

# **What is Different About Ag-Biotech? An Investigation of University Agricultural Patenting**

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## **Abstract**

This work seeks to understand the differences in patenting between agricultural biotechnology and other agricultural technologies. It seeks to answer the question: is ag-biotech different from other agricultural research in terms of patent production or patent quality? It does so by estimating count data models of the difference (if any) between ag-biotech patents and ag-tech patents as measured by (i) different parameters in their production functions and (ii) different levels of patent quality as measured by numbers of citations of those patents. The evidence presented here suggests that a lot more similarities than differences exist between the two types of university patents.

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Dire predictions in the popular and scientific press have been made about an increased commercialization of university research agendas due to the adverse incentive effects of industry funding and intellectual property rights (e.g. Brown, 2000; Harvey, 2000). Colleges of agriculture in the US are especially vulnerable to this critique because of their traditional role providing public goods in research (ESCOP, 2000). The growth in university patenting has happened at the same time as the agricultural biotechnology revolution. While new agricultural biotechnologies, ag-biotech, have received a lot of press about how they are changing the paradigms of university research they still represent only a small part of the research output of agricultural colleges. Ag-biotech is often seen as being different than other university agricultural technology research, “ag-tech,” because of it having intellectual property rights, more industry linkages, and being more commercially oriented. It is, however, possible that some of the effects attributed to ag-biotech are actually part of an overall pattern of agricultural patenting growth at universities rather than something specific about ag-biotech.

This work seeks to understand the differences in patenting between ag-biotech and other agricultural technologies, ag-tech. It seeks to answer the question: is ag-biotech different from other agricultural research in terms of patent production or patent quality? It does so by estimating the difference (if any) between ag-biotech patents and ag-tech patents as measured by (i) different parameters in their production functions and (ii) different levels of patent quality as measured by numbers of citations of those patents.

A first model, estimated in this paper, uses a panel count data technique to estimate a production function for each type of patent (ag-biotech and ag-tech) using the same independent variables and then performs statistical tests (both jointly and individually) on differences in parameters between the two patent types. In this case each observation in each equation represents a university during a particular year and the dependent variable counts the number of patents, either ag-biotech or ag-tech. Independent variables describe inputs in the university patent production function (faculty, financing, and tech transfer personnel).

The second model in this paper estimates an equation describing patent quality as measured by the number of citations. In this case each observation is an individual patent at a single university in a single year and the dependent variable is the number of citations of that patent since it was granted. Under an assumption of independent observations, this equation is estimated as a single period count data model. The key independent variables of interest denote whether the patent is an ag-biotech patent or an ag-tech patent.

The remainder of this paper is organized as follows. Section 2 describes the state of the literature. Section 3 develops a basic model of university patenting following Foltz, Kim, and Barham and uses that to inform two econometric models: a patent production function and a patent quality function. Section 4 describes the data. Section 5 provides an overview of trends in ag-biotech and ag-tech patenting at universities. Section 5 discusses the results of the econometric estimates, which is followed by a conclusion in Section 6.

## ***II. State of the Literature***

The growth in university agricultural patenting so far has dramatically outpaced economic analyses of the degree and effects of patenting at the university level. The classic work on university research, Jaffe (1989), finds an association between industry R&D and university research. Jaffe also finds suggestive evidence that university research promotes industry R&D rather than vice-versa. In agriculture, the seminal studies of the social returns to agricultural research and development (Alston and Pardey, 1995; Just and Huffman, 1992) essentially predated the mid-1990s take-off in agricultural patenting. Those studies do not explicitly incorporate either the potential positive or normative effects of agricultural patenting on agricultural productivity or the broader economy.

Evidence from the economics literature, e.g. Henderson, Jaffe, and Trajtenberg (1998) suggests that increases in the economic incentives for universities to produce patents, specifically the Bayh-dole act of the mid 1980's, lowers the quality of patentable research output. Thus, while perhaps not as dire as the worries in the popular press, it is reasonable to assume that intellectual property rights will change the quality and types of research in agriculture.

