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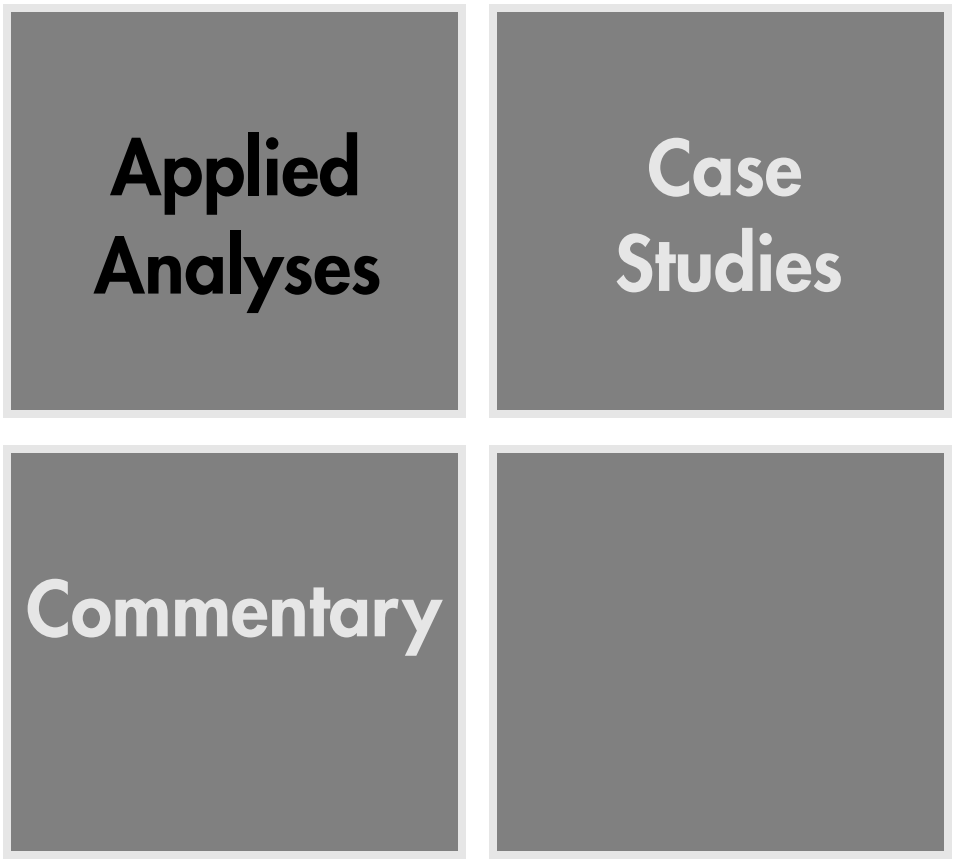

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Trends in University Ag-Biotech Patent Production

Bradford Barham, Jeremy Foltz, and Kwansoo Kim

This work exploits information on U.S. patents to identify trends in university ag-biotech patenting and citation performance. It sets forth some key issues concerning patterns of university ag-biotech patenting and then provides an empirical analysis of the evolving trends. Land grant universities account for most U.S. ag-biotech patents. The data show a path-dependent innovation pattern, in which there also seems to be a culture of patenting that develops at certain universities. Evidence shows that ag-biotech patents are more cited than the average university patent. Inequalities across land grant universities are also evident in the production of ag-biotech patents, although perhaps not to a much greater degree than underlying inequalities in funding and research qualities. The paper closes by considering how the evidence offered might be used to advance the public discussion regarding trends in agricultural biotechnology research in the United States.

Agricultural research has historically exhibited high rates of social return (Alston and Pardey), thereby bolstering the case for public support of research, especially at land grant universities. Recently, however, scholars and blue-ribbon review panels have expressed increasing concern that trends toward more patenting, especially in agricultural biotechnology (ag-biotech) are part of a privatization of publicly sponsored agricultural research. A vigorous policy debate and many recent publications including a report by the National Association of State Universities and Land Grant Colleges, an entire issue of *AgBioForum*, and books by Fuglie and Schimmelpfennig and Wolf and Zilberman have begun to consider the effects of ag-biotech patenting on the social returns from agricultural research. This current discussion, however, lacks systematic evidence about the actual patterns of university patenting, citation, licensing, and other outcomes associated with ag-biotech research.

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This article seeks to sharpen the focus of the ongoing policy discussion by answering six key questions about ag-biotech patenting at universities: (1) What are the temporal trends in university patents, citations, and revenues from ag-biotech research? In terms of university research, are we in the midst of an ag-biotech revolution? (2) Which are the leading universities in producing ag-biotech patents, securing citations, and earning revenues? (3) Is university leadership in this arena persistent over time or subject to major changes? (4) What are the main factors that explain university ag-biotech patent production and citations of those patents? (5) Is there evidence of local business or research spillovers from ag-biotech patents and citations as there have been in the pharmaceutical side of biotechnology research? (6) Overall, is ag-biotech research likely to increase or decrease historical patterns of inequality in resources and capabilities within land grant institutions?

