NBER WORKING PAPER SERIES

UNIVERSITIES AS A SOURCE OF COMMERCIAL TECHNOLOGY: A DETAILED ANALYSIS OF UNIVERSITY PATENTING 1965-1988

Rebecca Henderson
Adam B. Jaffe
Manuel Trajtenberg

Working Paper No. 5068

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 1995

Prepared for the Conference on University Goals, Institutional Mechanisms and the "Industrial Transferability" of Research, Stanford Center for Economic Policy Research, March 18-20, 1994. This paper is part of NBER's research program in Productivity. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

NBER Working Paper #5068
March 1995

UNIVERSITIES AS A SOURCE OF COMMERCIAL TECHNOLOGY: A DETAILED ANALYSIS OF UNIVERSITY PATENTING 1965-1988

ABSTRACT

This paper explores changes in university patenting behavior between 1965 and 1988. We show that university patents have increased 15-fold while real university research spending almost tripled. The causes of this increase are unclear, but may include increased focus on commercially relevant technologies, increased industry funding of university research, a 1980 change in federal law that facilitated patenting of results from federally funded research, and the widespread creation of formal technology licensing offices at universities.

Up until approximately the mid-1980s, university patents were more highly cited, and were cited by more technologically diverse patents, than a random sample of all patents. This difference is consistent with the notion that university inventions are more important and more basic than the average invention. The differences between the two groups disappeared, however, in the middle part of the 1980s, partly due to a decline in the citation rates for all universities, and partly due to an increasing share of patents going to smaller institutions, whose patents are less highly cited throughout this period. Moreover at both large and small institutions there was a large increase in the fraction of university patents receiving zero citations. Our results suggest that the rate of increase of important patents from universities is much less than the overall rate of increase of university patenting in the period covered by our data.

Rebecca Henderson
Alfred P. Sloan School of Management
Massachusetts Institute of Technology
E52-543
Cambridge, MA 02139
and NBER

Adam B. Jaffe
Department of Economics
Brandeis University
Waltham, MA 02254
and NBER

Manuel Trajtenberg
Department of Economics
Tel Aviv University
Tel Aviv 69978
ISRAEL
and NBER

I. INTRODUCTION

One of the most interesting indicators of the changing socio-economic role of universities in the last several decades has been an explosion in university patenting. In 1965, just 96 U.S. patents were granted to 28 U.S. universities or related institutions. In 1992, almost 1500 patents were granted to over 150 U.S. universities or related institutions. This 15-fold increase in university patenting occurred over an interval in which total U.S. patenting increased less than 50 percent, and patents granted to U.S. inventors remained roughly constant. This paper explores the changing nature of university patenting in some detail, both as a phenomenon of interest in its own right and as a window into the role of universities as a source of technology for the private economy.

At first glance, a focus on university patents might seem a strange route to better understanding of this relationship. University patents are a small fraction of all patents, and since in general universities are in the business of the creation and free dissemination of knowledge "for its own sake," one cannot expect to learn about the full spectrum of university research from their patenting behavior. Yet university patents are informative. They reflect research that the university believes has direct commercial application, and thus changes in patenting behavior may reflect changing motives within the university research community or shifts in the focus of university research from basic to more applied work. University patents are also interesting in their own right since they are a unique and highly visible method of "technology transfer" (Archibugi, 1992; Basberg, 1987; Boitani and Ciciotti, 1990; Trajtenberg, 1990). Understanding the ways in which university patenting behavior has changed over the last twenty years is an important component of understanding the ways in which the relationship between universities and the private economy has changed

(Blumenthal, 1986; Caballero and Jaffe, 1993; Dasgupta and David, 1987; David, Mowery and Steinmueller, 1992; Jaffe, Trajtenberg and Henderson, 1993; Mansfield, 1991; Pavitt, 1991).

In order to explore these issues we constructed a comprehensive database consisting of all patents assigned to universities or related institutions from 1965 until mid-1992, a one percent random sample of all U.S. patents granted over the same time period, and the complete set of all patents that cite either of these groups. Together these amounted to a data base of over 100,000 patents that included detailed information about each patent and about the linkages between them as revealed by patterns of patent citation.

Drawing on previous work, we construct measures of the "importance" and "generality" of university patents, and show that, averaged over the whole time period, university patents are both more important and more general than the average patent but that this difference has been declining over time, so that by the late 1980s we cannot find significant differences between the university patent universe and the random sample of all patents. We show that this decline has occurred across the broad spectrum of technological areas, does not appear to be due to any "truncation bias" resulting from our inability to observe future citations, and is not the result of the spread of patenting to smaller institutions. A major factor in the decline is a change in the fraction of university patents receiving no citations. In the mid 1970s, a random patent was 5 times as likely to get zero citations as a university patent. By the mid 1980s this difference had essentially disappeared. Thus a large fraction of the overall increase in university patents is due to a significant increase in the fraction of uncited patents. This raises the concern that the observed increase in university patenting may reflect an increase in their "propensity to patent" rahter than an increase in the output of "important" inventions.

The paper is organized into five sections. The following section describes in more detail the data we are using, and explains some of the institutional changes that appear to be related to the growth of patenting. Section III demonstrates the difference between university and other patents in the citation-based measures of importance, and the decline of that difference in the 1980s. Section IV explores possible explanations for that decline. Section V provides concluding observations.

II. THE GROWTH OF UNIVERSITY PATENTS

II.A. The Basic Numbers

This paper is part of a larger research project that exploits the declining cost of access to large quantities of patent data. We have some information on all patents granted since 1965, and complete information on all patents granted since 1975.[1] Appendix (1) describes in detail the data that are used in this paper. Our starting point consists of four sets of patents: all patents assigned to universities, granted between 1965 and mid-1992 (12,804 patents); a one-percent random sample of all U.S. patents[2] over the same period (19,535 patents); all patents after 1974 that cited the university patents (40,859 patents) and all patents after 1974 that cited the random sample patents (42,147 patents). For all of these

[1] There is no publicly available information on unsuccessful patent applications.

[2] By "U.S. patents" we mean patents granted by the U.S. patent office. By the end of this period, about half of such patents were granted to non-U.S. residents. About 1 percent of the patents assigned to U.S. universities were taken out by individuals who gave the Patent Office non-U.S. addresses.

patents we know the year of application,[3] the identity of the institution to which it is assigned, and the "patent class," a detailed technological classification provided by the patent office. These data allow us to observe the quantity of university patenting, as well as citation-based proxies for the "quality" of those patents, to examine how the quantity and quality have changed over time, and to compare both to the overall universe of U.S. patents.

Figure One illustrates the dramatic increase in patenting to which we have already alluded. Panel A compares the rate of university patenting to all U.S. patents and domestic U.S. patents. Panel B shows university patenting relative to university research, and an analogous ratio for the U.S. industrial sector. University patenting has not only increased, they increased more rapidly than overall patenting and much more rapidly than domestic patenting, which is essentially flat until the late 1980s. In addition, university patenting has increased more rapidly than university research spending, causing the ratio of university patents to R&D to more than triple over the period. In contrast, while domestic patenting was roughly constant, industry research spending increased significantly, particularly between the mid-70s and the mid-80s, so that the ratio of domestic patents to domestic R&D nearly halved over the period. Said differently, universities' "propensity to patent, " given their research effort, has been rising significantly at the same time that the overall propensity to patent has been falling. Note that the increase in university patenting has been fairly continuous since the early 1970s. There is some evidence of an acceleration in the late

---

[3]We prefer to date patents by the year of application rather than the year of grant, because that is when the inventor identified the existence of a new invention, and there are variable lags involved between application and grant date. Because of these lags, however, totals by date of application are incomplete for years approaching the 1992 data cutoff date, since some patents applied for at the end of the period were almost certainly still under review at the time we collected our data. Thus we terminate our time-sensitive analyses in 1988.

1980s, but this is a period in which both university research and overall patenting accelerate as well, making it difficult to assess its significance.

The increasing propensity of universities to patent is also evident in a significant increase in the number of universities and related institutions taking out patents. Whereas in 1965 about 30 universities obtained patents, in 1991 patents were granted to about 150 universities and related institutions. None the less, university patenting remains highly concentrated, with the top 20 institutions receiving about 70 percent of the total, and M.I.T., the most prolifically patenting institution, alone receiving about 8 percent. The top 10 institutions and their total patent grants for 1991 are shown in Table 1.

The increase in university patenting has not been uniform across the spectrum of technologies. To examine this issue, we define 5 broad classes of technologies, based on the much finer classification used by the patent office:[4]

- Drugs and Medical Technologies ("Drugs/medical");
- Chemicals and Chemical Technologies Excluding Drugs ("Chemical");
- Electronic, Electrical, Optical and Nuclear Technologies ("Electronics, etc.");
- Mechanical Technologies ("Mechanical"); and
- All Other.

---

[4] Full details of this classification are given in Jaffe, Adam B. (1986) "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits and Market Value," *American Economic Review*, December 1986, pp984-1001.

Panel A of Figure 2 shows the breakdown of university patents into these fields over time; Panel B shows it for all patents.[5] The differences are dramatic, if not surprising. As of the end of the 1980s, Drug and Medical patents comprise about 35 percent of the university total, up from less than fifteen percent in 1965; chemical patents 25-30 percent; electronic and related patents 20-25 percent; mechanical patents 10-15 percent; and about 5 percent other. In contrast, overall patenting is 30-35 percent mechanical; 20-25 percent each for chemical and electronics, 10-15 percent other, and less than 10 percent drugs and medical. Thus universities are much more interested in drugs and medical technologies, and much less interested in mechanical technologies, than other inventors, and the difference has increased over time.

II.B. The Broader Context of Increased University Patenting

Federal law affecting university patenting. A major factor in the increased university patenting rate is likely to be a change in federal law that occurred in 1980. Up until that time, the federal government had the right to claim all royalties or other income derived from patents resulting from federally funded research. Federally funded researchers could apply for patents, and could assign those patents to universities, but the exclusive property right associated with the invention remained with the government whether or not a patent was issued. The only way that a university could profit from federally-derived patents was to seek a title rights waiver from the funding agency. Some agencies provided such waivers,

[5]This and all subsequent analyses are based on our 1/100 random sample of all patents. Given the large number of such patents (over 500 per year), the composition by field of the sample is very likely to be close to the composition by field of the universe of all patents. Note that the random sample does *not* exclude university patents. Even at the end of the period, however, university patents are less than 2 percent of the total.

but their availability and the procedures that had to be followed varied from agency to agency, and were generally cumbersome. Since approximately 70 percent of university research during this period was funded by the federal government, this was a major barrier to widespread university patenting. University patents from this period thus have to represent either (1) the fruits of that portion of university research not funded by the federal government; (2) patents sought only for the public or professional prestige that they confer, rather than their commercial profit potential; or (3) inventions from federal research for which a specific title rights waiver was sought and received from the federal agency funding the research.