Recent literature on ag-biotech has pointed out that differences in property rights and industry market structure imply that ag-biotech deviates from the standard models of innovation in agriculture. Moschini and Lapan (1997) show that conventional measures of welfare will over estimate the impacts of agricultural R&D when intellectual property rights are established over those innovations. Zilberman et al. (1997) see public research and extension as essential to assuring competition in the ag-biotech industry and access to genetic materials and techniques. A recent flurry of research (see for example papers in the conference volumes: Santaniello, et al. 2000; and Evenson, et al. 2000) has started the process of evaluating public and private incentives of agricultural research with intellectual property rights with a focus on ag-biotech. Other recent papers have developed the theory of public/private interactions (e.g. Hall, Link, and Scott, 2000; Rausser, Simon, and Ameden 2000, 1999) and the economics of intellectual property rights in agricultural in general (e.g. Evenson, 2000). As yet, no study has analyzed all types of university agricultural patenting.

Foltz, Kim, and Barham (2000) take a step in that direction by using a reduced form model to analyze the factors that account for ag-biotech patenting success among universities. Their approach builds on Blundell, Griffiths, and Van Reenen (1995) to capture the inherently dynamic and nonlinear process of technological innovation using a dynamic count model, wherein a feedback mechanism between previous success in innovation (patent production) is incorporated explicitly into the modeling structure. They find important dynamic effects as well as the importance of technology transfer efficiency in ag-biotech patenting.

### ***III. A Framework for Patent Production and Quality Ag-Biotech versus Ag-Tech***

The first focus of this paper is to estimate a reduced form model of the determinants of agricultural patent production. This is a special case of the agricultural knowledge function of the type estimated by Pardey (1989). The standard departure point in the literature (e.g. Hausman, Hall, and Griliches; Blundell, Griffiths, and Van Reenen, 1999) is a patent production equation of the form

$$Y_{it} = f(x_{it}, u_{it}) \text{ for } i = 1, \dots, N \text{ and } t = 1, \dots, T, \quad (1)$$

where  $Y_{it}$  is a count of patents produced and  $x_{it}$  is a vector of the characteristics of university  $i$  and general conditions outside the university that influence the process (e.g. government policy). The term  $u_{it}$  represents unobservable university differences. Let the relationship between patents produced,  $y_{it}$ , and university characteristics,  $x_{it}$ , be thought of as the outcome of both a research,  $R_{it}$ , and a patenting process,  $H_{it}$ . The research process involves inputs into the production of knowledge, often independent of economic considerations, while the patenting process will be an explicit function of the potential value of that research as intellectual property rights and university patenting experience.

Let the overall research produced by a university,  $R_{it}$ , be described by a classic production process using labor, capital, and structures (labs, etc.) to produce research in the following fashion:

$$R_{it} = r(L_{it}, K_{it}). \quad (2)$$

In this equation labor,  $L$ , will include the number of scientists, the quality of scientists, and the quality of the research neighborhood. The research neighborhood accounts for knowledge spillovers and potential agglomeration effects. Capital,  $K$ , includes research funds from federal, state, industry, and university sources. For our purposes, one needs to note that the research process happens prior to the patent application. Typically the research leading up to a patent would take a couple of years, if not considerably longer.

By contrast, the variables influencing the patenting process, described in the equation  $H_{it}$ , will be contemporaneous to the patent application. The function describing patent development is as follows:

$$H_{it} = h(D_{it}, G_{it-1}), \quad (3)$$

where the variable  $D_{it}$  describes labor and capital inputs in the technology transfer office and  $G_{it-1}$  represents the culture and information that the university has developed in producing patents in the past, which feeds into the technology transfer process. Better technology transfer offices would likely be more able to create value out of research through their contacts.