In this article, we draw on U.S. patent and citation data to answer these six fundamental questions. The next section describes in more detail these six questions. A third section provides a careful description of the data used for the analysis. The empirical analysis in the fourth section offers evidence on the evolving trends of university ag-biotech patenting and citations to help answer the key questions. The article closes by considering how the evidence offered can advance the public discussion on ag-biotech research in the United States.

Key Issues

In recent years, a number of key issues associated with university production of ag-biotech patents have been raised. The time is ripe for an appraisal of the data in this arena to identify what is known and what needs further investigation.

Ag-Biotech Patenting Trends

Which universities are taking the lead in ag-biotech patenting and how many patents are they producing? While public debate on the merits of ag-biotech patenting has intensified, actual data on the number of ag-biotech patents produced and who is producing them have been nonexistent. Aside from knowing who has produced how many patents are land grant universities the leaders in ag-biotech patenting or whether other types of universities (e.g., Harvard, MIT, and Stanford) are major players due to complementarities with non-agricultural biotech research? **[1]** Q1

Persistence

Does initial success in ag-biotech patenting produce the ability to do more patenting? Is there persistence in university patenting (and citations)? If this were the case, universities which did not enter the ag-biotech patent game early would find it difficult to catch up. In the literature on industry innovation, this persistence in innovation is often described as "deepening." The opposite dynamic would be a process of widening in which over time, more universities can participate in the production of ag-biotech patenting. Patterns of widening are common

when information flows easily across institutions and there are few barriers to entry. In contrast, patterns of deepening are common when there are constricted information flows and increasing returns in innovation production.

A related concern is whether the incentive to patent encourages universities and their scientists to act more like companies and withhold information from competitors rather than like the knowledge generators and sharers they have historically been. Of course, many other things besides the degree of information sharing across universities will determine persistence, including heavy investment costs in laboratories, dynamic learning in the tech transfer process, and the like. Thus, evidence of persistence, while it cannot be equated directly with problems of information flows, provides some suggestion as to whether it could be a problem.

Determinants of Patenting Success

What are the key determinants of ag-biotech patenting performance across universities? How important is the land grant effect (a history of agriculture-related research)? Does industry financing matter? Are there identifiable synergies with biology departments? How important are technology transfer offices? We augment the patent data used here with results from an econometric analysis developed in Foltz, Kim, and Barham to provide some initial answers to these questions.

University Research Spillovers

Are there significant economic spillovers from university ag-biotech patenting? While traditional agricultural research is well known to create significant spillovers both locally and nationally, the intellectual property rights associated with ag-biotech patenting create a different dynamic. At issue is who uses and who benefits from patented ag-biotech innovations. Citation data offer evidence on the relative levels of usage of university patents in other patents from the same university, U.S. companies, other universities, and foreign companies. Work by Jaffe, Trajtenberg, and Fogarty has also shown a significant correlation between patent citations and the economic and technological importance of patents.

Local Spillovers

Does university ag-biotech patenting produce spillovers that are locally appropriated within a state's economy or is the research a national public good? Studies of pharmaceutical biotech (e.g., Audretsch and Stephan; Zucker, Darby, and Brewer) find evidence that university research has generated industry clusters concentrated around major research universities due to knowledge spillovers into local companies, as well as the creation of start-up companies based on university technology. Recent work on ag-biotech (e.g., Foltz, Barham and Kim; Zilberman, Yarkin, and Heiman) has tended to presume that ag-biotech research will produce a strong pattern of local spillovers from universities.

Many states have started to invest heavily in promoting ag-biotech research capacity in order to take advantage of these perceived agglomeration economies or local spillovers. In the case of ag-biotech, the technology may have national or

international rather than local adoption patterns and be produced by dominant global firms, thus undercutting in two ways the logic of public investment in university research for the purpose of generating local economic spillovers. The citations data used here offer preliminary evidence on the geography of economic spillovers from ag-biotech patenting by addressing whether university ag-biotech patents foster more ag-biotech research by in-state companies or out-of-state companies.

