

## Are There Synergies or Tradeoffs Between Articles and Patents in University Ag-Biotech Research?

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## **I. Introduction**

The last decade has seen a major shift in the research portfolios of agricultural colleges at land grant universities with more effort being dedicated to agricultural biotechnologies. Land grant universities in the U. S. have gone from producing 1283 ag-biotech articles per year and 16 patents in 1991 to 1780 articles and 105 patents in 2001. One incentive for a shift toward biotechnologies has been the possibility of universities gaining intellectual property rights, patents, and a potential revenue stream from ag-biotech research. This paper examines the empirical evidence for synergies or tradeoffs associated with the rapid rise of ag-biotech patenting at Land Grant Universities by examining the question of whether journal articles and patents appear to be complementary or competing activities in agricultural biotechnology research.

Part of the logic of the Bayh-Dole act of 1980 that allowed universities to patent and license their innovations was that doing so would enhance rather than detract or distract from the scientific process. Rausser (1999) reports that universities have responded to the Bayh-Dole act by expanding technology transfer activities in ways similar to private companies. Henderson, Trajtenberg, and Jaffe have shown a reduction in the quality of patents produced by universities since the advent of the Bayh-Dole act, presumably due to the increased pressure to commercialize innovations. Some have expressed concerns over an increase in secrecy in the scientific community due to patenting (see e.g. Kennedy, 2000).

In the case of Land Grant universities, Parker and Zilberman present concerns that incentives to patent might shift university professors' research agendas away from the pursuit of public knowledge and toward patentable innovations. Weatherspoon,

Oehmke, and Raper (2000) argue that commercialization of Land Grant research agendas moves them away from their mission of conducting and disseminating unbiased research for the public good and toward serving narrower private purposes. In addition, some of the popularly voiced opposition to agricultural biotechnology has suggested that patenting by public sector institutions induces too much applied, commercial, research at the expense of farmer-oriented research (see e.g. RAFI, 2000). If such an increased commercialization and a concomitant turning away from basic research were underway, it would represent a major shift in the historic mission of the Land Grant system.

Despite these concerns with the potential problems associated with university patenting in general and ag-biotech patenting in particular, little direct empirical evidence has been provided on tradeoffs associated with the rise of ag-biotech patenting at Land Grant universities. One potentially obvious tradeoff would be in terms of journal article production, whereby the pursuit of patentable innovations would crowd out the process of drafting, submitting, and revising journal articles for publication because of competing time pressures and/or for reasons of keeping certain scientific advances secret prior to securing patents. Another possible tradeoff is that the quality of journal articles might decline with increased patenting effort because of the shift toward more applied research associated with the pursuit of commercial innovations.

Conversely, synergies might be more important than tradeoffs, if the underlying output of research knowledge is recognized as an input that can be used to generate both journal articles and patents, and that the two activities can thus be pursued jointly without much crowding out, as long as a capable technology transfer office exists to carry shoulder the burden of the patenting process. Where these synergies, or economies of

scope, dominate tradeoffs, or any diseconomies of scope, then both the quantity and quality of patents and journal articles could be positively correlated with one another.

In previous work, we demonstrated that the recent takeoff in ag-biotech patenting among U.S. universities was fairly highly concentrated in the hands of a few major Land Grant institutions (Barham, Foltz, and Kim). We also found that ag-biotech patent output is supported by previous patenting experience, efficiency of patenting efforts, and economies of scope with the biological sciences, as well as by more traditional research production variables, such as federal funding and the quantity and quality of researchers (Foltz, Kim, and Barham). In other words, some of the variables shaping university ag-biotech patent production are suggestive of the presence of increasing returns due to either scale and/or scope effects. Similar scale effects may be prevalent in private industry where ag-biotech companies consolidated to a significant extent in the recent decade (add citation here). More direct evidence of increasing returns is identified in the seed industry by Graff, Rausser, and Small, who find significant production complementarities in firms that control both conventional germplasm and ag-biotech patents. Our hypothesis is that synergies dominate tradeoffs in the case of university journal article and patent production because the key input for both is high quality research knowledge that can be applied to produce both outputs jointly.

The efficiency and equity implications associated with this issue are significant. First, if synergies are dominant, then there are efficiency grounds for supporting the increased emphasis of universities on patent production that may not be receiving sufficient attention. Second, if increasing returns within the agricultural biotechnology research process of Land Grant universities are present both in terms of scope and scale,

then it is not hard to imagine the top producers capturing the dominant share of university-level benefits associated with this line of research in a virtuous, dynamic cycle of more, high quality research production fueling future research successes.<sup>2</sup> This prospect will be bolstered, especially if the ag-biotech patents payoff in the form of licensing revenues, sponsored research agreements, and successful start-up ventures, such that universities with more patents can pursue even more research with the support of these funds. Such a cycle is both socially attractive because of the efficiency gains associated with increasing returns but also potentially troubling in its implications for the future vitality of those Land Grant universities which cannot get up to the scale of research production that allows them to exploit the increasing returns. Because Land Grant universities are also the leading providers of high-end university education and extension work, a growing disparity among them fueled by divergence in the research realm could be of broader concern.