Models of patent production typically use a count data framework (Hausman, Hall, and Griliches; Blundell, Griffiths, and Van Reenen, 1995). These models assume either a Poisson or Negative Binomial distribution on the dispersion term (Cameron and Trivedi). The first moment condition for these models is:

$$E(Y_{it}) = e^{X_{it}'\beta}, \quad (4)$$

where  $Y_{it}$  represents patents produced. Accordingly, the patent model presented in equation (4) above can be parameterized by the following linear equation:

$$X_{it}'\beta = \theta_0 + \theta_1 L_{it-1} + \theta_2 K_{it-1} + \theta_3 D_{it} + \theta_4 G_{it-1} + \eta_i + \nu_t, \quad (5)$$

where the first two variables represent parameterizations of the research process and the last two denotes the patent application process. The variables  $\eta_i$  and  $\nu_t$  denote the university and time specific unobservables, respectively. More specifically,  $L_{it-1}$  represents the labor inputs (both quantity and quality) in the research production process, and  $K_{it-1}$  measures the financial capital in the research process. All variables in the research process are lagged 2 years to account for research gestation periods. The variable  $D_{it}$  in the patent generation process represents the degree of university interest and competence in patenting innovations as evidenced by technology transfer office inputs. The last variable,  $G_{it-1}$ , represents the potential dynamic learning and perhaps financing effect from previous successful patents in the research area (see Foltz, Kim, and Barham).

Formally, the dependent count variable,  $y_{it}$ , is assumed to be *iid* negative binomial with parameters  $\alpha_i$ ,  $\lambda_{it}$  and  $\phi_i$  where we have set  $\lambda_{it} = \exp(x_{it}'\beta)$ . This gives  $y_{it}$  mean  $\alpha_i \lambda_{it} / \phi_i$  and variance  $(\alpha_i \lambda_{it} / \phi_i) * (1 + \alpha_i / \phi_i)$ . In the random effects model it is commonly assumed that the dispersion parameter,  $(1 + \alpha_i / \phi_i)^{-1}$ , will vary between groups according to a Beta distribution with parameters (a, b)<sup>1</sup>. Following Hausman, Hall, and Griliches these assumptions produce a model with the joint density for the  $i^{\text{th}}$  group as follows:

$$\Pr\{y_{i1}, \dots, y_{iT}\} = \left( \prod_t \frac{\Gamma(\lambda_{it} + y_{it})}{\Gamma(\lambda_{it})! \Gamma(y_{it} + 1)} \times \frac{\Gamma(a + b) \Gamma(a + \sum_t \lambda_{it}) \Gamma(b + \sum_t y_{it})}{\Gamma(a) \Gamma(b) \Gamma(a + b + \sum_t \lambda_{it} + \sum_t y_{it})} \right). \quad (6)$$

This formulation provides the basis for the log-likelihood function to be estimated.

### ***Patent Importance Estimation***

The second equation in this work describes patent quality as measured by the number of citations. Studies of patent citations have shown that they do provide a reasonable proxy for both quality of a patent and knowledge spillovers from it, because each time a new

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<sup>1</sup> See Cameron and Trevedi (1998) for a description of Gaussian random effects models which make the alternate assumption of a normal distribution on the dispersion parameter. Unfortunately these models do not have clean analytics, making estimation less certain. Cameron and Trevedi also develop moment based methods possible with the negative binomial model.

patent uses a piece of research from another patent it is obligated to cite the previous patent (Jaffe, Trajtenberg and Henderson; and Henderson, Jaffe, and Trajtenberg). Thus, at a minimum, a patent citation suggests a knowledge spillover (either direct or indirect) and often suggests that some royalties or licensing revenues are being or will later be paid. Trajtenberg (1990) suggests patent citations are a useful method to adjust patents for quality. Work by Jaffe, Trajtenberg, and Fogarty has shown a significant correlation between patent citations and the economic and technological importance of patents.