In 1980 Congress passed The Patent and Trademark Amendments of 1980 (Public Law 96-517), also known as the Bayh-Dole Act. The Bayh-Dole Act gave universities (and other non-profit institutions, as well as small businesses) the right to retain the property rights to inventions deriving from federally-funded research. The 1984 passage of public Law 98-620 expanded the rights of universities further, by removing certain restrictions contained in Bayh-Dole regarding the kinds of inventions that universities could own, and the right of universities to assign their property rights to other parties.

Both pieces of legislation may have reflected concern that the results of university research were not being effectively transferred to the private sector (U.S. General Accounting Office, 1987). If inventions often burst forth from federally funded research in a form that permitted immediate commercial application without significant development expenditure, continued federal possession of the associated property rights would be a reasonable policy stance to take toward new knowledge generated at public expense.

However few inventions come out of basic research in a form that permits immediate commercial application, and significant additional investment is typically required to transform the results of university research into marketable products. The proponents of the Bayh-Dole Act of Public Law 98-620 reasoned that no private firm is likely to make such investments if the ultimate property right in the underlying invention is publicly held.

Thus since 1984, universities have had very broad rights to exploit inventions derived from their research, even if it is federally funded. They can charge royalties for the use of the patent, and they can assign the patent to a third party if they so desire. As a result, major research universities now typically have explicit policies requiring faculty and other researchers to assign patents deriving from on-campus research to the university, and specifying how any income deriving therefrom is to be divided among the institution, the researcher and research centers or departments.

An increase in organized university "technology" offices. Though it is obviously difficult to separate the chicken from the egg, since after the passage of Bayh-Dole there has been a dramatic increase in the scale and significance of the patenting and technology licensing function at universities. The Association of University Technology Administrators (AUTM) has recently begun conducting surveys of its members. The surveyed institutions[6] employed 546 full-time equivalent professional employees in technology transfer and licensing activities. In 1992, they received royalties totally about $230 million on about 3000

[6]Survey responses came from 112 U.S. institutions that were granted 1169 patents in Fiscal Year 1992, compared to our data that indicates about 1500 patents were granted to over 150 institutions. Thus survey totals are lower bounds on the actual numbers.

licensing agreements; an additional 3000 active agreements were not currently generating revenue.[7]

Increased industry funding of university research. Another factor related to the increase in university patenting is an increase in industry funding of university research from 2.6 percent in 1970, to 3.9 percent in 1980 and 7.1 percent in 1992.[8] This trend is presumably the result of both an increase in the supply of such funds, and in the "demand" in the sense of an increased desire by universities to do the kinds of applied research that interests industry. This desire might be driven either by the universities' increasing interest in applied research, *per se*, or by the perception that a decline in the rate of growth of federal support for university research has made industry funds an increasingly necessary source of support.

Thus the historical record provides us with a series of mutually reinforcing trends: An increased applied and commercial focus of universities, as evidenced by a rapidly increasing propensity to patent; a change in federal law that facilities university patenting; an expansion of the institutional ability and focus on patenting in the form of university technology offices; and an increased role for industry funding at the university. It is impossible to assign the roles of "cause" and "effect" to these different trends. The increase in university patenting predates the passage of Bayh-Dole, but continued exponential growth

---

[7]The AUTM Licensing Survey, Fiscal Years 1991 and 1992. AUTM categories included in the quoted totals are U.S. Universities, U.S. Hospitals, Third-Party Management Firms and Research Institutes. Excluded are government and Canadian universities. The royalty total has been adjusted to eliminate double counting that results from shared license agreements (personal communication, Ashley Stevens, AUTM).

[8]With federal funding at 60 to 70 percent of the total, the remainder is funded by state and local governments and institutions' own funds.

probably could not have been sustained without removal of the cumbersome barriers to patents from federal research. The increase in universities' institutional commitment to patenting, in the form of new and expanded licensing offices, would likely not have occurred if the impetus towards more commercial research, and the change in federal law had not occurred. But once created, these offices presumably facilitate the patent application process and thereby contribute to the increased patenting. Finally, increased industry funding is probably partially a response to universities' increased interest in applied research, but it, in turn, increases the resources for these activities and thereby also supports increased patenting.

III. CHARACTERIZING UNIVERSITY PATENTING

III.A. Citation-based Measures of Importance and Generality

There is evidence that the flow of technology out of universities contributes to technological innovation in the private sector (Jaffe, 1989), and a widespread belief that more effective transfer of technology from universities to the private sector would be beneficial to innovation and growth (U.S. GAO, 1987). In this light, the rapid increase in university patenting appears to be a highly desirable trend, to the extent that it signals an increase in the successful commercial application of university-derived technology. It is widely known, however, that patents vary tremendously in their importance, making it dangerous to draw conclusions about aggregate technology flows based on numbers of patents (Griliches, 1990). In this section, we look more carefully at the university patents, to understand better what the patent data do and do not say about increases in the flow of technology out of universities.

In an earlier paper (Trajtenberg, Henderson, and Jaffe, 1992), we used patent citation data to construct a variety of measures that we interpreted as capturing the importance or "basicness" of the invention covered by a patent. Implicit in this approach is a view of technology as an evolutionary process, in which the significance of any particular invention is evidenced, at least partly, by its role in stimulating and facilitating future inventions. We assume that at least some of such future inventions will reference or cite the original invention in their patents, thereby making the number and character of citations received a valid indicator of the technological importance of an invention.[9]

The first citation-based measure that we introduced in the previous paper we called "importance." We define "importance" as:

$$Importance_i = Nciting_i + \lambda \sum_{j=1}^{nciting_i} Nciting_{i+1j}$$

where $0 < \lambda < 1$ is defined as an arbitrary "discount factor" that in the previous paper we set to 0.5. In the absence of data about "second generation" citations in the data set on which this paper relies, we set λ equal to zero, and measure importance simply by total citations received. We hypothesize that this measure captures the technological impact of an invention as reflected in the number and importance of its descendants (Carpenter and Narin, 1993; Trajtenberg, 1990).

[9]Citations or references serve the legal function of delimiting the scope of patent protection, by identifying technological predecessors of the patented invention. Thus if patent 2 cites patent 1, it implies that patent 1 represents a piece of previously existing knowledge upon which patent 2 builds, and over which 2 cannot have a claim. The applicant has a legal duty to disclose any knowledge of the prior art, but the decision as to which patents to cite ultimately rests with the patent examiner, who is supposed to be an expert in the area and hence to be able to identify relevant prior art that the applicant misses or conceals. Trajtenberg (1990a and 1990b) showed that citation-weighted patents were a good proxy for the consumers' surplus generated by inventions. For more discussion of the value and limitations of citation data, see Trajtenberg, Henderson and Jaffe (1992)

We hypothesize that patents that cover more "basic" research will be cited by work in a broader range of fields, and define "generality" as:

$$General_i = 1 - \sum_{k=1}^{N_i} (\frac{Nciting_{ik}}{Nciting_i})^2$$

where k is the index of patent classes and N_i is the number of different patents to which the citing patents belong. Notice that $0 \leq$ General ≤ 1, and that higher values represent less concentration and hence more generality.

Citation-based measures of importance and generality are, to some extent, influenced by variations in citation practices across time and technological areas. They are also very influenced by the fact that when we count the citations seen to date of a patent issued in, for example, 1989, we are missing many more of the citations that it will ultimately receive than we are missing in our count of the citations of a patent issued in 1975. For these reasons, when comparing importance or generality it is necessary to control for time and technological field effects. The special difficulties raised by the truncation in time are discussed further below.

III.B. Comparing University and Random Sample Patents

As a first step in exploring the degree to which university patents are more important or more general than the random sample of patents, Table Two presents the results of regressions of our measures of importance and generality on a series of dummy variables for application years and technological areas, and dummy variables for whether or not the original patent was a university patent. These regressions are based on application years 1965-1988 for importance and 1975 to 1988 for generality.[10] Over the entire period, controlling for technological field effects and time effects, university patents received almost 25 percent more citations on average, and this difference is highly significant statistically. They were also about 15 percent more general, again a statistically significant difference. These overall averages conceal a moderate amount of variation across fields. The difference between university and random sample patents is largest in Electronics, etc., and Mechanical patents, and smallest in the Drug/medical area.[11]

These results control for time effects, but they do not allow the university/random sample difference itself to vary over time. Results of regressions that allow each year-cohort of patents to have its own university/random sample difference are shown graphically in Figure Three. To make sure that the university/random sample difference is not due to the different technological focus of the two samples, the regressions underlying Figure Three replace the 5 technology field dummies used in Table Two with 364 separate dummies for Patent Office patent classes. While the year-by-year differences are somewhat noisy, there is a clear overall trend: the university/random sample difference grew during the 1970s, reached a plateau during the period from about 1975 through about 1982, and fell significantly after that. The regression results underlying Figure 3 show that the differences

[10]The generality measure cannot be calculated for the pre-1975 patents because we lack information on the citing patents before 1975, and we terminate the analysis in 1988 because a significant fraction of 1989 applications might be granted after mid-1992 when our data end. Also, those granted in 1990 and 1991 would have very little time to receive citations.

[11]The differences across fields must, however, be interpreted with caution because of the changing composition over time. See discussion surrounding Figure Four, below.

between the two groups are statistically significant between 1970 (1975 for generality) and about 1982 or 1983; after that the two groups are not statistically different from one another in either generality or importance.

III.C. Robustness of the Apparent Decline

The regressions underlying Figure Three appear to show that university patents were significantly more important and more general than corporate patents in the 1970s, but that this difference declined sharply in the early 1980s, so that by the mid-1980s at the latest there was, overall, no statistically significant difference between the two groups. In this section, we explore a number of possible explanations for this decline, focusing particularly on the degree to which this result may reflect truncation bias, or be an artifact of our use of citation data and the way in which citation patterns have changed over time.

First, although the regressions underlying Figure 3 control for field and time effects, they do not control for time-field interaction effects. For example, it could be that Drug patents have become increasingly less citation-intensive over time, relative to other fields. If so, then university patents (which are increasingly concentrated in the Drug/medical area) would appear to be increasingly less important in the sense of receiving fewer citations, because the regressions underlying Figure 3 control only for the *average* level of citations in drug-related patent classes. To test for this possibility, as well as to examine whether the decline in university citation-intensity is concentrated in particular fields, we re-ran versions of the regressions underlying Figure 3 *separately* for each of the 5 major fields, including application year and patent class dummies, and parameterizing the difference between university and random sample as a cubic function of time.