Inequality

Does ag-biotech patenting generate inequalities among universities? One of the arguments for allowing universities to patent their innovations is the incentive provided by the potential for revenues from those patents. Some observers (e.g., Oehmke et al.) have expressed concern that ag-biotech patenting may become a lucrative revenue stream only available to the larger, more research-oriented land grant universities, leaving smaller universities at a disadvantage in this and other arenas. The patent data are used to provide evidence of the levels of inequality of patent production, which is then compared with levels of inequalities in graduate student enrollments and agricultural research funding. Citation data also provide a crude measure of the extent of inequality in the quality of ag-biotech research.[1]

Data on Ag-Biotech Patenting

The patent data used here come from a search of the U.S. Patent Office database for university-owned agricultural biotechnological utility patents.[2] 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) extensively uses a product produced on a farm; (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 nonagricultural product; or (iv) any vaccine or vaccine technique or disease diagnostic technique that is intended primarily for use in humans, or human diseases, or on diseases not currently treated in animals. The database does include utility patents on plants intended only for ornamentation as long as they fit the definition of biotechnology.

The search yielded 795 ag-biotech patents owned by 107 different universities as of the summer of 2000. It is worth noting that patents represent only a small component of the research output of universities. Thus, the ag-biotech patent numbers are not meant to represent overall university ag-biotech research output. They do, however, provide an accurate measure of the intellectual property rights owned by a university in ag-biotech and are likely in most cases to be strongly correlated with overall research production in this arena.

The patent data were then used to search for citations. Studies of patent citations have shown that they provide a reasonable proxy for the quality of a patent and

knowledge spillovers from it, because new patents that use a piece of research from another patent must cite the previous patent (Henderson, Jaffe, and Trajtenberg; Jaffe, Trajtenberg and Henderson).[3] Thus, at a minimum, a patent citation indicates a knowledge spillover (either direct or indirect) and often suggests that some royalties or licensing revenues are being or will later be paid.

The U.S. Patent Office database was searched for citations on each of the identified university ag-biotech patents. Citing patents were then retrieved to check whether the citation was by the same authors, or by a U.S. university, business, or foreign entity. The citation was also checked to identify whether either the authors or the assignee (university or company) of the citing patent was registered in the same state as the original patent owner. One can thus distinguish between different types of in-state citations: those made by the same researchers, those assigned to the same university with different authors, those assigned to a business in-state or business patents with in-state inventors, and those assigned to another university in-state. The last category has very few observations.

Empirical Evidence

Key Trends in U.S. University Ag-Biotech Patent Production

Judging by the recent explosion of accepted patents among U.S. land grant universities, the long-touted ag-biotech revolution is underway. The number of U.S. university-owned ag-biotech patents accelerated gradually from around 10 granted per year at the outset of the 1980s to around 25 per year in the early 1990s (figure 1).[4] The takeoff year was 1996, when the 78 patents granted