In this case each observation is an individual patent at a single university in a single year and the dependent variable is the number of citations of that patent since it was granted,  $C_i$ . Since each observation is independent this equation can be estimated as a single period count data model, which is a simplified version of the panel data count data model described above (See Cameron and Trivedi, 1998).<sup>2</sup>

The key independent variables of interest are variables denoting whether the patent is an ag-biotech patent or an ag-tech patent. Other independent variables include the number of years the patent has been in force  $T$ , measures of the quality of the university  $K$  and  $L$  (university funding, agricultural graduate students), measures of technology transfer inputs both quantity and quality,  $D$ . The parameterization of the count data model equation will be as follows:

$$X_i' \beta = \gamma_0 + \gamma_1 L + \gamma_2 K + \gamma_3 D + \gamma_4 G_{t-1} + \gamma_5 T_i + \gamma_6 T_i^2 + \gamma_7 A_i + \varepsilon_i \quad (7).$$

The variable,  $G_{t-1}$ , represents the potential dynamic learning and perhaps financing effect from previous successful patents in the research area.  $G_{t-1}$  is defined as the sum of the current agricultural patents owned by the university at the time the patent was granted as a measure of the previous knowledge stock that might influence the number of citations. The variable  $T_i$  and  $T_i^2$  represents the number of years and years squared that the patent has been in force. The variable  $A_i$  represents the class of patent, (e.g. food, fertilizer, animal husbandry, etc.) and whether it is ag-biotech or ag-tech. The error term  $\varepsilon_i$  is assumed to be patent specific.

Since "basic science" patents are more likely to be used as building blocks in other patents, it is expected that they would generate more citations than applied patents. The degree to which something is "basic science" cannot easily be distinguished. Therefore, a number of strategies are employed to capture this effect. One is to use the class the patent came from as a measure, under the assumption that some classes are more applied than others. In addition, the patent class information controls for differences in

<sup>2</sup> The standard negative binomial model (NB2 in Cameron and Trivedi, p.71) has density:

$$f(y | \mu, \alpha) = \frac{\Gamma(y + \alpha^{-1})}{\Gamma(y + 1)\Gamma(\alpha^{-1})} \left( \frac{\alpha^{-1}}{\alpha^{-1} + \mu} \right)^{\alpha^{-1}} \left( \frac{\mu}{\alpha^{-1} + \mu} \right)^y, \quad \alpha \geq 0, \quad y = 0, 1, 2, \dots,$$

while its log-likelihood function will have the following form:

$$\ln L(\alpha, \beta) = \sum_{i=1}^n \left\{ \left( \sum_{j=0}^{y_i-1} \ln(j + \alpha^{-1}) \right) - \ln y_i! - (y_i + \alpha^{-1}) \ln(1 + \alpha e^{x_i' \beta}) + y_i \ln \alpha + y_i x_i' \beta \right\}.$$

levels of patenting by fields. For example, there are vastly more patents granted each year in the food science category (US Class 426) than there are in the fertilizer category (US Class 71). One might expect that in a field with more patenting overall, the chances of a patent being cited by another would be greater. Another strategy employed in the estimations, uses co-ownership of patents as a measure of basic research. Patents that are co-owned by businesses (5% of the total) are expected to be more applied and therefore less cited, while patents co-owned by the USDA (2% of the total) are expected to be basic science and more cited.

#### ***IV. Data***

##### ***Patent data source***

The data divides into research output (patents) and on the inputs to the research process. A patent data search identified all ag-biotech and ag-tech utility patents owned by US universities from a search of the complete U.S. patent office database<sup>3</sup>. Among European and World patents, it is well known that U.S. patents represent the more innovative patents because of stronger property rights protection<sup>4</sup>. The appendix describes the process used to determine which patents are agricultural and biotechnological.

