mill. of '92 $)		0.266**	0.138**		0.224*	0.160
		(0.063)	(0.047)		(0.091)	(0.084)
Log (Endowment in mill. of '92 $)		0.019	-0.018		0.050**	-0.043**
		(0.011)	(0.010)		(0.018)	(0.018)
Auxiliary/Total Rev.		-1.382**	0.142		-2.388**	0.459
		(0.401)	(0.157)		(0.635)	(0.351)
Enrollment/Faculty		-0.009*	-0.004*		-0.008	-0.002
		(0.004)	(0.002)		(0.006)	(0.005)
Number of Observations	6,552	4,678	4,678	5,088	4,378	4,378
R-squared	0.84	0.86	0.90	0.83	0.85	0.89
Root MSE	0.429	0.400	0.342	0.634	0.595	0.506

Notes: see the text for definitions of the variables.

Table 8—Pooled OLS Research Regressions: Top 10 Universities (Robust, Clustered S.E. in Parentheses)

Variable or Statistic	Log (Papers)		Log (5-year Citations)	
	Eq. 8.1	Eq. 8.2	Eq. 8.3	Eq. 8.4
Field Dummies Included	Yes	Yes	Yes	Yes
University Dummies Included	No	Yes	No	Yes
Regression Structure	Total	Within	Total	Within
Time Trend	0.0084	0.0084	0.0260**	0.0124
	(0.0042)	(0.0094)	(0.0081)	(0.0093)
Public (1 if yes, 0 if no)	-0.082		0.187	
	(0.112)		(0.220)	
Log (R&D Stock in mill. of ’92 $)	0.380**	0.356**	0.352**	0.333*
	(0.088)	(0.098)	(0.107)	(0.112)
Log (Graduate Students)	0.327*	0.302*	0.334*	0.293*
	(0.117)	(0.123)	(0.138)	(0.143)
Log (Tuition + Public*State	-0.180*	-0.010	-0.332*	0.174
Appropriations in mill. of ’92 $)	(0.070)	(0.151)	(0.108)	(0.162)
Log (Endowment in mill. of ’92 $)	0.031	-0.056	0.183*	0.055
	(0.052)	(0.079)	(0.084)	(0.076)
Auxiliary/Total Rev.	-1.013	-0.745	-1.085	-0.618
	(0.998)	(0.954)	(1.434)	(1.519)
Enrollment/Faculty	0.022	-0.016	0.025	-0.010
	(0.013)	(0.009)	(0.021)	(0.011)
Number of Observations	1,201	1,201	1,121	1,121
R-squared	0.85	0.86	0.87	0.88
Root MSE	0.412	0.406	0.517	0.504

Notes: see the text for definitions of the variables.

Table 9
Relationship of Ranked University-Fields
To Private, Public, and Top 10 Schools
(Row Percents in Parentheses)

University Type	Rank of University-Field		
	Top 20%	Middle 40%	Bottom 40%
Private	72 (33.6%)	90 (42.1%)	52 (24.3%)
Public	56 (13.8%)	160 (39.4%)	190 (46.8%)
Top 10	70 (66.7%)	32 (30.5%)	3 (2.9%)

Notes: Data consist of 620 university-fields from 103 universities after exclusion of missing values.

Table 10—Stratified OLS Research Regressions:
Top 20, Middle 40, and Bottom 40 Percent University-Fields
(Robust, Clustered S.E. in Parentheses)

Variable or Statistic	Log (Papers)		Log (5-year Citations)	
	Total Regression	Within Regression	Total Regression	Within Regression
Panel A: Top 20 Percent University-Fields				
Equation No.	Eq. 10.1	Eq. 10.2	Eq. 10.3	Eq. 10.4
Time Trend	0.0054	0.0086	0.0216**	0.0126
	(0.0034)	(0.0048)	(0.0050)	(0.0080)
Log (R&D Stock in mill. of '92 $)	0.310**	0.284**	0.277**	0.270**
	(0.057)	(0.076)	(0.058)	(0.077)
Log (Graduate Students)	0.157**	0.196**	0.139**	0.193**
	(0.049)	(0.062)	(0.052)	(0.075)
Number of Observations	1,501	1,501	1,407	1,407
R-squared	0.89	0.91	0.91	0.92
Root MSE	0.365	0.328	0.447	0.413
Panel B: Middle 40 Percent University-Fields				
Equation No.	Eq. 10.5	Eq. 10.6	Eq. 10.7	Eq. 10.8
Time Trend	0.0028	0.0148**	0.0301**	0.0439**
	(0.0032)	(0.0035)	(0.0046)	(0.0059)
Log (R&D Stock in mill. of '92 $)	0.296**	0.266**	0.301**	0.304**
	(0.034)	(0.037)	(0.042)	(0.048)
Log (Graduate Students)	0.151**	0.135**	0.075	0.043
	(0.041)	(0.053)	(0.047)	(0.062)
Number of Observations	3,077	3,077	2,877	2,877
R-squared	0.89	0.93	0.89	0.92
Root MSE	0.349	0.283	0.492	0.420