This work must be regarded as an exploratory empirical inquiry into the relationship between ag-biotech patent and article production in Land Grant universities that uses both quantity and quality measures to identify the potential synergies or tradeoffs involved. Rather than a definitive piece testing a formal model of economies of scope and scale (cites), it is intended as a first step in guiding future research on the issue of increasing returns within university research production processes. In that spirit, we employ non-parametric regression techniques that allow the production data to indicate

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<sup>2</sup> Baumol argues that the technological dynamism of the modern capitalist system stems primarily from the systematic nature of research production that has come to dominate in both the private and public sectors over the past century, and that this process tends to be self-reinforcing within successful research institutions.

the potential presence or lack of increasing returns, i.e., the economies of scope and scale that are our focus.

We use two quantitative outputs, journal articles and US patents, but also their qualitative counterparts: the number of citations of those patents and journal articles.<sup>3</sup> The analysis starts by demonstrating the dramatic but staggered growth paths of university ag-biotech patents and articles in the 1990s. This is followed by an investigation of increasing returns in the production of articles and patents. Two types of increasing returns are examined: scope in which higher levels of article production are associated with higher levels of patent production; and scale in which higher quantities of patents (articles) produces higher quality patents (articles). Finally, we close the circle by analyzing the relationship between quality measures of articles and patents in order to see whether the economies of scale and scope serve to reinforce the advantageous position of the top-research producing universities.

## **II. Data and methods:**

The data used in this study were collected from two sources: the US Patent and Trademarks Office (USPTO) for patents and from the Science Citation Index (Web of Science) database for articles. Articles and patents were chosen so as to produce a consistent dataset that would represent the majority of research considered to be agricultural biotechnology. Both searches were conducted in two basic steps. First, articles (patents) credited to researchers at Land Grant institutions were identified as

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<sup>3</sup> Some strands of the literature (e.g. Cockburn, Henderson, and Stern, 1999; and Xia and Buccola, 2000 ) call patents “applied” research and journal articles “basic” research. It is not clear, especially at Land Grant universities where research articles on applied topics are the norm, that this distinction is as clear cut. The primary key distinction is the intellectual property on patents which restricts access and increases commercial potential in a way not applicable to journal articles.

being on biotechnology topics. Then, within the realm of biotechnology, articles and patents were chosen for inclusion if they were identified as pertinent to agriculture.

Specifically, the patent data were drawn from a search of the U.S. Patent office database for university-owned utility patents that were both agricultural and biotechnological.<sup>4</sup> We considered all patents in U.S. classes 435, 800, 935 as biotech and then searched within them for those that were agricultural. The definition of agriculture we used required that the technology: 1) uses extensively a product produced on a farm; or 2) modifies or improves a product produced on a farm; or 3) modifies, improves, or produces a food, wood, or aquaculture product. Note that this definition excludes a number of technologies including: (i) any animals or plants produced entirely for research purposes (e.g., mice, rats, monkeys); (ii) any animal primarily designed as a pet: e.g. dogs and cats; (iii) any product that merely uses animal or plant cells in minor quantities for a non-agricultural product; or (iv) any vaccine or vaccine technique or disease diagnostic technique that is intended primarily for use in humans, or on human diseases, or on diseases not currently treated in animals. Note that the database does include utility patents on plants intended only for ornamentation so long as they fit the definition of being biotechnology.

The ag-biotech articles were culled from the Science Citation Index (ISI Web of Science, 2002). Articles were chosen by key words related to biotechnology genetic modifications (genet\*, gene, genom\*) and then searched for agricultural topics.<sup>5</sup> The

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<sup>4</sup> While these data include utility patents on plants, plant variety protection and plant breeders rights were excluded because they represent a much lower level of intellectual property protection as well as lower levels of novelty required for a successful application.

<sup>5</sup> We experimented with a number of other key words for the search including: enzyme, protein, RNA, DNA, and transgenic. These key words were rejected for greatly increasing the size of the set of biotechnology papers over which to search for agricultural topics without significantly increasing the number of agricultural biotechnology articles found.

same definition of agriculture was used as in the patent search, with some slight modification given that articles do not represent final products in the same way that patents do. We culled from among those identified as biotechnological, all articles that included (1) basic and applied genetics, genomics, breeding, physiological or pathological studies of: plants (e.g. arabidopsis), crops (e.g. potato, tomato, barley, rice, maize, soybean, tobacco, alfalfa, etc.), vegetables (e.g. cabbage, cucumber, onion, etc. ), fruits (e.g. citrus, berries, grapes, apples, melons, etc.), seeds, weeds, or grasses; (2) genetic or medicinal studies related to farm animals such as: cows, pigs, chickens, sheep, rabbits, horses; (3) Studies on insects, viruses, fungi, or bacteria that are related to the pathology of plants, crops, or farm animals (includes veterinary medicine); (4) genetic technologies or research related to food production or food poisoning; (5) forestry research. Research types that were excluded were: (1) marine plant biology; (2) research on aquatic life such as sea-urchin or fish (e.g. rainbow trout, zebrafish, etc.); (3) entomology related to human diseases; (4) veterinary medicine related to cats, dogs, or other pet animals; (5) genetic studies on wildlife species such as pigeons, condors, or songbirds; (6) genetic studies of amphibians such as snakes, salamanders, or lizards.

The search yielded 718 ag-biotech patents assigned to 52 Land Grant universities between 1991 and 2001. Over that same period 18,577 ag-biotech articles were identified as belonging to authors at those same universities. Both article and patent counts credit a university with a single patent or article if at least one author is affiliated with the institution. While necessarily adding some noise to the data, we decided that any other scheme for crediting authors would cause its own problems of equal or greater magnitude.