Using the definition in the appendix, the search chooses all ag-biotech and ag-tech patents granted after 1976 and through the end of 1999. During this time period US universities received 795 ag-biotech and 760 ag-tech patents. The patent data were then used to search for citations. A patent citation suggests a knowledge spillover (either direct or indirect) and often suggests that some royalties or licensing revenues are being or will later be paid. Thus, citations of patents represent both proxies for the quality of the research and potentially for the revenues being generated.

##### ***Input data sources***

The input data for the study have already been collected from National Science Foundation (NSF) and the Association of University Technology Managers (AUTM) databases. The inputs to the research process include labor,  $L$ , (faculty numbers, salary, agricultural graduate students), capital,  $K$ , (federal, state, and industry funding deflated to a common year), and university technology transfer input variables in the patent production process,  $D$  (number of tech transfer personnel, tech transfer efficiency: the percent of invention disclosures that end up as patent applications).

#### ***V. Descriptive Statistics:***

##### ***Patents:***

The annual number of agricultural patents issued to universities grew from 40 to 50 per year in the late 1980s, to over 150 per year in the mid to late 1990s, and appears likely to

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<sup>3</sup> The database includes only utility patents and not plant patents, which provide plant variety protection. Plant patents have lower novelty standards and provide lower levels of intellectual property rights than utility patents. For this reason, most genetically altered plants are submitted for utility patent protection and very few plant patents involve genetic alterations.

<sup>4</sup> In particular recent reticence by European governments to patent life forms have made US patents the intellectual property right of choice for protecting agricultural innovations.

continue growing at a very rapid rate. Graph 1 shows this growth in university agricultural patent production over the last 25 years. As is evident, agricultural patenting started at levels of around 20 ag-tech and 10 ag-biotech patents per year from 1976-1985. From that point, coinciding with the Bayh-Dole act, levels increased for the next decade to approximately double the level. In 1995 for the first time more ag-biotech patents were granted to US universities than ag-tech patents. From 1995 on, ag-biotech patenting has exploded while ag-tech patenting has stay relatively stable. This explosion of ag-biotech patenting might stem from the clarification of regulations and loosening of rules for field testing that took place in the early 1990's. Given the 3-5 year time lag from research beginning to patent granting, such a change in the regulatory framework would become evident in the data starting around 1995. From the graphs, it would seem that while the Bayh-Dole act has increased agricultural patenting, recent movements in ag-biotech patenting are also being driven by other forces.

Table 1 shows the top 20 universities in producing agricultural patents. All of them are major producers of both ag-biotech and ag-tech patents and all are Land Grant Universities. While Kansas State, Clemson, and Nebraska produce more than twice as many ag-tech as ag-biotech patents, most universities produce about even numbers of the two. The data shows that overall, agricultural patent holdings among U.S. universities are concentrated with the top five holders having 27% of the total number of patents, the top 10 having 42%, and the top 20 having 63%. Agricultural patent holdings among U.S. universities though dominated by public land-grant institutions, also includes such private universities as MIT and University of Pennsylvania as top 30 holders.

Table 2 shows the most frequent type of agricultural products patented by US universities. While an ag-biotech class is first on the list, patenting of food products runs a close second. The ag-tech patents are distributed among the agricultural patent classes in about the same proportion as patents owned by companies or other entities. In each class, they represent about 1% of the total patents assigned in this time period. In the ag-biotech classes, university patents represent a higher proportion of between 5 and 10%.<sup>5</sup>

### ***Citations***

Graph 2 shows the average levels of citations by year of the patent grant. Average levels of citations are 3.5 per year, though as the graph distinctly shows some years have shown much more cited patents. The graph demonstrates that almost no citations appear in the first 3 years of a patent's life, but most appear within the first decade of its existence. The most cited patent in the database has 128 citations. The citations, however, are concentrated among patents, with 40% of the patents having no citations while only 20% had more than 5 citations.