Figure 1. University ag-biotech patent production

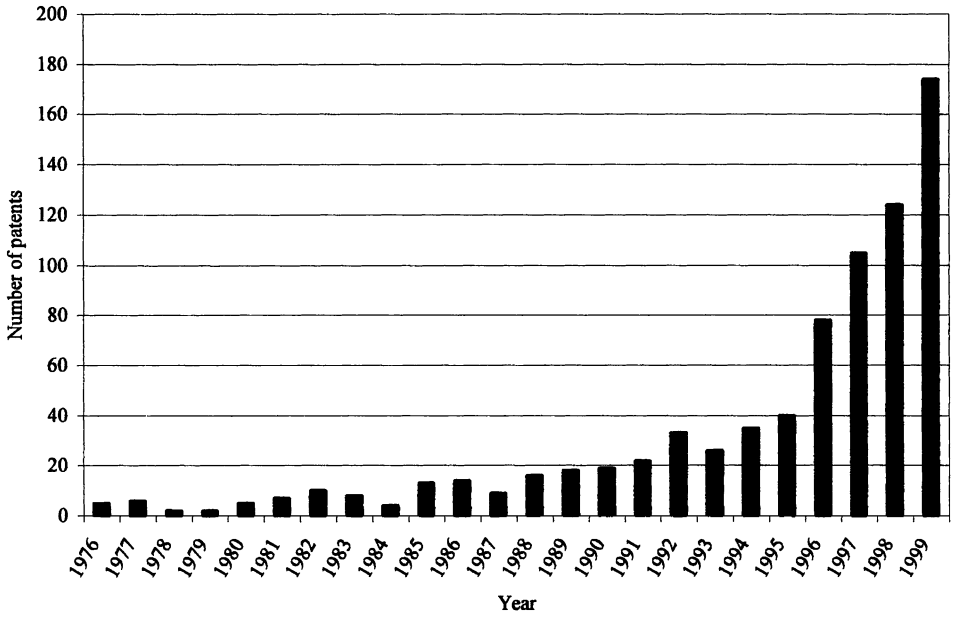


Table 1. University ag-biotech patent rankings

Rank 2000	University	Stock of Patents in 2000	Production of Patents, 1996–2000	Production of Patents, 1976–1995	Rank 1995
1	U. of Wisconsin	53	24	29	1
2	Cornell	52	31	21	2
3	Iowa State	47	36	11	5
4	Michigan State	44	37	7	12
5	UC–Davis	32	25	7	12
6	U. of Florida	29	15	14	3
7	Purdue	26	13	13	4
7	U. of Minnesota	26	19	7	12
9	Louisiana State	24	16	8	9
10	North Carolina State	21	11	10	7
11	Texas A&M	19	14	5	22
11	UC–Berkeley	19	8	11	6
13	Rutgers	18	14	4	24
14	U. of Georgia	17	9	8	9
15	Oregon State	14	4	10	8
16	U. of Maryland	13	5	8	9
16	U. of Pennsylvania	13	13	—	—
18	U. of Kentucky	12	10	2	40
19	Ohio State	11	4	7	12
19	Penn State	11	10	1	53
	Total	795	501	294	

represented nearly a doubling of the previous year's output. Since then, each year has given rise to over 100 ag-biotech patents and a further doubling over between 1996 and 1999. Thus, between 1995 and 2000, the 501 patents secured by U.S. universities exceeded their cumulative total of 294 during the previous 20 years of ag-biotech patenting.

Who Are the Leaders?

The first two columns of table 1 show that the top 20 universities, ranked by accepted ag-biotech patents between 1976 and 2000, are all public land grant institutions with agricultural colleges, with the exception of the University of Pennsylvania (#17).[5] As of the summer of 2000, the top five ag-biotech patent holding universities were the University of Wisconsin with 53, Cornell with 52, Iowa State with 47, Michigan State with 44, and the University of California at Davis with 32. The next five universities, University of Florida, Purdue, University of Minnesota, Louisiana State, and North Carolina State have more than 20 ag-biotech patents, and the 11th–20th all have, as it turns out, between 11 and 19 ag-biotech patents. Overall, ag-biotech patent holdings among U.S. universities are moderately concentrated. The top five holders have 29% of the total

number of patents, the top 10 have 45%, and the top 20 have 63%. Public land grant institutions that hold 84% of the total issued in the past 25 years dominate ag-biotech patent holdings among U.S. universities.

Persistence

Using 1996 as the takeoff year, we divided the sample into a ranking for the whole period and one for the pre-takeoff period up to 1995. Over time, these ag-biotech patent production rankings show strong signs of persistence within the top 20, with a few notable changes occurring within the top 20. Table 1 illustrates this persistence by comparing the top ranked ag-biotech patent holders during the 1976–1995 period with those of the 1996–2000 period. The table shows a number of key features:

1. There was minimal entry into the cohort of top patenting universities in the post-1995 takeoff period. In particular, 13 of the top 15 patent-holding universities in 1995 were among the top 20 patent producers between 1996 and 2000, including all of the top 7 and 8 of the top 10.
2. Two universities that became major producers after 1995, Texas A&M and Rutgers University (at #11 and #13), were ranked #22 and #24 in 1995. The University of Pennsylvania was the only "new entrant" in ag-biotech patent production to break into the top 20.
3. Despite the overall persistence, some universities greatly increased their patent holdings between 1995 and 2000. For example, Michigan State and the University of California–Davis became patent leaders by producing more than three times as many ag-biotech patents between 1996 and 2000 as they owned in 1995.

Determinants of Patenting Success

This subsection summarizes the major determinants of successful patent production using results from a dynamic count model reported in Foltz, Kim, and Barham. The count data model results show significant dynamic feedback effects from knowledge accumulation in the patenting process, which may help explain the persistence in university ag-biotech patent production described above. The results also find university-specific effects in which the overall propensity of technology transfer offices to patent all research influences the production of ag-biotech patents. These findings suggest the existence of important learning costs for universities that are not yet active in ag-biotech patenting.

As expected, the estimates also show strong evidence of a land grant effect in which labor quality and federal and state funding in agricultural research are major determinants of ag-biotech patent production. In addition, the results suggest that funding in the biological sciences may spill into ag-biotech patenting. The econometric estimates, however, do not reveal strong linkages between ag-biotech patent production and levels of industry funding. In other words, industry funding does not seem to have contributed significantly to patent production in university ag-biotech research.

Citations: Quality, Spillovers, and Local Spillovers

Quality

Patent citation data can be used to construct a measure capturing the importance of the invention conveyed by a patent. Notice that this approach requires an implicit view of technology as an evolutionary process, in which the significance of a particular invention can be evaluated by the degree of its impacts on future inventions. For example, a citation of Patent X by Patent Y means that X possesses a piece of knowledge upon which Y invented, thus indicating the significance of X in stimulating and facilitating the invention of Y.