Figure Four plots the predicted differences based on the cubic coefficients. While there are variations in timing and the magnitude of the peak, all of the areas show an initial rise, a peak somewhere between 1975 and 1981, and the disappearance of any university superiority by the second half of the 1980s.[12] It is interesting to note in this context that the Drug/medical field showed a small and insignificant overall university advantage in Table 2. Figure Four shows that this is not the result of a consistent lack of difference; rather it results from the fact that the decline in advantage began early. This, combined with the fact that the number of university drug/medical patents is rising rapidly (so that the overall totals are dominated by recent patents) renders the overall difference insignificant. More generally, the decline in the university advantage is not a result of field effects and seems to occur across all of the fields.

The preceding regressions "control for" time effects, in the sense that we are comparing university patents applied for in a given year to random sample patents applied for in the same year. None the less, the proximity of the rapid decline in the university advantage to the end of the data period raises the issue of whether the decline might be an artifact of the truncation of the citation information in 1992. There are a number of reasons to suspect that such bias could be present. To see this, consider the distribution of citations over time from year of grant, i.e., the probability of receiving a citation in the year of grant, the next year, the second year, and so forth.

---

[12]Figure Four shows results only for importance; the patterns for generality are similar.

Assume first that the *shape* of this distribution for university patents is the same as for the random sample, but that in every year university patents receive proportionately more citations. The overall mean difference between the two would be the area between the two distribution curves, i.e., the cumulative difference. If we cut this off early in the distribution, the absolute difference that we have observed will be less than if we wait and look at a later date when the cumulative area between the two curves will be larger. This could conceivably explain the apparent disappearance of the difference between the two groups at the end of the observed period.

This hypothesis suggests a simple test: run the regression in logs, thereby capturing the proportionate difference between the two groups rather than the absolute difference. This requires eliminating from both groups those patents with zero citations. On this more limited data set, the log-citation regression produces results, (not reproduced here), that are broadly consistent with those reported above. The overall difference between the two groups in importance is about 15 percent; this overall difference conceals variation, with a high of about 30 percent in the mid to late 1970s, falling to insignificance by 1984. Thus the results cannot be explained by truncation of lag distributions, if the two distributions have the same shape.

A more subtle possible problem is that university patents may, on average, come later than those for universities, meaning that the truncation has a more severe effect on them than on the random sample patents. In order to test for this possibility, we took all of the post 1974 patents[13] (both university and random sample) and created a data set with 1

[13]For the patents before 1975, we know the total number of citations received (i.e. importance) but we do not know the identity of the citing patents, so we cannot decompose that total by year.

observation for each year from the date of application of the cited patent until 1992, indicating the number of citations *in that year*. We then ran a regression with this per-year citation count as the dependent variable, and included as controls patent class and application year of the cited patent (as before), but now also including dummies for the *lag* between the application year of the cited and citing patents, allowing different lag coefficients for the university and random sample cited patents.[14] In addition to these controls, we allowed for a university/random sample difference in each application year. Thus this more complicated regression estimates the difference between the average university and random sample patents in a given year, controlling for the predicted levels based on the years remaining to truncation and the average citation lag structure for each sample. The results of this exercise are very similar to the simpler ones reported earlier, with the university-corporate difference declining sharply around 1981 or 1982 and becoming statistically insignificant shortly thereafter.

In summary, then, university patents in all fields were more important and more general than average in the 1970s; this advantage disappeared in all fields by the mid-1980s; and this disappearance does not appear to be an artifact of truncation. In the next section we explore further the nature of the decline.

IV. THE NATURE OF THE DECLINE

In this section we explore several potential issues with respect to the declining relative importance of university patents. First, we examine whether the change in the average

[14]There were 30 dummies altogether: a university and a random sample set, each with 1 for lags of 0 or 1, 1 for each value 2-14, and one for 15 or more.

relative importance is the result of a shift or a twist in the importance distribution -- in particular whether it is driven by an increasing number of uncited university patents as the propensity of universities to patent has increased; second, we ask whether declining relative importance is likely to be the result of the *increasing* importance of non-university patents; and, finally, we examine whether the decline appears to be related to the spread of patenting to many more institutions.

Thinking about changes in the propensity to patent is facilitated by having a simple model of the decision to apply for a patent. This model is illustrated graphically in Figure Five. It seems reasonable to assume that inventions have a quality or value distribution, with many low-quality or low-value inventions, and few high-quality or high-value inventions. Patenting is a costly process, and conveys expected benefits that are increasing in the quality of the invention, but which also depend on the legal, competitive and institutional environment of the inventor. Assuming that inventors have some knowledge at the time of invention about the quality of their invention, this implies that there will be a "threshold" quality, above which a patent will be applied for, and below which it will not. Changes in the "propensity to patent" can be thought of as movements in this threshold. It follows that reductions in the cost of patenting (e.g, via elimination of the need to get funding agency approval for the patent application) or increases in the benefits of patenting (e.g. if patents become more enforceable) will be associated with a fall in the average quality of patented inventions, as low-quality inventions that were previously unpatented now join the patent distribution. This reasoning suggests that the fall in average university quality may simply be the result of the addition of many low-quality patents due to a reduction in the patenting threshold.

It also suggests that the change in relative importance is unlikely to be the result of increasing importance of non-university patents. As shown in Figure One, the late 1980s were a time of increasing propensity to patent. That is, the overall patent/R&D ratio, which had been falling for most of this century, began to rise slightly. This is generally attributed to the creation of a special Court of Appeals for hearing patent cases, and the issuance of several decisions that have increased the perceived likelihood that patents will be enforced (Schwartz, 1988). Thus, the overall patenting threshold has probably been moving to the left, thereby, if anything, reducing the overall quality of patents.

Returning to the university patents, we can look at how the distributions over "quality" have shifted over time: if the increase in university patenting reflects an increase in the rate of patentable inventions, so that the top part of Figure 5 is most relevant, then we would expect to see little change in the general shape of the quality distribution of university patents over time. In contrast, if it reflects an increased propensity to patent, so that the bottom half of Figure 5 is more relevant, we would expect to see large increases in the fraction of university patents receiving very few citations.

Distinguishing between these effects over time is complicated by the difficulty of controlling for time and truncation effects. Figure Six shows the distribution of patents across citation intensities for both the university and the random sample in 1975 and 1984, in each case looking only at those citations received in the first 8 years (to control for truncation effects), and showing also the distribution for the random sample (to control for time effects). The top panel shows that in 1975, the university distribution had fewer patents with zero citations, and more patents at virtually every other citation level. By contrast, in 1984, the university distribution actually has more density at zero than the random sample. In both years, the university distribution appears to have more density in the extreme right-hand tale.

Figure Seven looks specifically at the issue of zero-citation patents, but compares the university patents and the random sample from 1975 through 1987. To control for truncation we look at those patents that have zero citations in the first 5 years. Figure Seven shows that the decline in the university advantage flowing from a relatively low proportion of zero-citation patents has been dramatic. Hence there is strong evidence that part of the decline in average relative importance is an influx of low-importance patents, possibly associated with the effective reduction of the threshold for patent application by universities.

Identifying the decline with an increase in zero-citation patents does not, of course, explain what caused it. The "threshold" story is plausible but difficult to prove. A final aspect that we explored was to examine whether the decline might be associated with the spread of patenting beyond the handful of institutions that were active in the early years. For this to explain the decline in quality, it would have to be the case that the share of patents attributed to "large" institutions had declined. There are various ways to measure this. Figure Eight shows that such a decline has, in fact occurred: since 1965, the fraction of patents going to the top 4 institutions has fallen from about 50% to about 25%. The Herfindahl index of concentration across institutions has also declined, from about .1 in 1965 to about .04 in 1988. Interestingly, the citation-weighted Herfindahl has declined somewhat less than the unweighted Herfindahl, suggesting that the institutions getting more patents are getting more highly cited ones, and/or institutions getting better patents have not had the same decline in importance as other institutions.

We explored these possibilities directly by running a regression analogous to that underlying Figure 3, but in addition allowing the difference between university and random sample patents to differ not only over time, but also according to the "size" of the institution. To do this, we grouped all institutions that got any patents over the period into 3 categories: (1) those institutions in the top decile in terms of the number of successful patent applications in 1988; (2) those institutions that got fewer patents than the top decile but more than the bottom quartile in 1988; and (3) those institutions that were in the bottom quartile in terms of patent total in 1988 plus those that had no successful applications in 1988 but received at least one patent from some other year. As in Figure 3, the regression used citations received as the dependent variable, and included controls for application years and patent classes.

The results are illustrated in Figure 9. The results show that, except possibly for a few years in the second half of the 1970s, the bottom group of universities never produced patents that were statistically distinguishable from the random sample. At the same time, the 15 schools that comprise the top decile of institutions had patents that were even more superior to the random sample than those of other universities, so that it is the case that on average those institutions that patent more are receiving patents of higher quality. None the less, this elite group has seen a decline in their relative quality since about 1983. Overall, then, the decline in the university average has two components: the very best institutions are indeed producing patents that are not as good (on average) as they were before; and, in addition, an increasing fraction of the university total is coming from smaller institutions, who have always produced patents that were not as highly cited as those from the larger institutions.

V. CONCLUSION

Patenting by universities has risen dramatically in the last 25 years, and this increase is clearly associated with an overall increase in university attention to commercial applications of technology. The extent to which it should be taken as evidence of a large increase in the contribution of universities to commercial technology development depends, however, on the extent to which it represents more commercially useful inventions, and the extent to which it represents simply increased filing of patent applications on marginal inventions. Figure Ten provides a summary cut at this issue. It shows again the overall increase in patenting (the heavy middle line), juxtaposed with two contrasting components of that total. The bottom line is the number of patents from each year that have received no citations. It is virtually flat until the early 1980s, showing that the roughly 5-fold increase in overall patenting up until that time was not accompanied by much of an increase in the number of these low-importance patents.

The dotted line at the top is the number of high-importance patents, dubbed "Winners" in the graph and plotted on the right-side axis. This is the number of patents that received more citations than the mean of the top 10 percent of random sample patents from the same year. This series increases *faster* than the overall total up until the early 1980s, implying that the proportion of very important patents was increasing over this period. From

1981 on, however, this series fluctuates up and down with no clear trend. Despite the approximate doubling in the total number of patents after 1980, there is no increase in the number of very important patents.