The patent and article data were then used to search for citations. Studies of patent citations have been to provide a reasonable proxy for both the quality of a patent and knowledge spillovers from it, because each time a new patent uses a piece of research from another patent it is obligated to cite the previous patent (Henderson, Jaffe, and Trajtenberg). Article citations are commonly used as measures of quality in studies of departmental or university quality (e.g. Adams). Despite their wide use, caution in interpreting citations as strong quality measures is warranted. As the editor of the journal *Science* recently wrote: “Citation indices...are easily misjudged: Some of our best papers are lightly cited, and some less important ones get referenced everywhere.” (Kennedy, 2002, p. 1193)

### **Methods:**

Strict evidence of increasing returns depends on finding that unit costs fall with increased output over a substantial range of production. The distinction between economies of scale and economies of scope as sources of increasing returns is that, in the former, unit costs of one output fall with increased output of that product whereas, in the latter, unit costs of two or more outputs fall as they are produced together. Underlying these declining unit costs could be some significant (fixed or non-rivalrous) input that is spread over more output of one or more products, such as research knowledge applied to two or more outputs, or else improved efficiency that arises with more production such as dynamic learning effects.

This empirical inquiry does not involve any formal measure of costs associated with university research production. As such, the evidence offered cannot be viewed as

conclusive with regards to the presence or lack of increasing returns. Rather, what is searched for in this inquiry is evidence that is consistent or not with economies of scope and scale in the production of articles and patents. In particular, a positive and increasing slope in the production of articles and patents is viewed as consistent with economies of scope. That is, more output of one output gives rise to more output of another at an increasing rate. In the case of economies of scale in the production of patents and articles, we examine whether universities with more of either output are getting a higher quality output as measured by a higher citation rate per article or patent. If they are, then that suggests the presence of economies of scale: universities receive a better average product when they produce more. Finally, we test to see whether universities with higher quality articles also have higher quality patents, i.e. whether the other synergies are reinforcing, creating the potential for a virtuous cycle of universities with more research production getting higher quality outputs in both arenas.

To search for evidence consistent with increasing returns or synergies, we employ a non-parametric approach that places a minimum of assumptions on the relationships between the variables. This approach allows the data more “degrees of freedom” than the conventional parametric regression in which the justification of a model specification is often required (Manski; Blundell and Duncan). This flexible technique allows the data to show the underlying relationship between the variables in question without imposing them *a-priori* through *ad-hoc* functional forms.

Following Blundell and Duncan the general model of interest in this paper, with for example  $y$  measuring university patents and the variable  $x$  articles, is given by:

$$y=g(x) + \varepsilon$$

where  $\varepsilon$  is defined such that  $E(\varepsilon|x) = 0$ . Non-parametric regression allows us to avoid imposing parametric assumptions or restrictions on the function  $g(x)$ , the conditional mean. Instead, the conditional mean  $g(x)$  is replaced by a local estimator of the form:

$$E(y | x) = \int y f(y | x) dy = \frac{\int y f(y, x) dy}{\int f(y, x) dy},$$

where  $f(y|x)$  is the conditional density of  $y$ . The numerator and the denominator are then replaced by a locally based Gaussian kernel estimator,<sup>6</sup>

$$E(y | x) = \frac{\sum_{j=1}^n K_h(x_i - x_j) y_j}{\sum_{j=1}^n K_h(x_i - x_j)}, \quad i = 1, 2, \dots, n,$$

where  $y$  is the random variable of interest,  $x$  is the conditioning variable,  $K_h$  is the Gaussian kernel with bandwidth  $h$  which we set to  $(4/n*(m+2))^{1/(4+m)}$ , and  $n$  and  $m$  are the number of observations and the number of columns in  $x$ , respectively.

### III. Trends in articles and patents

Barham, Kim, and Foltz demonstrate a “take-off” in ag-biotech patenting in the mid-1990’s, and Figure 1 below shows the growth in both accepted patents and published articles in ag-biotech from 1991-2001. Clearly, there is a take-off in article production that pre-dates the growth in patenting. The two curves suggest a four-to-five year gap between the initial growth spurt in ag-biotech articles and the subsequent growth

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<sup>6</sup> A number of alternate estimators are available for estimating the kernel function including the Epanechnikov and Parzen estimators.

spurt in patents. The parallel “S” curves would seem to point toward synergies, perhaps lagged, between articles and patents.

Both curves demonstrate a type of “S” curve in which after an initial rapid growth period production levels off, with article production remaining more or less constant from 1995-2000 and patents dropping from their peak in 1999 but staying above 1997 levels. Both curves suggest that the growth spurt in ag-biotech research overall has leveled off in the later part of the 1990’s. In the case of articles, this leveling off may be caused by maximum number of pages in the journals likely to publish ag-biotech articles or journal editors allocating a maximum number of pages within a journal to ag-biotech. With patents, the spike in patenting in the late 1990’s coincides with the height of the (as yet unrealized) euphoria on the commercial potential of ag-biotech. While it is unclear whether a downturn in patenting is underway, the 1990s growth spurt in university ag-biotech patents seems to have ended. Many explanations are possible including: the easy fruit have been picked from the article shelf, patenting is harder to do because of patent stacking or hold-ups (Graff and Zilberman?), and/or technology transfer offices are reacting to lowered commercial expectations in ag-biotech by seeking fewer patents.