Following Henderson, Jaffe, and Trajtenberg, we define a citation-based importance measure by total citations received. The number of total citations per patent (mean citations) varies approximately between 2 and 12 per year (figure 2). The higher citation numbers correspond to the middle and late 1980s and lower numbers to the later periods of our data. The recent drop-off probably represents a data artifact rather than an actual trend toward lower citation levels. The first citations of a patent typically appear at least 3 years after a patent has been granted, so that recent ag-biotech patents would show, on average, fewer citations.

About 45 percent of the patents had received at least one citation by the summer of 2000, which is lower than the percentage (about 70–90%) reported in Jaffe, Trajtenberg, and Henderson for their sample of all university patents. However, since more than half of the ag-biotech patents were granted in the late 1990s, a more appropriate comparison is with the pre-1996 data, of which 83% had at least one citation. The mean number of citations received per patent over all data periods is 2.75. Again truncating our sample at 1996, however, the mean number of citations

Figure 2. Average citations per patent

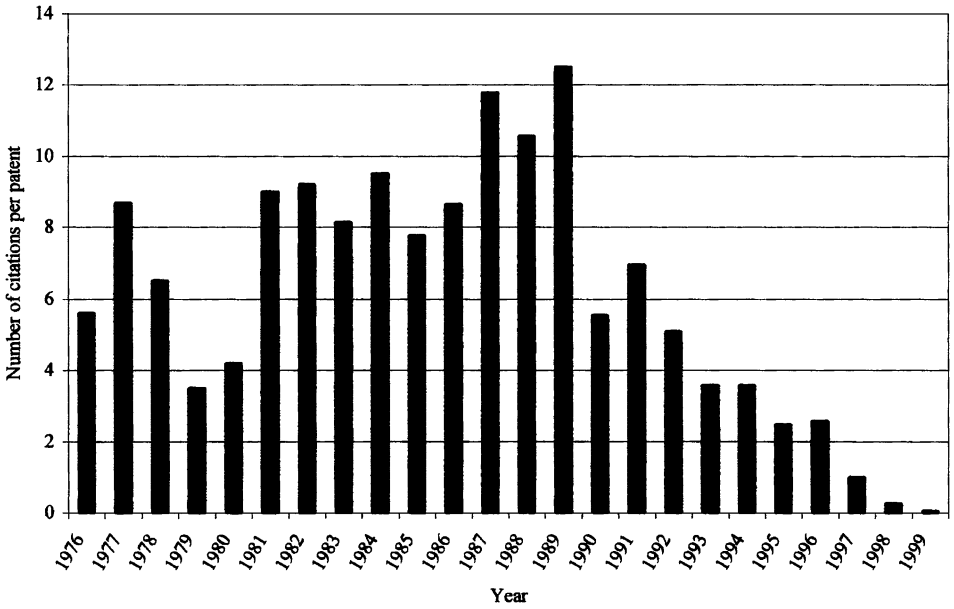


Table 2. Citations by the top 20 patenting universities

	Total Citations		Business		Universities		Foreign	
University	**No.**	**Rank**	**No.**	**%**	**No.**	**%**	**No.**	**%**
U. of Wisconsin	186	1	93	50.0	74	39.8	15	8.1
Cornell	101	6	51	50.5	26	25.7	17	16.8
Iowa State	124	5	74	59.7	30	24.2	11	8.9
Michigan State	37	19	18	48.6	13	35.1	4	10.8
UC–Davis	47	14	13	27.7	14	29.8	19	40.4
U. of Florida	81	8	51	63.0	20	24.7	9	11.1
Purdue	76	9	44	57.9	14	18.4	15	19.7
U. of Minnesota	51	12	30	58.8	13	25.5	6	11.8
Louisiana State	37	20	13	35.1	20	54.1	4	10.8
North Carolina State	43	17	11	25.6	19	44.2	12	27.9
Texas A&M	45	16	23	51.1	19	42.2	3	6.7
UC–Berkeley	82	7	46	56.1	14	17.1	15	18.3
Rutgers	75	10	72	96.0	0	0.0	1	1.3
U. of Georgia	33	23	14	42.4	6	18.2	11	33.3
Oregon State	51	13	23	45.1	10	19.6	14	27.5
U. of Maryland	24	28	10	41.7	8	33.3	4	16.7
U. of Pennsylvania	3	63	1	33.3	1	33.3	0	0.0
U. of Kentucky	12	36	5	41.7	5	41.7	1	8.3
Ohio State	136	4	60	44.1	33	24.3	30	22.1
Penn State	5	55	1	20.0	1	20.0	3	60.0
Total	2,188		1,142	52.2	567	25.9	336	15.4

reaches 7.13.[6] This compares favorably to 6.12 for 1975 and 4.34 for 1980, found by Jaffe, Trajtenberg, and Henderson for all university patents, suggesting that ag-biotech patents by this measure may be more important research innovations than the average university patent. Since most of these are still young patents, more citations of these ag-biotech patents can be expected in the near future.