Table 10—Stratified OLS Research Regressions:
Top 20, Middle 40, and Bottom 40 Percent University-Fields
(Robust, Clustered S.E. in Parentheses)

Variable or Statistic	Log (Papers)		Log (5-year Citations)	
	Total Regression	Within Regression	Total Regression	Within Regression
Panel C: Bottom 40 Percent University-Fields				
Equation No.	Eq. 10.9	Eq. 10.10	Eq. 10.11	Eq. 10.12
Time Trend	0.0088*	0.0208**	0.0383**	0.0509**
	(0.0044)	(0.0030)	(0.0055)	(0.0065)
Log (R&D Stock in mill. of '92 $)	0.222**	0.203**	0.264**	0.252**
	(0.044)	(0.038)	(0.049)	(0.051)
Log (Graduate Students)	0.083	0.100	-0.006	0.089
	(0.051)	(0.056)	(0.055)	(0.069)
Number of Observations	2,736	2,736	2,548	2,548
R-squared	0.81	0.87	0.84	0.89
Root MSE	0.447	0.374	0.624	0.541

Notes: see the text for definitions of the variables. Top 20, middle 40, and bottom 40 percent groups are ranked according to field using 1993 NRC rankings, except for agriculture and medicine, where, because of missing data, university-fields are ranked by size of R&D expenditure. All regressions include field dummies. Total regressions exclude university dummies while within regressions include them. Also included are Log (Tuition + Public*State Appropriations), Log (Endowment), Auxiliary/Total Revenue, and Enrollment/Faculty.

Table 11—Faculty Compensation Equations
(Robust, Clustered S.E. in Parentheses)

Variable or Statistic	Private Universities			Public Universities		
	Full	Asst	Full-Asst	Full	Asst	Full-Asst
	11.1	11.2	11.3	11.4	11.5	11.6
Year	0.0164**	0.0245**	-0.0080**	0.0139**	0.0149**	-0.0010
	(0.0028)	(0.0027)	(0.0019)	(0.0019)	(0.0018)	(0.0010)
Large City (1 if yes, 0 if no)	0.099**	0.053*	0.046**	0.029	0.016	0.013
	(0.025)	(0.023)	(0.014)	(0.028)	(0.019)	(0.023)
Log (R&D Stock/ Faculty)	0.049*	0.070**	-0.021	0.000	0.018	-0.017
	(0.019)	(0.021)	(0.013)	(0.024)	(0.019)	(0.012)
Log ((Tuition + Public* State	0.083	-0.034	0.117**	0.159*	0.147*	0.012
Appropriations)/ Faculty) [a]	(0.057)	(0.051)	(0.041)	(0.064)	(0.043)	(0.034)
Log (Endowment/ Faculty)	0.042*	-0.012	0.054**	0.012	-0.002	0.014*
	(0.020)	(0.021)	(0.012)	(0.008)	(0.008)	(0.007)
Auxiliary/Total Revenue	-0.064	-0.241	0.177	-0.109	-0.282	0.173
	(0.283)	(0.229)	(0.156)	(0.276)	(0.183)	(0.174)
Enrollment/Faculty	-0.005	-0.000	-0.005*	-0.005	-0.003	-0.002*
	(0.003)	(0.004)	(0.002)	(0.003)	(0.002)	(0.001)
No. of Observations	485	485	485	879	879	879
R-squared	0.77	0.69	0.45	0.46	0.54	0.13
Root MSE	0.078	0.087	0.053	0.109	0.093	0.068

Notes: Dependent variable is Log (Wage + Fringe Benefits) in equations labeled "Full" for full professors, and "Asst" for assistant professors; it is the difference in the logarithm of wage + fringe benefits for full and assistant professors in equations marked "Full-Asst". [a] The variable "Public" equals 1 if a university is public, and 0 otherwise, so the variable equals the logarithm of tuition for private universities and the logarithm of tuition + state appropriations in public universities.

Table 12
Scientific Papers, PhDs and R&D Stock
By University Type, Selected Years
[Value Relative to 1982 in Brackets]

University Type, Variable	1982	1986	1990	1995	1999
Panel A. Private Schools					
Papers	27,591	30,776	33,342	40,022	41,952
	[1.00]	[1.12]	[1.21]	[1.45]	[1.52]
5-year Citations	83,641	110,371	140,938	187,763	--
	[1.00]	[1.32]	[1.69]	[2.24]	
PhD Degrees [a]	48,374	48,512	55,178	60,278	63,840
	[1.00]	[1.00]	[1.14]	[1.25]	[1.32]
R&D Stock (mill. of ’92 $) [b]					
Using GDP Implicit Price Deflator	10,296	11,709	14,641	17,775	21,099
	[1.00]	[1.14]	[1.42]	[1.73]	[2.05]
Using BEA University R&D Input Deflator	11,927	13,109	15,435	17,873	20,478
	[1.00]	[1.10]	[1.29]	[1.50]	[1.72]
Panel B. Public Schools					
Papers	49,851	56,312	63,566	73,985	74,158
	[1.00]	[1.13]	[1.28]	[1.48]	[1.49]
5-year Citations	101,746	125,394	173,066	229,657	--
	[1.00]	[1.23]	[1.70]	[2.26]	
PhD Degrees [a]	116,709	117,402	126,311	153,026	155,505
	[1.00]	[1.01]	[1.08]	[1.31]	[1.33]
R&D Stock (mill. of ’92 $) [b]					
Using GDP Implicit Price Deflator	18,400	21,771	27,963	36,385	42,257
	[1.00]	[1.18]	[1.52]	[1.98]	[2.30]
Using BEA University R&D Input Deflator	21,312	24,366	29,468	36,567	41,030
	[1.00]	[1.14]	[1.38]	[1.72]	[1.93]