It is important at this point to emphasize that citations are but one measure of the impact of patents. Figure Ten suggests that the 1980s were a stagnant period for important university patents, yet this is precisely the period in which there has been a large increase in actual commercial licensing of university technology and generation of significant licensing revenue. Clearly, more detailed analysis of university technologies and of technology transfer are necessary in order to understand what has been happening to the flow of technology out of universities. The citation data do, however, suggest that great care should be taken in drawing conclusions on the basis of patent counts alone.

BIBLIOGRAPHY

Archibugi, D. : "Patenting as an Indicator of Technological Innovation: A Review," Science and Public Policy, Vol. 19, No. 6, pp. 357-368, 1992.

Association of University Technology Managers, The AUTM Licensing Survey, Fiscal Years 1991 and 1992, 1993.

Basberg, B. : "Patents and the measurement of technological change: A survey of literature," Research Policy, Vol. 16, pp. 131-141, 1987.

Blumenthal, D. : "Academic-Industry Relationships in the Life Sciences (Extent, Consequences, and Management)," JAMA, Vol. 268, pp.3344-49.

Boitani, A. and E. Ciciotti: "Patents as Indicators of Innovative Performances at the Regional Level", in R. Cappellin and P. Nijkamp, eds., The Spatial Context of Technological Development, Aldershot: Gower, p. 139-163, 1990

Caballero, R. and A. Jaffe: "How High are the Giants' Shoulders: An Empirical Assessment of Knowledge Spillovers and Creative Destruction in a Model of Economic Growth," in O. Blanchard and S. Fischer, eds., NBER Macroeconomics Annual, Volume 8, M.I.T. Press, 1993

Carpenter, M. and F. Narin. :"Citation Rates to Technologically Important Patents," World Patent Information, Vol. 5, No. 3, pp. 180-185, 1993.

Dasgupta, P. and P. David. : "Information Disclosure and the Economics of Science and Technology," Chapter 16 in G. Feiwel (ed.), Arrow and the Ascent of Modern Economic Theory, NYU Press, 1987.

David, P.A., D. Mowery and W.E. Steimueller: "Analyzing the Economic Payoffs from Basic Research," Economics of Innovation and New Technology, Vol.2, No.1, pp. 73-90, 1992.

Griliches, Zvi, (1990) "Patent Counts as Economic Indicators..."

Jaffe, Adam (1989) "Real Effects of Academic Research," American Economic Review, LXXIX, 957-70.

Jaffe, Adam Manuel Trajtenberg, and Rebecca Henderson, "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," Quarterly Journal of Economics, 1993

Mansfield, Edwin, "Academic Research and Industrial Innovation," Research Policy 20 (February 1991): 1-12.

_______________, "Academic Research Underlying Industrial Innovation," Working Paper, University of Pennsylvania, 1992.

National Science Board: Science and Engineering Indicators, Washington, 1989, 1991.

National Science Foundation: University Industry Research Relationships: Myths, Realities and Potentials, U.S. Government Printing Office, 1982.

Pavitt, K. : "What Makes Basic Research Economically Useful," Research Policy, 20, 1991

Schwartz, H. F. :Patent Law and Practice, Federal Judicial Center, Washington, DC: 1988

Trajtenberg, M. : "A Penny for Your Quotes: Patent Citations and the Value of Innovations," Rand Journal of Economics, Vol. 21, No. 1, pp. 172-187, 1990a.

Trajtenberg, M., R. Henderson and A Jaffe: "Ivory Tower versus Corporate Lab: An Empirical Study of Basic Research and Appropriability." National Bureau of Economic Research Working Paper No. 4146, August 1992.

U.S. General Accounting Office, Patent Policy: Recent Changes in Federal Law Considered Beneficial, GAO/RCED-87-44, 1987

Appendix One: The Data

A patent is a government-granted property right in the commercial use of a device or process (Schwartz, 1988). For a patent to be granted, the invention must be nontrivial, meaning that it would not appear obvious to a skilled practitioner of the relevant technology, and it must be useful, meaning it has potential commercial value. Ideas per se are not patentable. If a patent is granted, a public document is created containing extensive information about the inventor, her employer, and the technological antecedents of the invention. There is no public record of unsuccessful patent applications.

This paper examines the changing nature of university patenting using 3 large datasets of U.S. patents:

- a comprehensive or near comprehensive database of all patents assigned to universities or related institutions from 1965 until mid-1992 (13,024 patents);
- a one percent random sample of *all* U.S. patents granted over the same time period (19,528 patents);
- all patents from 1975 until mid-1992 that cited *either* the university patents or the patents in the one percent random sample (60,215 patents).

We began by identifying all patents granted to universities and related institutions during the period 1965-1992.[15] To do this, we started with 243 patent assignees identified by the Office of Technology Assessment and Forecasting of the Patent Office in the mid-1980s as universities and related institutions. We supplemented this list by searching the patent database for all assignees containing the phrases "university," "research foundation," and the like, and then inspecting these by hand to determine if they were actually universities or related institutions. Altogether, we identified 657 assignees as universities. Many of these were minor spelling variations, typographical errors, or combinations of other institutions. After standardizing the institution names, we ended up with 244 distinct institutions that received over 13 thousand patents during the period.[16]

---

[15] The commercial source from which we acquired these patent data contained grants through August of 1992. For the purpose of reporting totals for 1992, we have scaled up the totals through August by 12/8. Much of our analysis includes year dummy variables, or examines contrasts between university patents and other patents, in which cases the 1992 truncation does not create any bias.

[16] Some patents are assigned jointly to a firm and a university; these are discussed further below, but for the purpose of the aggregate analyses these were considered university patents. Universities differ in the extent to which distinct schools or campuses patent under their own names or those of the parent. For example, patents from all campuses of the University of California are assigned to the Regents of the University of California; in

Our second step was to identify a 1/100 random sample of all U.S. patents over the same period.[17] This sample consists of almost 20 thousand patents. We have assignee names for these patents as well, but the number of assignees is much larger and hence standardization would be a much more time-consuming task. We do not utilize the assignee information for the random sample patents in this paper.

The final step was to identify all subsequent patents citing both the university and the random sample patents. Because of data limitations, this was done in two different ways. For patents from 1965 through 1974, we know only the total number of citations they received through 1991. For patents granted between 1975 and 1992, we know the actual patent numbers of all the citing patents, through August of 1992 (over 60 thousand patents). Thus for the later the patents, we have a slightly more complete *count* (through August 1992 instead of end of 1990), and we know more about the citing patents, including their patent classifications. Since we use the patent classifications of the citing patents for some of our analyses, we will for these purposes focus only on patents granted after 1975.

The information from the patent record that we use in this research is as follows:

- **the date of grant ("year")**. (The patent also contains the date of application, which for most purposes is a more appropriate means for dating the invention. However the information in our database on application dates is not complete, so we have limited our analysis to grant dates.)

- **the organization or organizations (if any) to which the inventor assigns the property right conveyed by the patent** ("assignee").

- **the primary classification of the patent** within the patent office's technological classification system ("class"). There are currently about 400 such classes. Examples of patent classes include "Measuring and Testing" and "Multicellular Living Organisms and Unmodified Parts Thereof."

- **the references to earlier patents** required by the patent examiner to recognize the existence of earlier related property rights, and thereby delimit the property right being conveyed in the current patent ("citations").

---

other states different parts of the state system each hold patents separately.

[17] This was done by simply selecting all patents whose patent numbers ended in a distinct 2-digit sequence. Since patent numbers are assigned sequentially, this gives us every 100th patent issued.

TABLE ONE

TOP TEN INSTITUTIONS FOR UNIVERSITY PATENTS, 1991

Institution	Patent Count
Massachusetts Institute of Technology	100
The University of California	91
The University of Texas	82
Stanford University	56
Wisconsin Alumni Research Foundation	44
University of Florida	43
Iowa State University Research Foundation Inc	39
California Institute of Technology	32
University of Minnesota	30
Johns Hopkins University	26

TABLE TWO

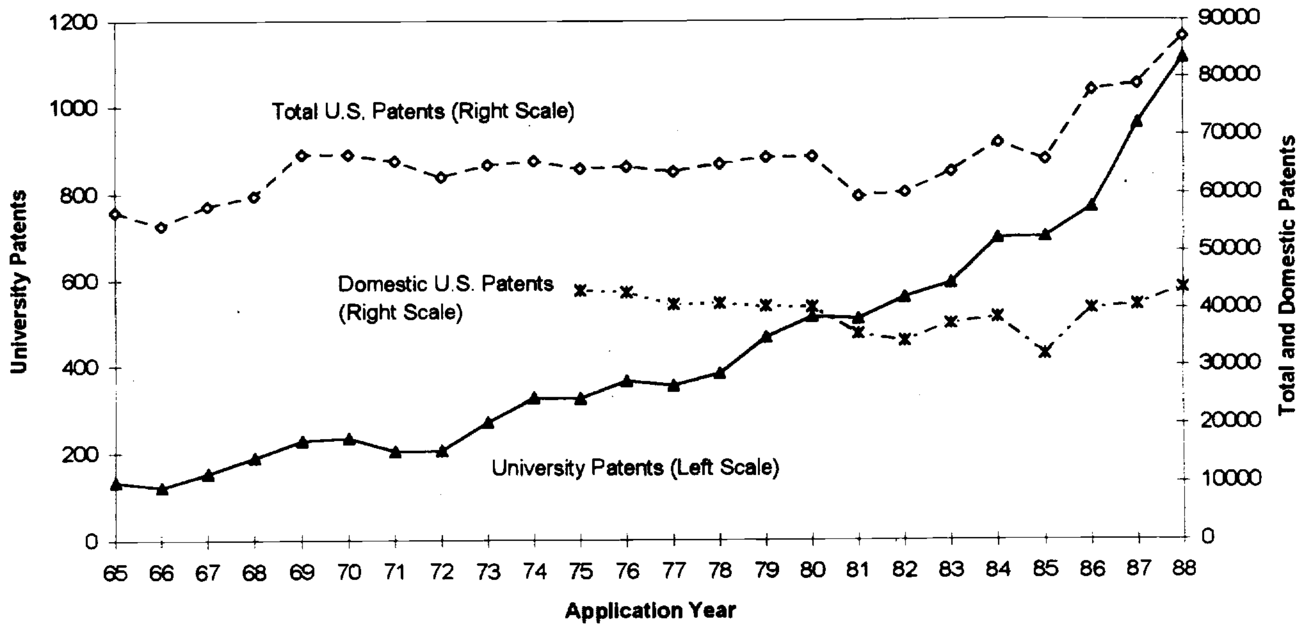
Comparison of University and Random Sample Patents