## ***VI. Econometric Estimations***

### ***Production function***

Table 4 shows the estimates of ag-biotech patent production from a maximum likelihood estimation of a random effects negative binomial model. The table presents

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<sup>5</sup> This number cannot be estimated accurately because ag-biotech patents cannot be separated from biotech patents in the overall patent data. This estimate is based on overall levels of biotech patenting.

three models: ag-biotech patents, ag-tech patents, and the two combined. Models 1 and 3 pass a likelihood ratio test of the random effects versus a pooled data model at a greater than a 99% level, while the ag-tech model is not significantly different from a pooled data model. Also, all models produce estimates of dispersion, the parameters of the beta distribution (a,b), which are significantly different from zero. The signs on the coefficients on all models are generally as expected, with the possible exception of a non-significant negative sign on industry financing in two of the models. As expected, the time dummy captures significantly lower levels of patent acceptances for applications made in 1997 and 1998, due to the short time horizon in the data.

Among the funding variables, state and own institutional funding are the only ones to have a significant effect on ag-biotech patent production. The lack of a significant effect of industry funding on ag-biotech patent production, a consistent result across all models, suggests that industry funding is not the primary driving force in university ag-biotech patent production. The positive coefficient on own institutional funding gives some evidence of the presence of a virtuous circle in ag-biotech funding since some of the own institutional funding can come from patent revenues. The estimates also demonstrate evidence of the importance of the land grant infrastructure, since one measure of this feature, agricultural science graduate students, is positive and significant. The econometric estimates, surprisingly, do not support the idea of a strong complementarity between research programs in the biological sciences and agricultural patent production and in fact suggest a negative effect. The labor variables show that average faculty salary is significantly related to university ag-biotech patent production perhaps capturing an effect of faculty quality. However, quantity of faculty fails to explain patent output.

The variables measuring university patent production efforts find a similar relationship between university patent production and labor variables in the technology transfer process. Model 2 shows the technology transfer office labor quantity variable is significant. For Models 1 and 3, the measure of technology transfer efficiency (*EFFOTT*) in turning invention disclosures into patent applications is significant and positive. The strength of this effect suggests that this efficiency in managing all invention disclosures may carry over into patent application management.

The dynamic effects formulation does give rise to a significant parameter estimate on  $G_{it}$ , and suggests a potential dynamic feedback. Consistent with the results for ag-biotech innovation reported by Foltz, Kim, and Barham, the results here show evidence of history dependence in innovation activities for all types of agricultural patents.

#### ***Testing Production Function Differences:***

The results from the ag-biotech and ag-tech patent production functions look similar to each other and to the total agricultural patent function. Only the estimated parameter for the ratio of patent applications to disclosures, *Effott*, is significantly different at a 5% level between the two types of patents. On the other hand, a likelihood ratio test of restricting the parameters between the two equations to be the same yields a  $\chi^2$  test

statistic of 208 with 15 degrees of freedom, which rejects the restricted model of all the parameters being the same at all common significance levels. Thus ag-biotech and ag-tech do seem to be produced by slightly different systems, but the regressions used here are not able to elucidate exactly how.

### **Importance function**

Table 5 shows the estimates for three negative binomial models of the importance function. In order to take into account complementary data limitations, the models use different sets of explanatory variables. The first uses the full set of 1552 patents, but only measures of patent type, co-ownership, and cumulative patenting experience as independent variables. The second model, with 905 observations, adds in variables measuring total university funding and the number of agricultural graduate students.<sup>6</sup> The third model includes measures of the office of technology transfer input in patenting, but is estimated with only 674 data points. The two smaller samples only contain observations on patents produced in the 1990's, so their results may not be as accurate.

All models produce estimates with a number of significant variables, but none find any evidence that would distinguish university ag-biotech patents from ag-tech patents. Results vary a great deal between estimates, probably due to the major differences in the number of included data points. The two consistent results are that age is a primary determinant of the number of citations a patent receives and that patents co-owned by the USDA have lower citation rates. There is no evidence that ag-biotech patents are cited any more than the average university agricultural patent. The evidence in fact points in the opposite direction, though this may be due to the young age of most ag-biotech patents. Estimates with a single ag-biotech binary variable produced similar, non-significant, results. The cumulative number of patents owned by universities has a positive coefficient, though it is only significant in Model 2 at a 10% level.