Table 2 presents the total number of citations and a ranking of these universities by the number of citations for the top 20 ag-biotech patent-producing universities in 2000. Overall, the number of patents and the number of citations are positively correlated, with the top 20 universities, responsible for 63% of the patents, receiving 56% of the citations. Fifteen of the top 20 patent producers are also among the top 20 in total citations. The top three universities in terms of patents are also among the top six in terms of citations.

Although the numbers of citations and patents are correlated, some universities hold relatively few ag-biotech patents that have nonetheless been heavily cited. For example, Ohio University has 142 citations from 5 ag-biotech patents and Harvard University has 139 citations from 4 patents. To the extent that these heavily cited patents are associated with revenues or other benefits for the universities involved, these "winners" suggest that ag-biotech patenting can generate large returns from relatively few patents.

The data also show that universities producing more ag-biotech patents are not receiving higher rates of citation of those patents than universities producing lower numbers of patents. Indeed, estimates of the correlation of citations per patent and number of patents by a university were marginally negative (−0.07) for both the full and the pre-1996 samples and not significantly different from zero for either one. This suggests that, as measured by citations, there are no synergies between quantity and quality in ag-biotech patenting.

Spillovers

Investigating the data on who cites university ag-biotech patents may uncover evidence about the knowledge and economic spillover effects from university innovation. The data, however, only examine the group of "spillovers accompanied by citations," even though some citations can occur without producing either knowledge or economic spillovers and some spillovers can occur without generating a citation.[7] More than half of the citations were made by businesses (table 2). Universities accounted for about a quarter of the citations, followed by foreign assignees (both universities and businesses).[8] The residual category, not shown, is patents by individual unaffiliated inventors. Most of the top 20 producing universities had their ag-biotech patents cited at about the same rate by businesses, universities, and foreign inventors. The major exceptions are Rutgers University, where 96% of the citing patents were owned by businesses, and Penn State, where 60% of the citing patents were from foreign sources.

Local Spillovers

The proportions of these business citations that are localized in the same state as the university are shown in table 3. Overall, the in-state business citations represent only 6.8% of all citations and 13% of the business citations. This demonstrates very low levels of in-state business citations, especially when Iowa State accounts for more than one-third of the in-state citations. Iowa State's high level of localization reflects a very strong relationship between Pioneer Hybrid Seed Company and Iowa State University, rather than citations by start-up businesses.

Overall, the evidence suggests that while strong links exist between university ag-biotech patents and businesses, the degree of localization of those links has been quite small. These data are by no means definitive because ag-biotech patenting has recently taken off. However, they do suggest that ag-biotech is not yet following the same pattern of agglomeration effects seen in pharmaceutical biotechnology. To date, there seem to be relatively little new patentable research fostered in the proximate neighborhoods of land grant universities. Instead, significant local business spillovers seem to take place where universities happen to be located in the same state as major agribusiness companies (e.g., Pioneer in Iowa, and J. R. Simplot in Idaho) rather than vice versa. The recent takeoff in ag-biotech patents, however, could possibly give rise to a distinctive pattern of citations by local businesses, as the technology enters a second wave of commercial development. Thus, more definitive answers to confirm the low degree of spillover localization found so far will require either more time to be revealed in the pattern of citations or university-level data on current start-up efforts.

Table 3. Localization of business citations

	Business					
	Out of State		In State		Total	
University	No.	%	No.	%	No.	%
U. of Wisconsin	83	44.6	10	5.4	93	50.0
Cornell	46	45.5	5	5.0	51	50.5
Iowa State	21	16.9	53	42.7	74	59.7
Michigan State	18	48.6	0	0.0	18	48.6
UC–Davis	6	12.8	7	14.9	13	27.7
U. of Florida	49	60.5	2	2.5	51	63.0
Purdue	44	57.9	0	0.0	44	57.9
U. of Minnesota	27	52.9	3	5.9	30	58.8
Louisiana State	12	32.4	1	2.7	13	35.1
North Carolina State	9	20.9	2	4.7	11	25.6
Texas A&M	21	46.7	2	4.4	23	51.1
UC–Berkeley	37	45.1	9	11.0	46	56.1
Rutgers	72	96.0	0	0.0	72	96.0
U. of Georgia	14	42.4	0	0.0	14	42.4
Oregon State	22	43.1	1	2.0	23	45.1
U. of Maryland	9	37.5	1	4.2	10	41.7
U. of Pennsylvania	0	0.0	1	33.3	1	33.3
U. of Kentucky	5	41.7	0	0.0	5	41.7
Ohio State	59	43.4	1	0.7	60	44.1
Penn State	1	20.0	0	0.0	1	20.0
Total	993	45.4	149	6.8	1142	52.2