	Importance 1965-1988 n=28313	Generality 1975-1988 n=14775
Random Sample Mean		
Drug/Medical	4.00	0.258
Chemical	3.87	0.296
Electronics, etc.	4.23	0.288
Mechanical	3.77	0.265
All Other	3.47	0.203
Overall University Difference, controlling for field	0.918	0.0452
	(0.072)	(0.0049)
University Difference by field:		
Drug/Medical	0.311	-0.0168
	(0.199)	(0.0135)
Chemical	0.416	0.0480
	(0.124)	(0.0087)
Electronics, etc.	1.718	0.0582
	(0.141)	(0.0094)
Mechanical	1.290	0.0740
	(0.153)	(0.0107)
All other	0.396	0.0148
	(0.255)	(0.0180)

Notes: Standard errors in parentheses
Differences are estimated controlling for application year effects

FIGURE ONE

PANEL A
University Patents, All U.S. Patents, and Domestic U.S. Patents



PANEL B
Patent/Research Ratios

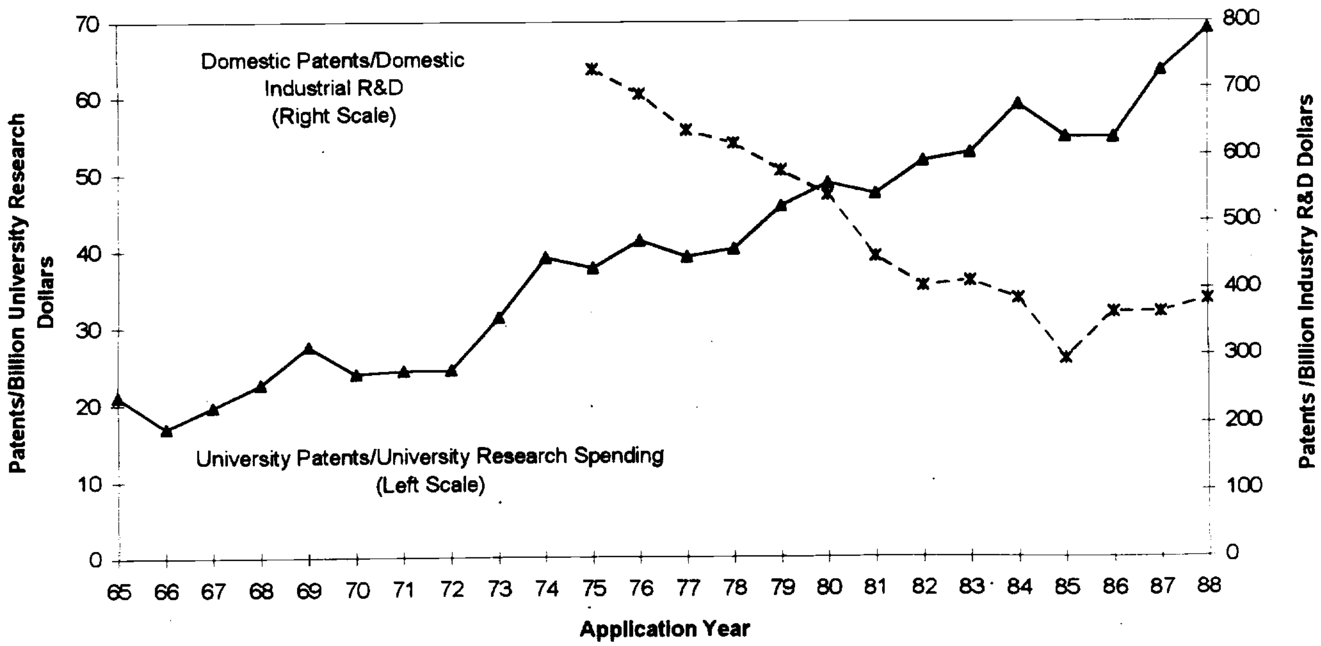
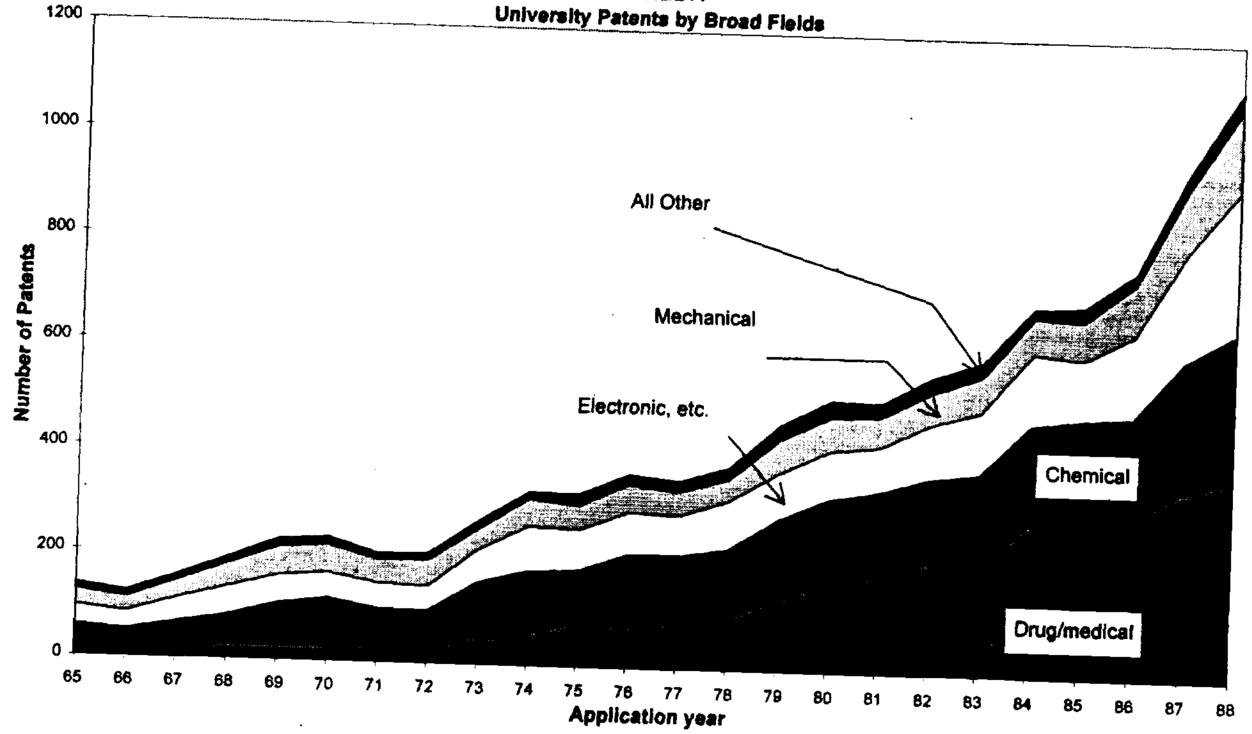