#### **IV. Economies of Scope in Articles and Patents: Trade-offs or Synergies?**

This section investigates the trade offs and synergies between article and patent production. In particular we search for evidence that patenting might be inhibiting article production, or that there might be opportunity costs in terms of article production in choosing to do patentable research. We investigate these issues first at the level of all US

land grant universities, pooling their data together over time, and then at the individual university level.

Before presenting the results, it is worth considering the question of the appropriate counterfactual. Since all universities in the sample were active in both articles and patenting, one does not observe the counterfactual of universities producing only one or the other. Thus, the available data are similar to an experiment with a treatment but no control subjects.

### **1. Global: Non-parametric curve of articles versus patents**

Two non-parametric estimates of the relationship between patents and article production are presented in Figure 2, with one curve showing 1991-1995 and the other 1996-2000. The estimation describes the number of ag-biotech patents at a particular university as a function of the number of ag-biotech articles produced at that university in the same period. Both curves show distinct upward trends, in which universities with more articles produce more patents. In the latter period that relationship became stronger and strongest among the universities producing the most articles. Globally, there is no sign of a tradeoff among these activities but rather an outcome that seems more consistent with robust growth of joint products from a shared research production process.

Perhaps most striking about the relationship between patent and article production is that there seems to be a threshold at just below 50 articles per year, above which increasing synergies occur. Put differently, it would seem that the synergies between articles and patents grow with more production of articles, i.e. that the economies of

scope may kick in at higher levels of research production. Whether these increasing returns are due to higher quality research or fixed costs, i.e. that universities producing more articles are also better able to invest in the technology transfer infrastructure necessary to be successful in patenting is an issue we consider further in section VI.

## **2. University Specific Economies of Scope**

While Figure 1 shows the time trend and Figure 2 shows the overall relationship between articles and patents, the global estimates may mask some synergies or trade-offs taking place at individual universities. Figure 3 shows, at the level of individual universities, the changes in article and patent production from the first to the second half of the 1990's. This provides a picture of both potential synergies or trade-offs and how those relationships might have changed between the first and second half of the decade of the 1990's. Arrows are provided for only a few universities so as not to confound the reader. At the individual university level, the same growth trend in patenting that is evident at the global level is very clearly evident. Almost all individual (98 %) land grant universities increased their patent production from the period 1991-1995 to 1996-2000. All of the universities producing more than 50 articles per year had significant increases in patent production. A number of mid-level article producers such as Rutgers University and Louisiana State University had significant increases in their production of patents. In addition, Michigan State University and Iowa State University had spectacular increases in patent production in the 1990s.

Most of the universities dramatically increased their patent production while either maintaining their article production or increasing it, providing evidence of synergies. Universities such as Rutgers, Wisconsin, Florida, and North Carolina State show at least 20% increases in articles and more than a 50% increase in patents produced, underscoring the apparent complementarity between the two activities. This provides evidence, if not of synergies, at least that there are not significant trade offs between patents and articles.

Most of the universities that exhibit the combination of significantly more articles along with more patents were high article producers (more than 50 per year) in the early period. This suggests, as Figure 2 did on an aggregate level, that there may be some thresholds to the synergy between articles and patents. In other words it is possible that one needs to produce a large number of ag-biotech articles to be able to generate strong synergies with patent production. Such thresholds to synergy might partially explain the strong position of the major land grant universities, such as UC-Davis, Cornell, Iowa State, and Wisconsin in ag-biotech patenting since they are also the major article producers. In order to be confirmed, these relationships deserve structural econometric exploration that would include estimates of the determinants of both research products.

A few universities show some slight evidence of trade offs. In particular Cornell, Montana, and Illinois have reduced ag-biotech article production while increasing patenting. These three universities represent different slices of the article production spectrum, with average yearly production rates of 14.5 at Montana, 45.7 at U. of Illinois, and 127.2 at Cornell, the leading producer of ag-biotech articles. While it is conceivable that Cornell researchers or administration might have pursued patenting at the expense of

article production, they nonetheless remained as the leading Land Grant university producer of ag-biotech articles.

## **V. Economies of Scale in Articles and Patents? The quantity and quality relationship**

This section uses the citation rate of articles and patents as a measure of the quality of the articles or patents, and explores whether universities that produces more articles (patents) also produce higher quality articles (patents). Such a relationship, if present, would give evidence of economies of scale in the quality of research outputs.

### **Measuring quality:**

In keeping with the established patent literature (e.g., Cockburn, Henderson, and Stern, and Henderson, Jaffe, and Trajtenberg) and the practice in most studies of departmental or university quality (e.g. Adams), we use the number of citations of an article or patent as the best available measure.<sup>7</sup> Since citations are time dependent with, for example, older articles receiving more citations than newer ones, we construct a citation measure for each university that is the deviation from the average citation rate of the average article published in the that year. For example, a 1995 ag-biotech article with 10 citations is compared to the average level of citations of all ag-biotech articles produced in 1995. In any one year the overall average citation rate is assigned a value of

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<sup>7</sup> Citations are necessarily an imperfect measure because some very innovative articles may get few citations because they are not part of an established literature, while other articles such as review articles may be highly cited not because of their quality or degree of innovation but because they provide a convenient citation for authors.