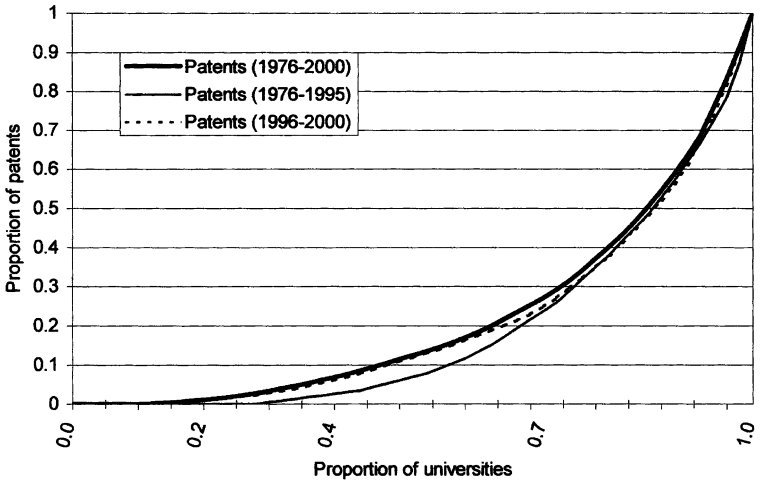
Inequality in Patent Production: A Lorenz Curve Analysis

The inequality analysis uses Lorenz curves, restricting the sample to land grant universities, because including universities that did not engage in any agricultural research would overstate levels of inequality. Figure 3 presents Lorenz curves for university ag-biotech patenting comparing the period up until 1995 with the last 4 years **[2]**. These curves exhibit considerable inequality with, for the full timeline, the top 10% of universities owning more than 35% of the patents and the top 20% owning almost 60%. While patenting in the last 4 years **[2]** has become mildly less concentrated as university participation widens, the top universities still own a disproportionate number of ag-biotech patents.

Q2

In figure 4, citation counts are examined in an attempt to adjust the patents for quality differences. These data show higher degrees of inequality, with even higher levels of inequality for recent patents. This finding suggests that the differences in patent quality are higher than those for measures of total patents. If that quality difference also showed up in variations in patenting revenues, one could expect to see increasing differences in university funding levels generated by patent production. This concern, however, can be partially tempered by our finding of no correlation between patent quantities and qualities.

Figure 3. Lorenz Curves for ag-biotech patents at land grant universities



Finally, figure 5 compares Lorenz curves for ag-biotech patenting to ones for agricultural college funding and numbers of graduate students in agricultural sciences. The figure shows that ag-biotech patenting has been more unequally distributed among universities than either overall agricultural science funding or graduate student numbers. However, these differences between patenting and financing are not large. Whether they will persist is also unclear, especially if the recent widening in patent production continues. While not definitive, the

Figure 4. Lorenz Curves for citations received in land grant universities

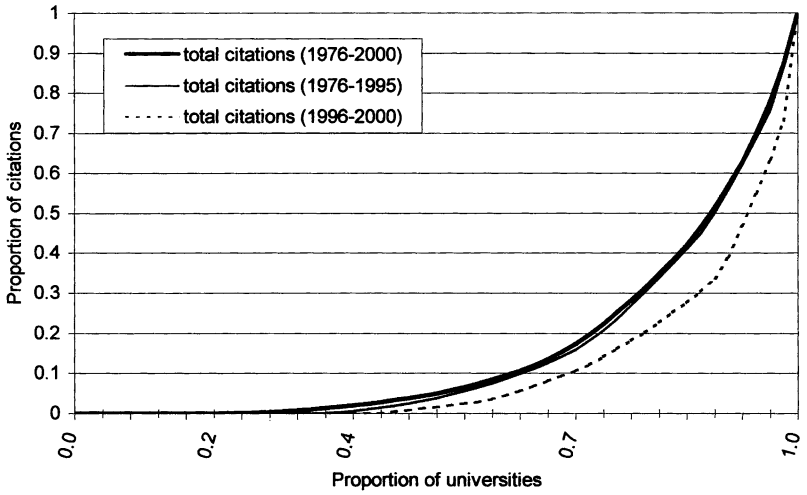
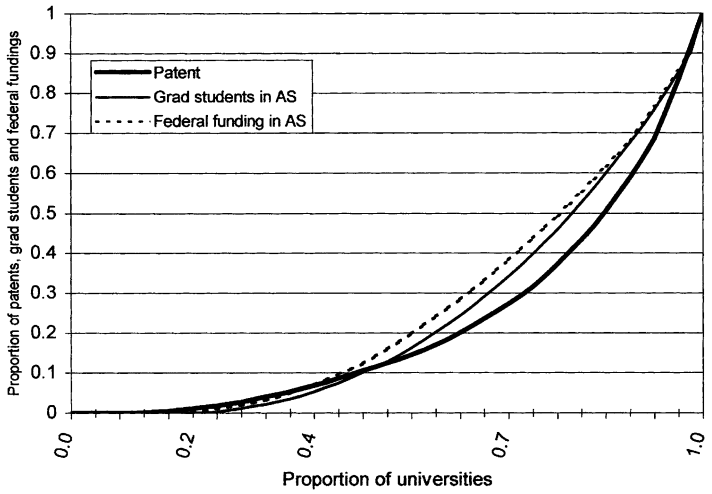