Note: Data are a balanced panel of university-fields, defined as a matched sample that includes the same observations in all years. The sample includes all the data. Papers and 5-year Citations Received are fractional and are adjusted for collaboration among universities. [a] PhD degrees are specific to university-fields and belong to 12 main fields of science and engineering: agriculture, astronomy, biology, chemistry, computer science, earth science, economics and business, engineering, mathematics and statistics, medicine, physics, and psychology. [b] R&D stock is deflated by the GDP implicit price deflator in the first row, and by the BEA University R&D input deflator (Robbins and Moylan, 2007) in the second row. Both price indexes are normalized to 1992.

Table 13
Research Output/R&D Stock
By University Type, Selected Years

University Type, Variable	1982	1986	1990	1995	1999
Panel A. Private Schools					
Papers/R&D Stock					
Using GDP Implicit Price Deflator	2.68	2.63	2.28	2.25	1.99
Using BEA University R&D Input Deflator	2.31	2.35	2.16	2.24	2.05
5-year Citations/R&D Stock					
Using GDP Implicit Price Deflator	8.12	9.43	9.63	10.56	--
Using BEA University R&D Input Deflator	7.01	8.42	9.13	10.51	--
PhD Degrees/R&D Stock					
Using GDP Implicit Price Deflator	4.70	4.14	3.77	3.39	3.03
Using BEA University R&D Input Deflator	4.06	3.70	3.57	3.37	3.12
Panel B. Public Schools					
Papers/R&D Stock					
Using GDP Implicit Price Deflator	2.71	2.59	2.27	2.03	1.75
Using BEA University R&D Input Deflator	2.34	2.31	2.16	2.02	1.81
5-year Citations/R&D Stock					
Using GDP Implicit Price Deflator	5.53	5.76	6.19	6.31	--
Using BEA University R&D Input Deflator	4.77	5.15	5.87	6.28	--
PhD Degrees/R&D Stock					
Using GDP Implicit Price Deflator	6.34	5.39	4.52	4.21	3.68
Using BEA University R&D Input Deflator	5.48	4.82	4.29	4.18	3.79

Note: Data are a balanced panel of university-fields, defined as a matched sample that includes the same observations in all years. The sample includes all the data, except for endowment. Papers and 5-year Citations Received are fractional and adjusted for collaboration among universities. R&D stock is deflated by the GDP implicit price deflator in the first row for each of the variables, and by the BEA University R&D input deflator (Robbins and Moylan, 2007) in the second row. Both price indexes are normalized to 1992.

Table 14
Enrollment, Faculty, and Financial Resources
By University Type, Selected Years
[Value Relative to 1982 in Brackets]

University Type, Variable	1982	1986	1990	1997
Panel A. Private Schools				
Enrollment	403,875	413,824	428,522	446,495
	[1.00]	[1.02]	[1.06]	[1.11]
Faculty	21,527	22,352	23,246	26,960
	[1.00]	[1.04]	[1.08]	[1.25]
Tuition (mill. of '92 $) [a]	2,975	4,034	5,026	6,668
	[1.00]	[1.36]	[1.69]	[2.24]
Endowment (mill. of '92 $) [b]	13,768	19,531	27,645	37,361
	[1.00]	[1.42]	[2.01]	[2.71]
Panel B. Public Schools				
Enrollment	1,895,564	1,908,438	1,999,802	2,053,056
	[1.00]	[1.01]	[1.06]	[1.08]
Faculty	80,112	80,458	84,448	86,158
	[1.00]	[1.00]	[1.05]	[1.08]
Tuition + State Appropriations (mill. of '92 $) [a]	14,554	17,400	19,706	21,242
	[1.00]	[1.20]	[1.35]	[1.46]
Endowment (mill. of '92 $) [b]	4,524	6,879	8,309	12,619
	[1.00]	[1.52]	[1.84]	[2.79]

Note: Data are a balanced panel, defined as a matched sample that includes the same observations in all years. This sample includes all the data except for endowment. Enrollment consists of all students, both graduate and undergraduate, in the fall of each year. Faculty include both tenure-track and non-tenure-track personnel. [a] Tuition and State Appropriations end in 1997 owing to suspension of data collection in the HEGIS surveys beginning in 1998. [b] Endowment data end in 1996 instead of 1997 owing to suspension of data collection in the HEGIS surveys beginning in 1997. The endowment data are missing for about 20 percent of universities so the matched sample is smaller than for other variables. Deflator for revenue and endowment is the implicit GDP deflator indexed to 1992.