FIGURE TWO

PANEL A
University Patents by Broad Fields



PANEL B
All U.S. Patents by Broad Field

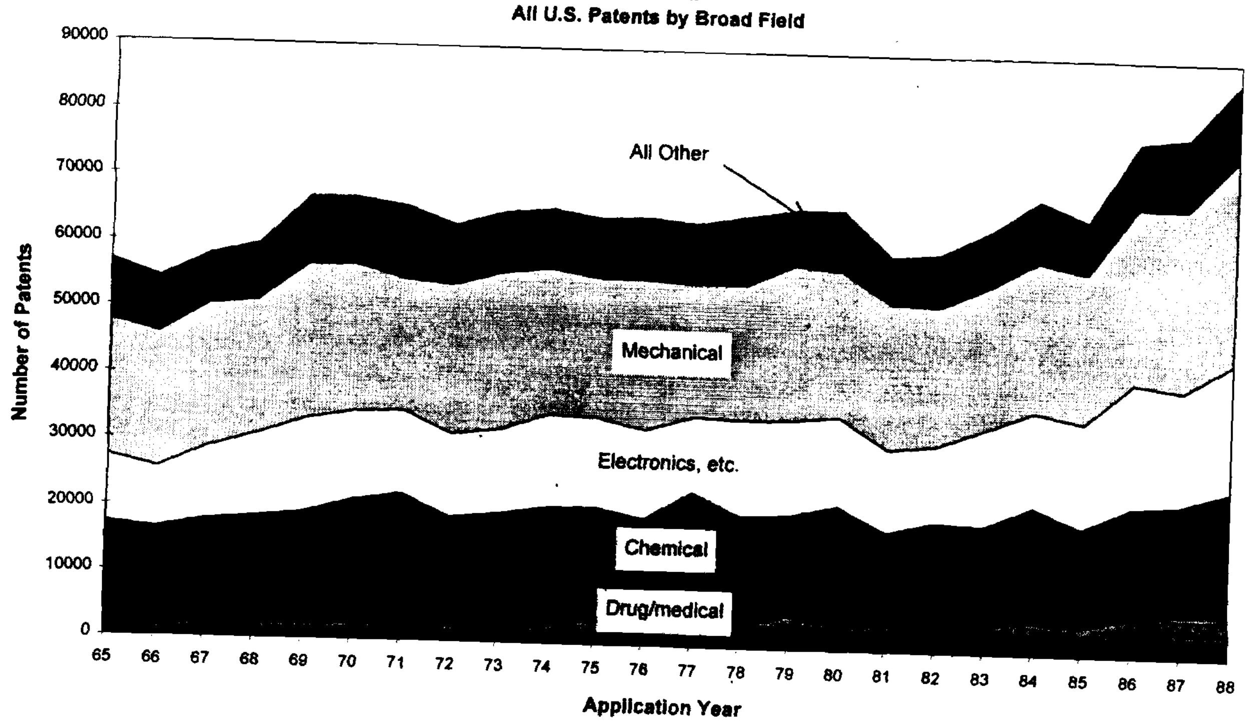


FIGURE THREE

The University Random Sample Contrast over time

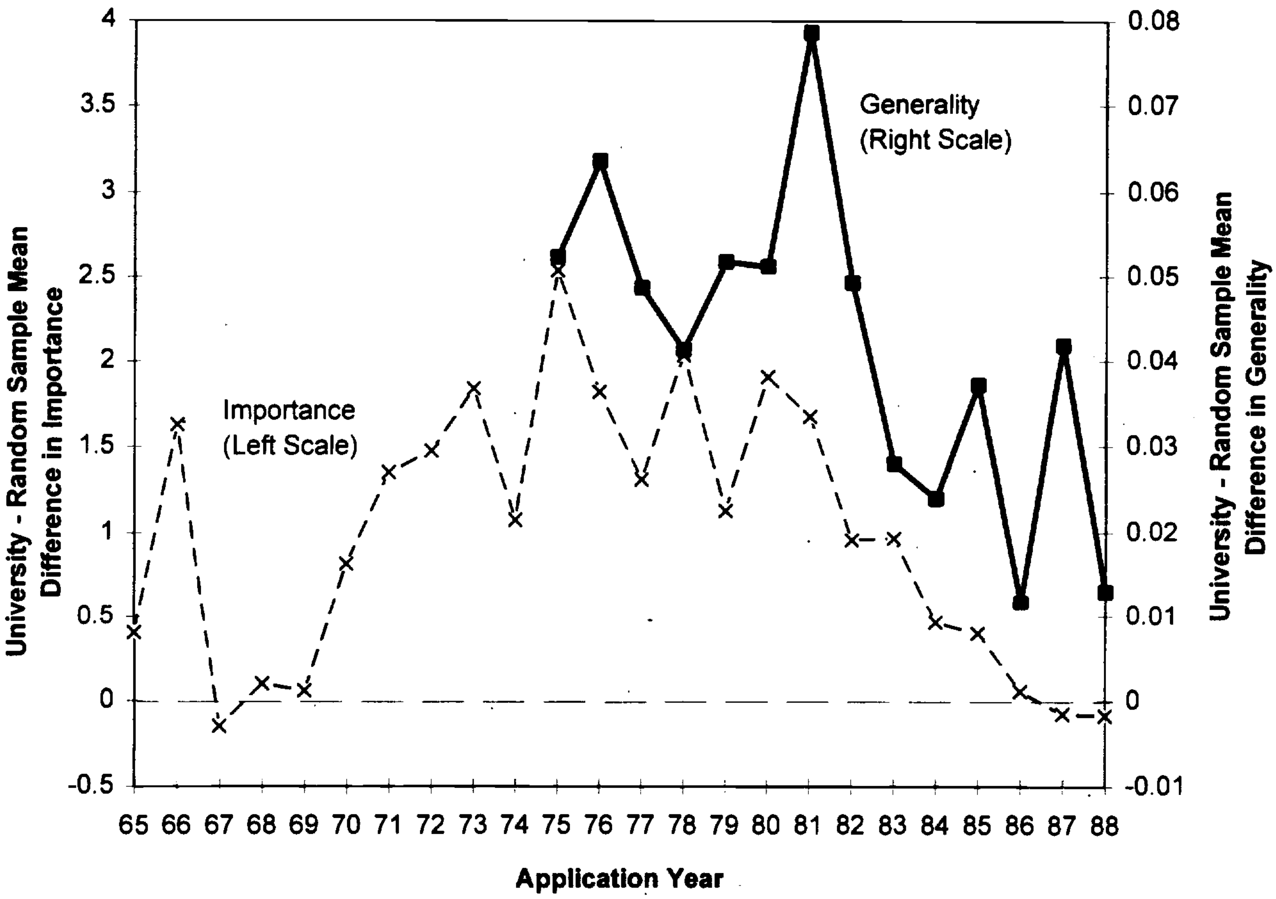


FIGURE FOUR

Path of University/Random Sample Difference in Importance by Field (Exponentially Smoothed)

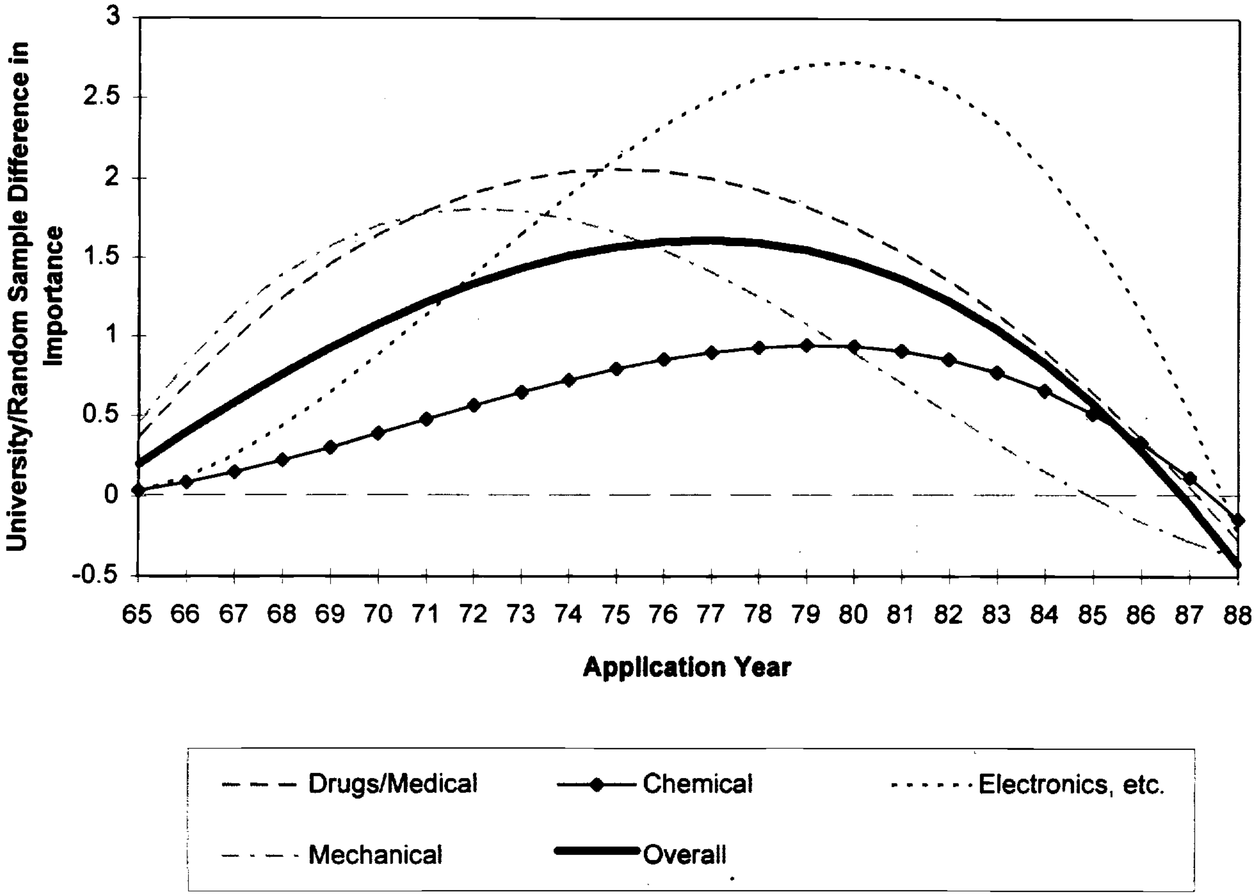
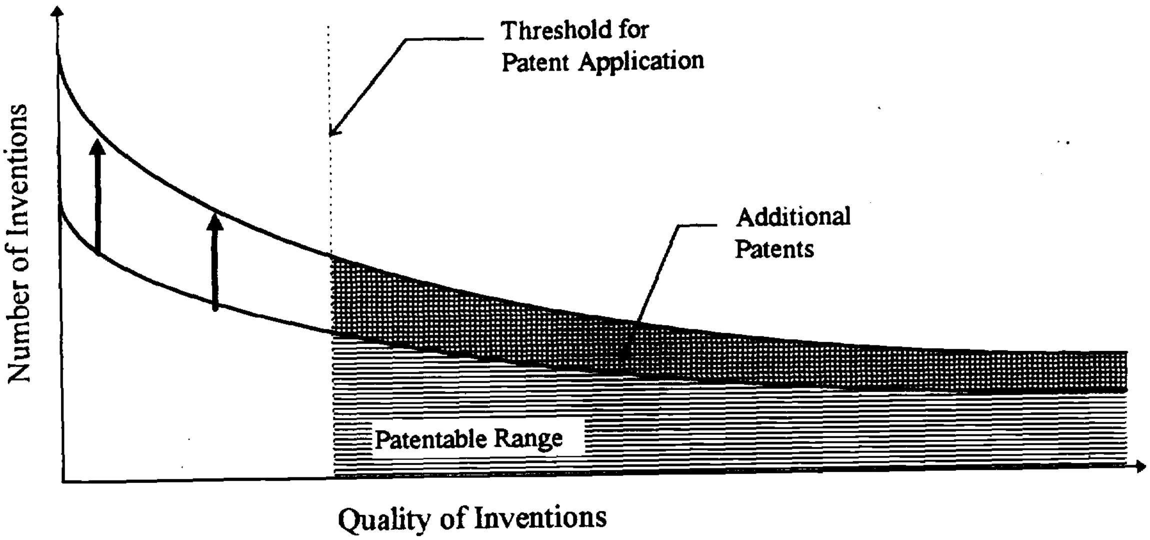


FIGURE FIVE

An Increase in Patenting Due to an Increase in the Rate of Invention



An Increase in Patenting Due to a Decrease in the Threshold for Patent Application