In model 2 and 3 the total university funding variable shows no significant effects. Additional estimates with funding broken down into sources, however, shows that industry financing has a significantly positive effect on the number of citations. This might suggest that universities with a more industry financing are either producing more of the types of technologies industries will use, or that the contacts they have create a greater awareness of technologies and therefore more citations. Patents co-owned by business have as expected fewer citations, though the effect is not significantly different than zero. It would seem that business influence on patentable research has relatively little measurable effect on the number of citations, and potentially therefore little influence on the quality of the research.

The addition of variables describing the technology transfer process provides relatively little explanation of levels of citations. More technology transfer personnel do have a positive influence on the number of citations, at a 10% significance level. This

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<sup>6</sup> Agricultural graduate student numbers represent a highly correlated proxy variable for agricultural college funding.

may suggest that universities with more personnel are better able to "advertise" the technologies they have, but that this effect is small.

### **Conclusions**

This work has set out to describe the differences between agricultural biotechnology patenting and the patenting of other agricultural products by universities. The evidence presented here suggests that a lot more similarities than differences exist between the two types of university patents. The significant variables in the ag-biotech and ag-tech production functions are similar, though the estimates show some subtle differences. Future research should develop estimates of these differences using improved data.

The citation estimates show no evidence that ag-biotech is more important than ag-tech, in terms of how often it is cited. Similarly there is no evidence that patents in fields with more patenting are more heavily cited than patents in fields with fewer patents. The lower citation levels of patents jointly owned by USDA remains a puzzle. Since none of those patents are at the major patent producing universities, it may be a function of the best universities having technology transfer personnel who can effectively exclude USDA ownership. If that were the case only mediocre patents from universities with mediocre technology transfer personnel would have joint ownership.

In sum, these results suggest that future research on agricultural patenting at universities should focus less on ag-biotech and more on all types of university agricultural research. The focus on ag-biotech recently may have blinded researchers and, perhaps, administrators to the potential of standard agricultural technologies as compared to agricultural biotechnology.

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*Appendix*  
**Defining Agricultural and Ag-biotech Patents**

In order to establish an appropriate agriculture patent database we use a consistent definition that says that agriculture:

- (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 aqua-culture product.

We add to that a definition of biotech:

- (4) that it contains some genetically altered material (US patent classes 435, 800, 935)

Note that the above definition includes a large number of patents that might not be specific to agriculture. However, the search strategy also excludes from our definition of ag-biotech products or processes with no direct connection to agriculture. Those excluded include:

- (1) any animals or plants produced entirely for research purposes (e.g., mice, rats, monkeys);
- (2) any animal primarily designed as a pet: e.g. dogs and cats;
- (3) any product that merely uses animal or plant cells in minor quantities for a non-agricultural product; or
- (4) 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.

The database does include patents on plants intended only for ornamentation.

**Table 1**  
**Top 20 Universities Producing Agricultural Patents**

| University                     | All Agricultural Patents | Ag-Biotech | Ag-Tech |
|--------------------------------|--------------------------|------------|---------|
| Cornell Univ.                  | 105                      | 52         | 53      |
| Iowa State Univ.               | 90                       | 47         | 43      |
| Univ. of Wisconsin-Madison     | 84                       | 53         | 31      |
| Michigan State University      | 75                       | 44         | 31      |
| University of California-Davis | 59                       | 32         | 27      |
| North Carolina State Univ.     | 57                       | 21         | 36      |
| Purdue Univ.                   | 49                       | 26         | 23      |
| Univ. of Florida               | 49                       | 29         | 20      |
| Louisiana State Univ.          | 45                       | 24         | 21      |
| Texas A&M Univ.                | 45                       | 19         | 26      |
| Univ. of Minnesota             | 44                       | 26         | 18      |
| Kansas State Univ.             | 43                       | 9          | 34      |
| Rutgers Univ.                  | 32                       | 18         | 14      |
| Univ. of California-Berkeley   | 29                       | 19         | 10      |
| Univ. of Georgia               | 28                       | 17         | 11      |
| Univ. of Texas at Austin       | 25                       | 9          | 16      |
| Oregon State Univ.             | 24                       | 14         | 10      |
| Washington State Univ.         | 23                       | 11         | 12      |
| Clemson Univ.                  | 21                       | 6          | 15      |
| Univ. of Kentucky              | 21                       | 12         | 9       |
| Univ. of Nebraska-Lincoln      | 21                       | 7          | 14      |