1, with higher quality articles then having a measure greater than one and lower quality articles receiving a measure between zero and one. This approach helps to minimize a bias that might exist for universities that had more articles late in the decade than early on.<sup>8</sup> Note that when aggregated and averaged across years at the university level, the distribution no longer necessarily centers on one.

### **Estimates of quantity/quality relationships:**

In order to show the relationships between quantity and quality of articles and patents we estimate two non-parametric kernel curves: one each for articles and patents showing the relationship between the quantity and quality. Figure 4 shows, for the first and second half of the 1990's, non-parametric regression curves of the relationship between the number of journal articles produced by a university and the average quality of those articles as measured in deviations from the yearly means. The curves both show similar upward trends suggesting that universities producing more ag-biotech articles are also producing articles that on average are more highly cited. Both curves are steeply sloped for the region below 20-30 articles per year, suggesting increasing returns to scale for relatively low levels of article production. Most of the returns to scale disappear after 30 articles per year, though both curves show positive slopes over most of the range.

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<sup>8</sup> If major universities or departments are more likely to have their work cited faster because their professors are more famous if perhaps not necessarily producing higher quality work, there may be a slight tendency for this measure to over count citations at the leading universities.

Scale economies in patenting are investigated in Figure 5, which shows the relationship between the number of patents and their average citation rate.<sup>9</sup> Both periods show a distinctive pattern with universities that produce more patents also having higher quality patents. The University of Florida adds an extra local spike to the 1991-1995 curve which is generally above the 1996-2000 curve. The 1996-2000 curve shows some evidence of a threshold effect, with only a slight positive relationship between patent numbers and patent citations up to about 2 patents per university per year, after which point patent quality is strongly increasing in the number of patents produced.

Taken together Figures 4 and 5 suggest via quality measures strong economies of scale in the production of ag-biotech patents and weaker economies of scale in the production of articles.<sup>10</sup> Put differently, in contrast to the literature, which suggests a quantity-quality tradeoff in patenting, the evidence from Figure 5 suggests that, as with articles, universities producing more patents are also producing higher quality patents.

## **VI. Quality Tradeoffs or Synergies:**

This section investigates whether there are tradeoffs or synergies in the quality of articles and patents. The first exercise is to investigate whether quality article production translates into more patents. The second part analyzes whether there is a direct relationship between quality articles and quality patents.

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<sup>9</sup> Universities without any patents have been dropped from the estimation since their citation rate is necessarily zero.

<sup>10</sup> Note that some of this difference may come from the differences of purposes between patents and articles. Journal editors are explicitly looking to publish articles that will be cited, which should produce a fairly uniform distribution of average citation rates. In contrast patent inspectors are tasked with choosing innovations that meet the patenting criterion, novel and useful, which may not necessarily produce patents that will be cited in any uniform pattern.

In section (IV) Figure 2 shows patents to be produced in a ratio of about 1 patent per 20 or 30 journal articles. Since patents explicitly require a degree of novelty that is stronger than the average scientific journal, there may be a positive relationship between the quality of articles and the quantity of patents produced. For example, universities with higher quality articles may be more likely to produce patentable ideas.

At the same time there are suggestions in the literature (e.g. Brown), although little supporting empirical evidence, that an increase in commercial research agendas, as evidenced by patenting, has reduced the quality of scholarly production, i.e. articles. Such a trend, if real, would have universities that are devoting increasing efforts toward patenting having lower levels of citations of their journal articles as they produced more commercial, or applied, research rather than basic research, which is thought to be more frequently cited.

Figure 6 shows the relationship between article quality and patent production (quantity). While the early period curve shows no distinctive trend in patent production across article quality, the later 1996-2000 curve shows a positive slope. The results suggest some sort of positive correlation between article quality and the production of patents at universities. This relationship, when understood along with the positive relationship between article quality and quantity, would reinforce some of the inequality increasing relationships mentioned above.

In the preceding sections, the quantity measures used have not accounted for the number of scientists engaged in ag-biotech research because such data are not readily available. The data have effectively demonstrated quantity/quantity synergy and quantity/quality synergies, but some of these synergies may be caused by correlations in

scientist numbers rather than by actual synergies in the production process. Since the citation rates of both patents and articles are item specific and independent of the number of scientists, analyzing the relationship between article quality and patent quality provides a clean measure synergies in the quality of research outputs.

Figure 7 shows a non-parametric estimate of the relationship between article citations and patent citations. Both curves show general upward trends, although in the first half of the decade the last data point of the distribution shows a negative relationship. Aside from that single data point, both curves show increasing slope at higher levels of article quality. These estimates reinforce the notion that article and patent production are synergistic activities. In particular, it would seem that high quality in articles is correlated with high quality of patents. Given that quality is also associated with quantity in both cases, especially patents, this finding would seem to close the circle on the notion that universities at the high end of patent and article production are also producing higher quality outputs that are likely to foster further success in competitive grant processes, sponsored research agreements, and patent revenues.

## **VII. Conclusions:**

This work has explored potential synergies and tradeoffs in the production of ag-biotech journal articles and patents at US Land Grant universities using non-parametric methods. The results show none of the expected tradeoffs between the basic research represented in journal articles and the commercial proprietary research represented in patents. In fact the results, contrary to many of the concerns expressed in the literature, suggest significant synergies between articles and patents in the ag-biotech field. There

may still be tradeoffs between basic and applied research in ag-biotech at Land Grant universities. If they exist, they likely reside not at the university level, but at the individual scientist or lab level.