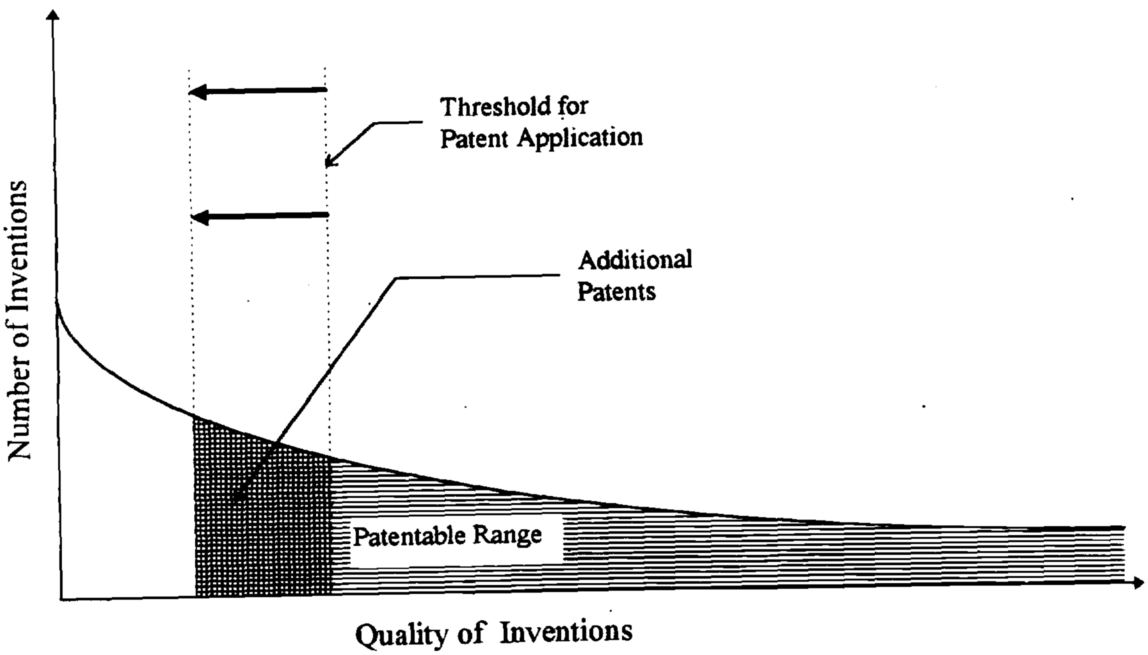
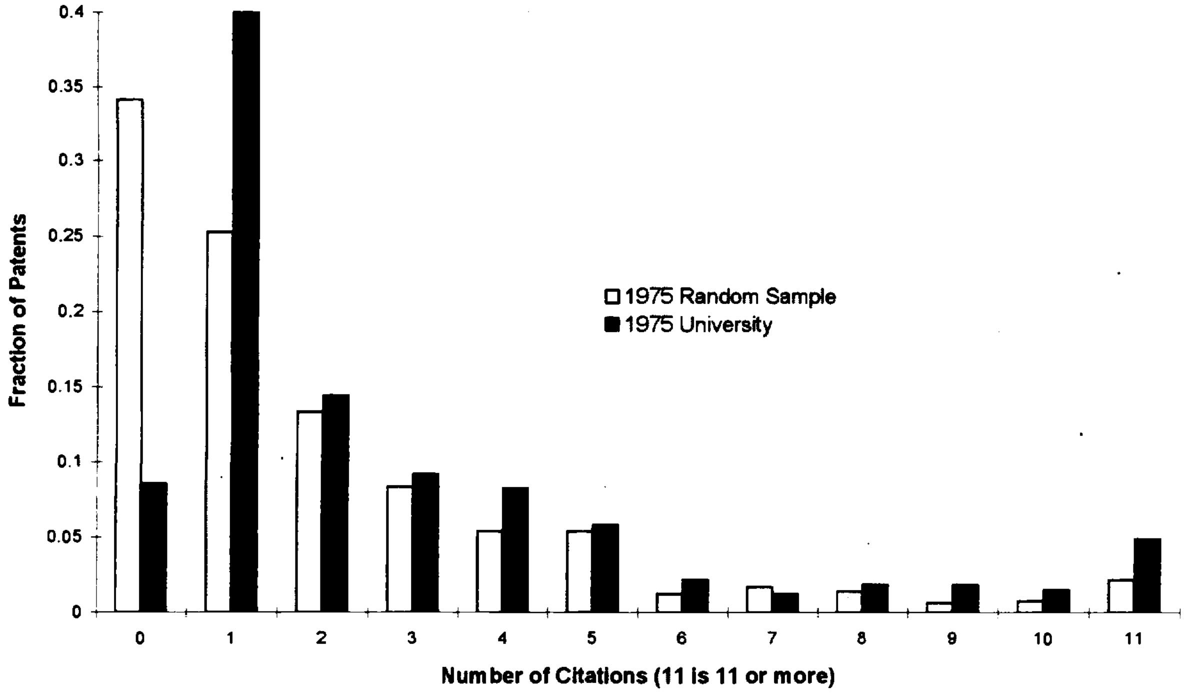


FIGURE SIX

PANEL A
Comparison of University and Random Sample Citation Distributions in 1975



PANEL B
Comparison of University and Random Sample Citation Distributions in 1984

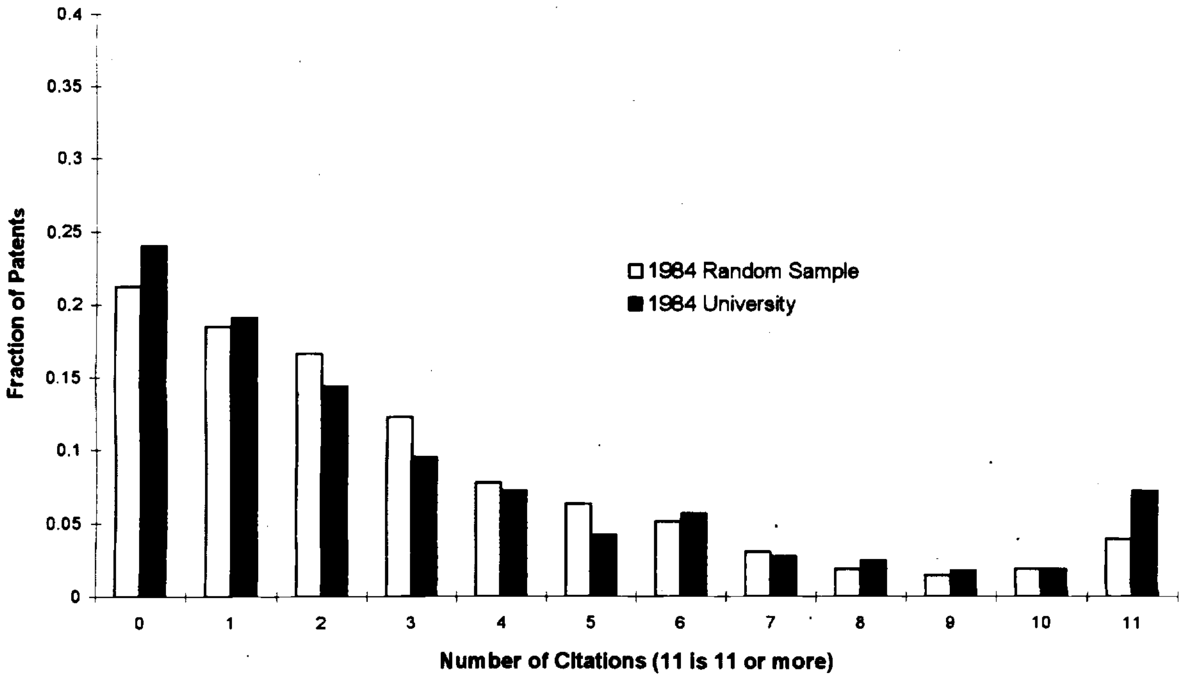


FIGURE SEVEN

Percent of Patents Receiving Zero Citations in the First 5 Years

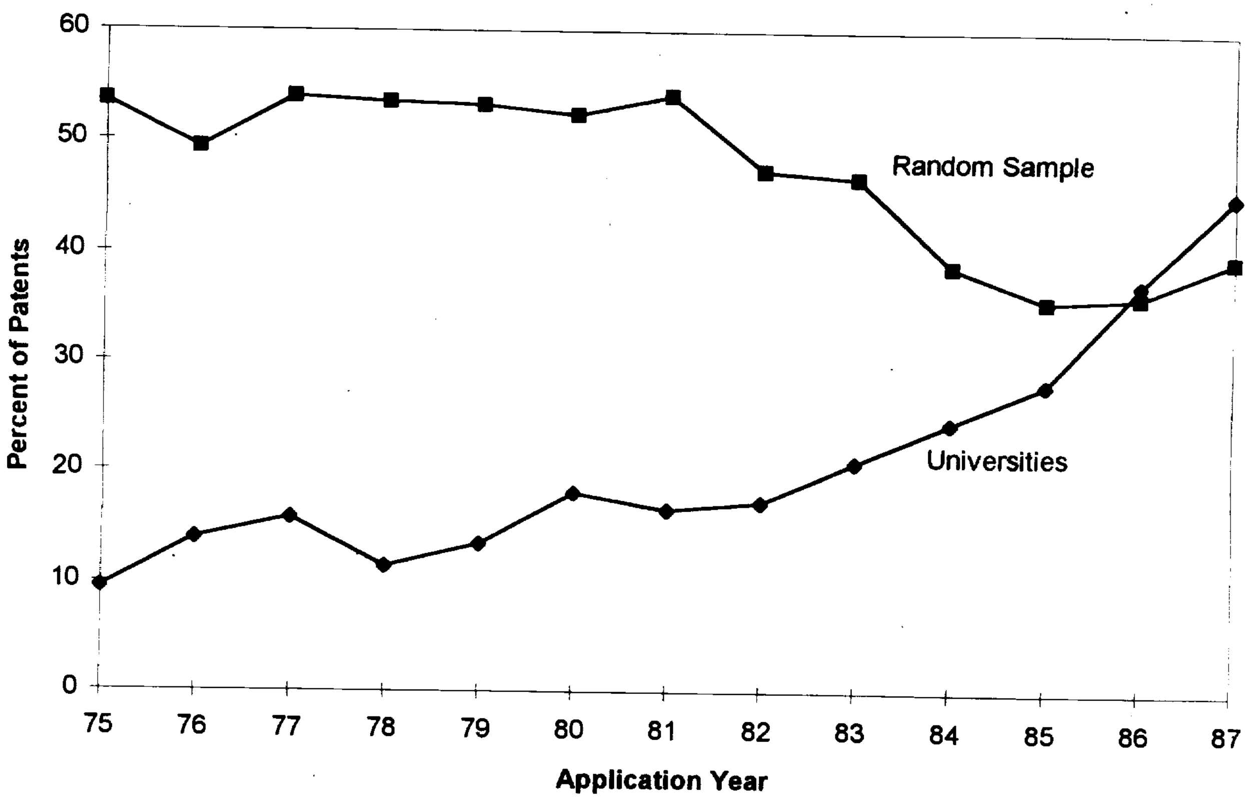


FIGURE EIGHT

Changes Over Time in the Concentration of University Patents Across Institututions