Figure 5. Lorenz Curves for ag-biotech patents, agricultural graduate students and federal funding in agriculture among land grant universities. Data on agricultural graduate students and federal financing in agriculture come from the National Science Foundation



evidence so far suggests that university ag-biotech patenting at the very least is not diminishing inequality among land grant universities and, if the imbalance in citations turns out to reflect revenue streams from ag-biotech research, may be increasing it.

Concluding Remarks

The last decade has seen a tremendous growth in university ag-biotech patenting fostered by new investments at land grant universities in ag-biotech research personnel, labs, and infrastructure. The year 1995 marks a takeoff point from which ag-biotech patent production at U.S. universities has doubled twice over a 4-year period. National policy makers should be heartened by the recent takeoff in university ag-biotech patenting, the high quality of the patents, and the national public goods nature of the patents. While it is still too early to judge economic returns to these patents, the high citation rates may suggest that they are relatively more important for the research community than the average university patent.

This ag-biotech patent production analysis also suggests some causes for concern. There is strong evidence of persistence in ag-biotech patent production and concentration of patents and citations among the major land grant universities. If current and future revenue streams associated with ag-biotech patents and citations prove to be significant, their concentration among a few key universities suggests the potential for further deepening of existing inequalities between major and minor land grant universities.

In terms of the potential spillover effects of ag-biotech patents, the citation data show that, while strong links exist between university ag-biotech patents

and businesses, the degree of localization may be quite small. In contrast to the computer and pharmaceutical industries, where local start-ups are major users of university technologies, major international firms are the main businesses citing university ag-biotech patents. While not definitive, our research suggests that university ag-biotech patents have not yet generated significant local spillovers, at least as measured by citations of patents.

Two of these concerns, persistence and inequality, are mitigated by the near zero correlation between the quantity of patents held by a university and the importance of those patents as measured by citations. In other words, there seems to be an equal chance that a given patent will turn out to be a major discovery regardless of whether a university is a major or minor participant in ag-biotech patenting. This suggests that patents are much like lotteries, where the probability of winning goes up with the number of tickets held but not the probability of any given ticket being a winner.

This analysis of U.S. patent data has offered preliminary evidence on several pressing questions in university ag-biotech patenting, but more research and data are needed. First, in focusing on patents, this inquiry has ignored the value of other ag-biotech research output, such as published papers, conference presentations, improved technical infrastructure, and a community of informed and skilled researchers and students. Second, while this work has used citations as a measure of quality, future research could improve on patent and citation measures with data on licensing revenues and university involvement in start-up companies. Finally, it remains to be seen to what extent commercial motives, either through direct industry financing or through the promise of patent revenues, influence the research at land grant universities to be more applied and aimed at patents rather than toward basic fundamental research. Future research investigating these issues would help further the ongoing discussion on the social returns associated with university ag-biotech patent production.

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Endnotes

[1] While revenue data are not available, it may be too early in ag-biotech patent production for it to be an accurate measure of value. Given the usual lag between patents and commercial development and the dramatic growth in patents in the last 4 years, it is likely that revenues from these patents are still relatively low in most universities.

[2] 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.

[3] As suggested by a reviewer, citations represent a crude measure of quality because attorneys may overuse citations as a way of indemnifying patents from litigation rather than as accurate reflections of prior art used in a patent.

[4] Patents are dated by the year of grant rather than the application year used in studies by Foltz, Kim, and Barham and Henderson, Jaffe, and Trajtenberg, which date patents by application year to reduce time lags between research completion and the patent date.

[5] Cornell University is both a public and private institution, but the agricultural college is a land grant institution and part of the public component of the institution.

[6] Although the five most cited patents account for one-fifth of the total citations, the distribution of citations by patent is fairly compact: 42% of the patents have more than 5 citations, and only 15% have more than 10 citations.

[7] For details on issues relating to the use of citation data to infer knowledge spillovers see Jaffe, Trajtenberg, and Fogarty and Jaffe, Trajtenberg, and Henderson.

[8] Note that university citations include 274 self-citations, in which the citing patent is assigned to the same university as the originating patent.

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Queries

Q1: Please check sentence for sense.
Q2: Article is being published in 2002. If you do not mean 1997 to 2001 please insert dates instead of "last 4 years."
Q3: Any update?