This work has, however, identified a potential cause for concern in the degree to which patent and article production exhibit increasing returns in both scope and scale. Such a finding reinforces a pattern of inequality already found in the competitive grant system. If the production of patents provides universities with another revenue source, then the types of inequalities that many USDA grant policies fight against, may be exacerbated.

The evidence on the relationship between basic and applied research provided by this data exploration opens a number of questions for future inquiry. The finding of synergies between articles and patents needs further analysis to help understand its determinants. In addition it may be that while there are synergies between articles and patents, it is worth investigating tradeoffs with other common university activities such as teaching and extension.

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Figure 1: Growth in Ag-Biotech Articles and Patents at Land Grant Universities

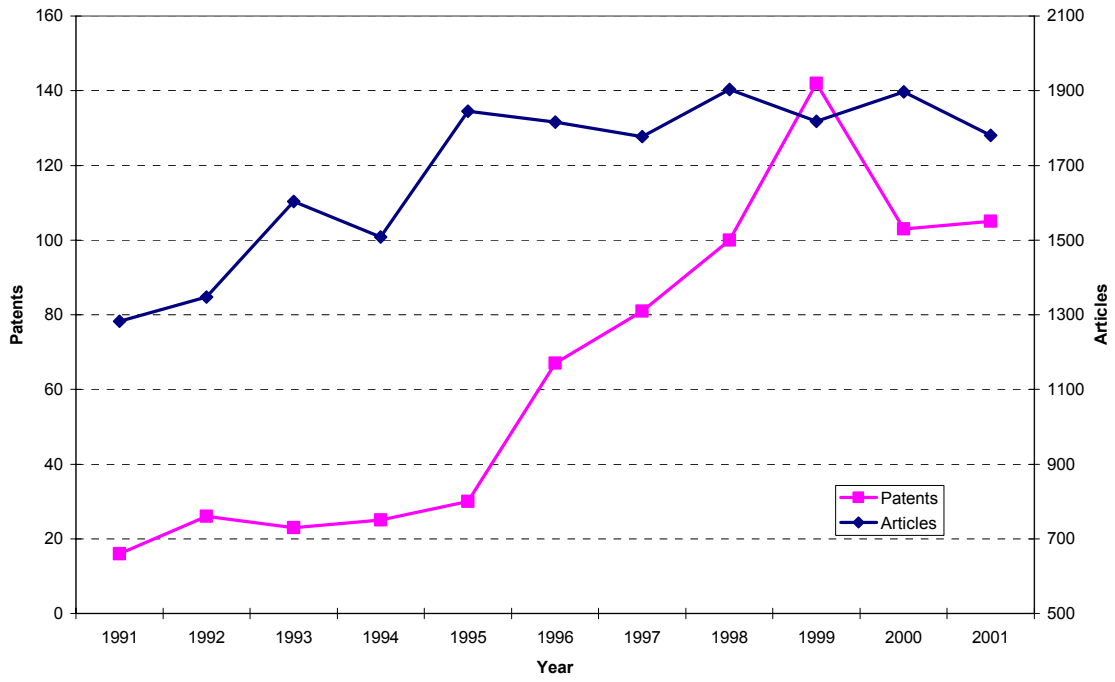


Figure 2: Patent and Article Production

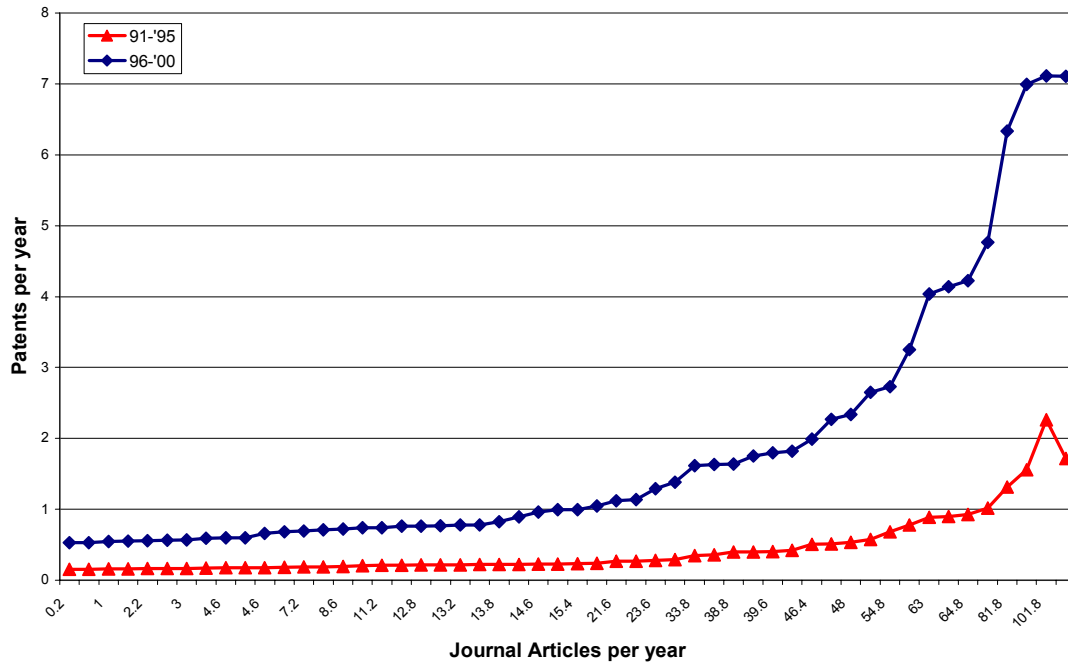




Figure 3: University Trends in Article and Patent Production

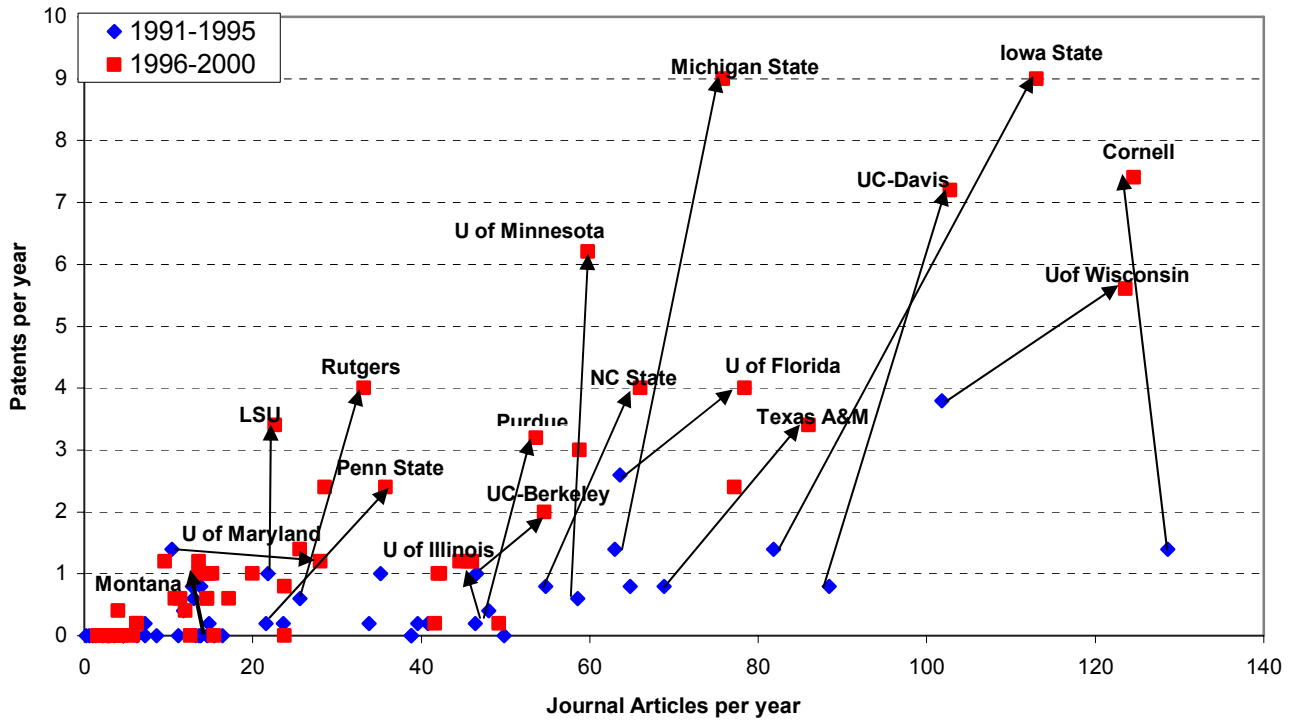


Figure 4: Article Quantity and Quality

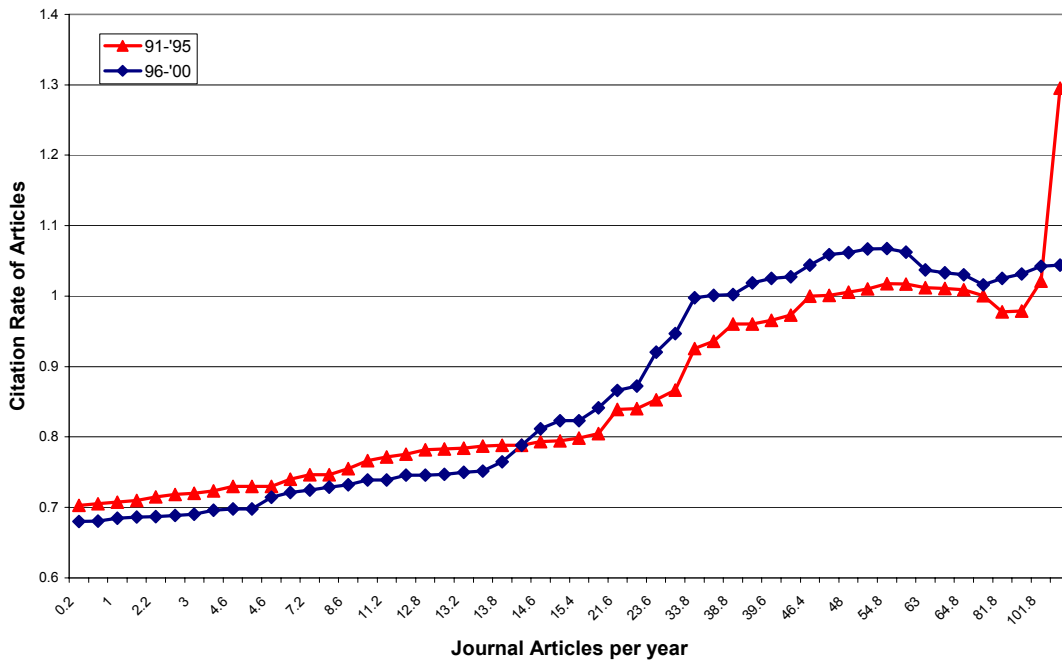


Figure 5: Patent Quantity and Quality

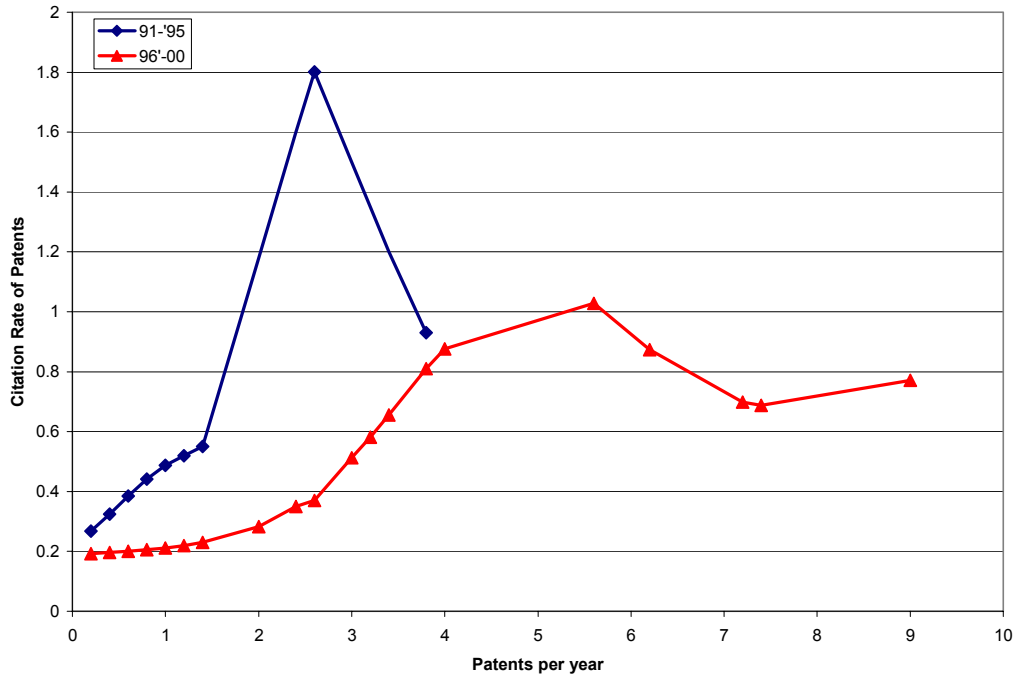


Figure 6: Article Quality and Patent Quantity

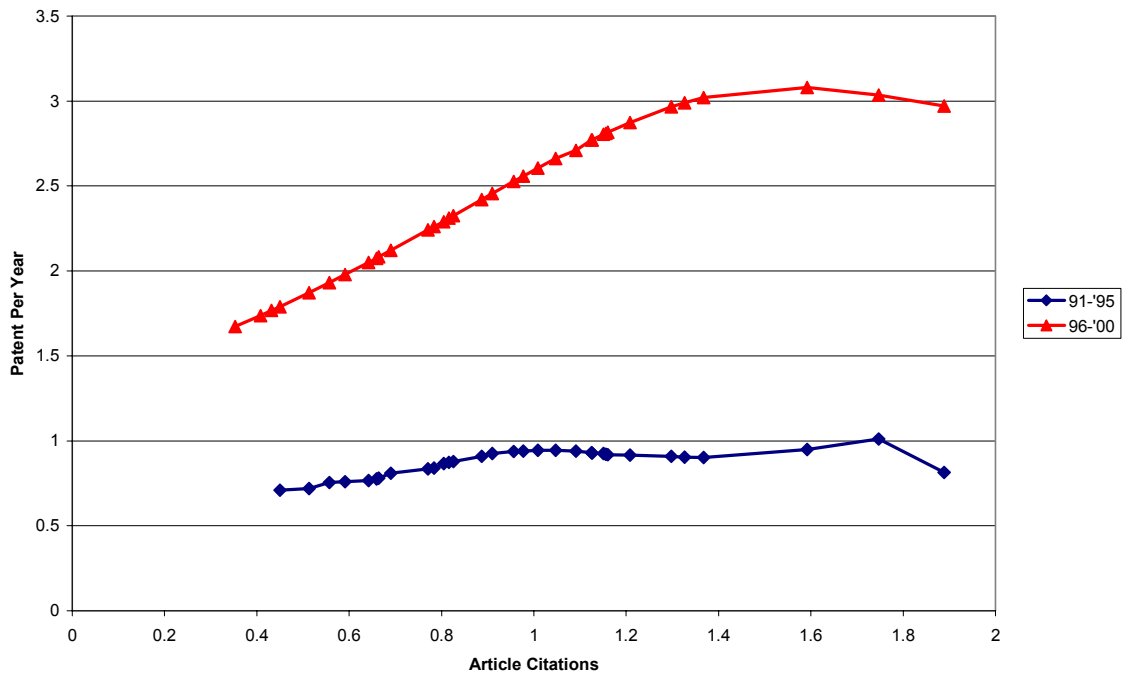


Figure 7: Patent and Article Quality