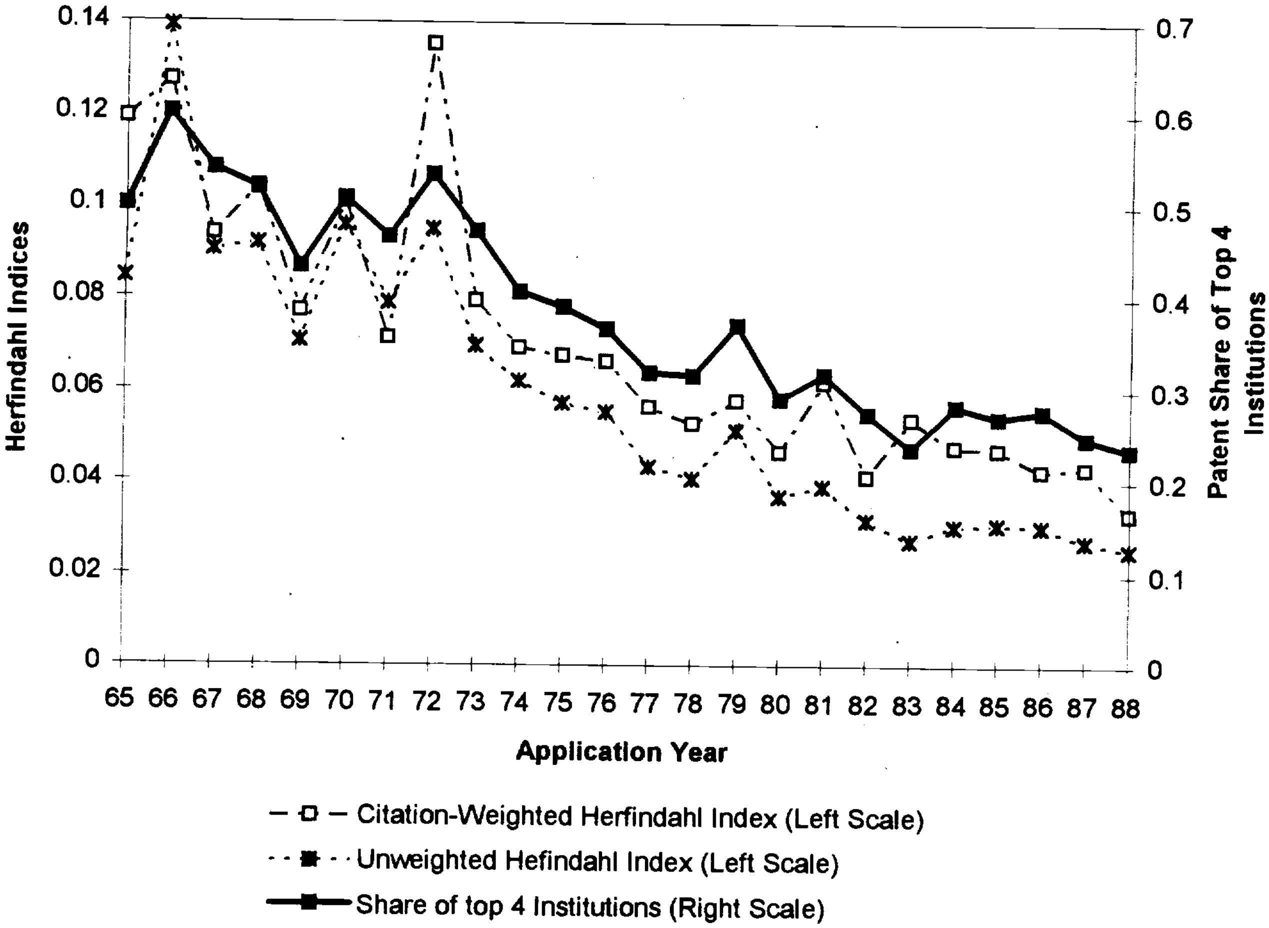


FIGURE NINE

Citation Intensity of University Patents Relative to Random Sample Over Time by Patent Ranking of Institution in 1988

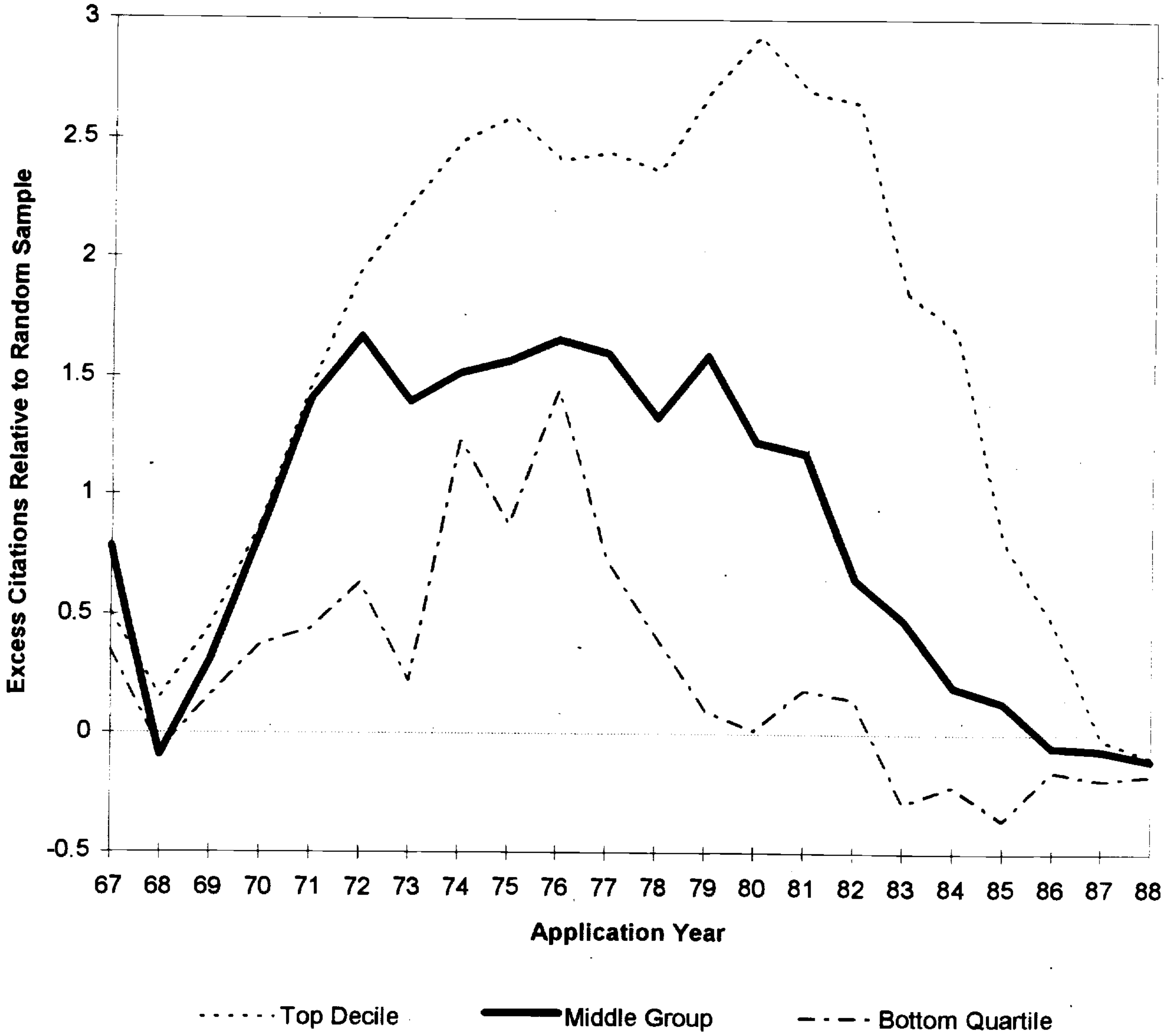
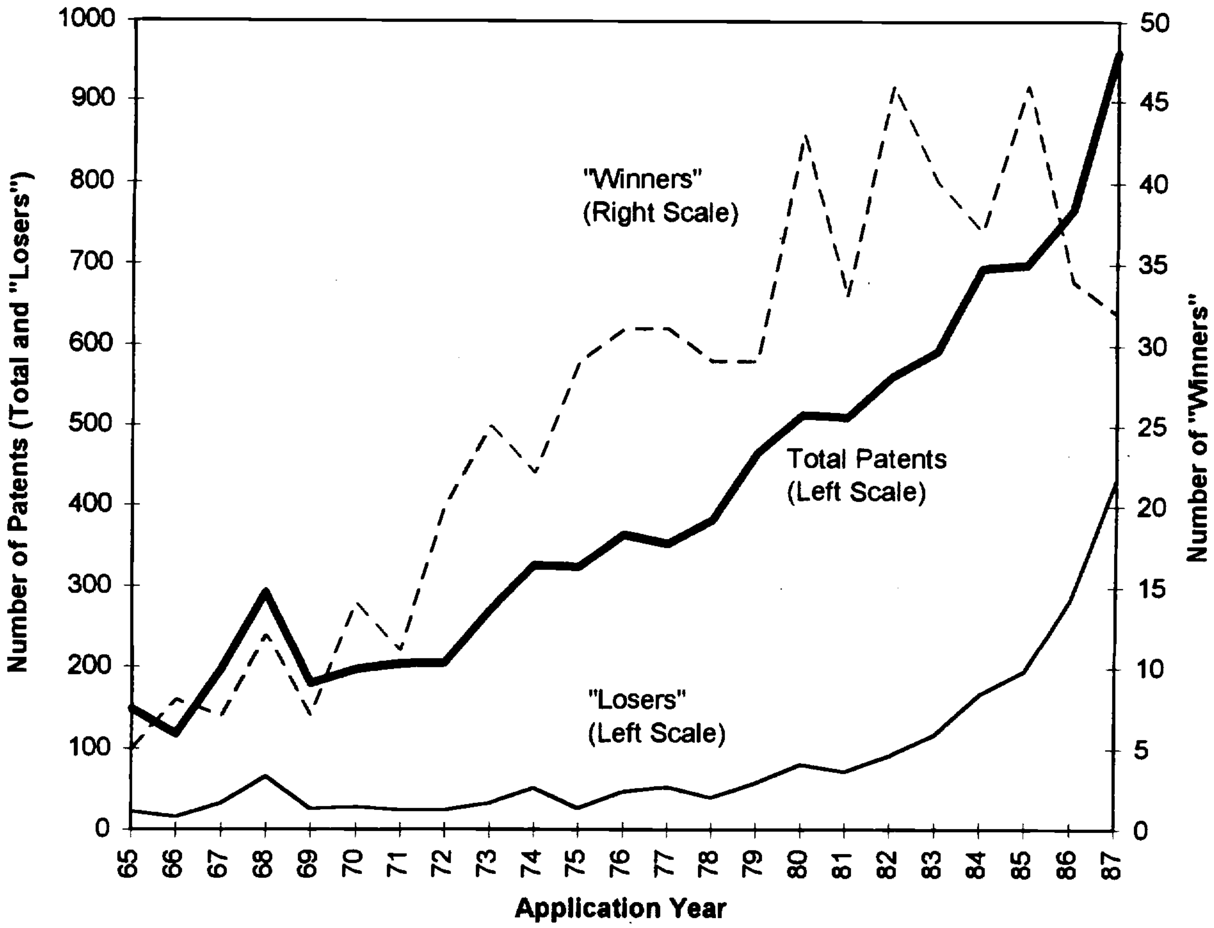


FIGURE TEN

Total University Patents, 'Winners," and "Losers"



"Losers" are patents with no citations by the end of the period.
"Winners" are patents with more citations than the mean of the top 10 percent of Random Sample Patents from the same year.