**Table 2**  
**Classifications of Major University Agricultural Patents**

| US Patent Class | Class Description  | University Owned Agricultural Patents |
|-----------------|--|---------------------------------------|
| 435             | Chemistry: Molecular Biology and Microbiology (ag-biotech)   | 303                                   |
| 426             | Food or Edible Material: Processes, Compositions, and Products <sup>7</sup>  | 274                                   |
| 800             | Multicellular Living Organisms and Unmodified Parts Thereof, (ag-biotech)  | 256                                   |
| 424             | Drug, Bio-Affecting And Body Treating Compositions (includes some biocides, pesticides) <sup>8</sup>               | 148                                   |
| 504             | Plant Protecting And Regulating Compositions (herbicides, pesticides) <sup>9</sup>                                 | 80                                    |
| 119             | Animal Husbandry   | 73                                    |
| 514             | Drug, Bio-Affecting And Body Treating Compositions <sup>10</sup>   | 66                                    |
| 47              | Plant Husbandry  | 50                                    |
| 530             | Chemistry: Natural Resins Or Derivatives; Peptides Or Proteins; Lignins Or Reaction Products Thereof <sup>11</sup> | 32                                    |
| 536             | Organic Compounds -- Part Of The Class 532-570 Series (ag-biotech)   | 31                                    |
| 56              | Harvesters   | 27                                    |
| 71              | Chemistry: Fertilizers   | 25                                    |
| 127             | Sugar, Starch, And Carbohydrates   | 25                                    |
| 111             | Planting   | 19                                    |
| 99              | Foods And Beverages: Apparatus   | 14                                    |

<sup>7</sup> Example patent: # 4,066,800 "Preparation of dairy-based cheese food"

<sup>8</sup> Example patent: #4,388,303 "Method to reduce animal browsing damage to plants employing selenium compound"

<sup>9</sup> Example patent: #5,104,437 "Method for treating cereal crop seed with chitosan to enhance yield root growth, and stem strength"

<sup>10</sup> Example patent: #5,760,082 "Dietetic foods containing conjugated linoleic acids"

<sup>11</sup> Example patent: #5,936,069 "Process for producing improved soy protein concentrate from genetically-modified soybeans"

**Table 3**  
**Data Summary**

| Variable    | Definition  | Mean   | Std. Dev. | Minimum | Maximum |
|-------------|---|--------|-----------|---------|---------|
| $Y_{it}$    | Number of Ag-biotech patents                          | 0.63   | 1.54      | 0       | 13      |
| $Y_{it}$    | Number of Ag-tech patents                             | 0.32   | 0.81      | 0       | 5       |
| $Y_{it}$    | Number of Agricultural patents                        | 0.96   | 2.07      | 0       | 16      |
| $C_i$       | Number of Citations per patent                        | 3.45   | 7.20      | 0       | 128     |
| $FED_{t-2}$ | Federal funding                                       | 70.665 | 83.511    | 0.132   | 692.704 |
| $STA_{t-2}$ | State funding   | 7.996  | 12.048    | 0       | 65.600  |
| $IND_{t-2}$ | Industry funding                                      | 6.768  | 7.041     | 0       | 54.573  |
| $INS_{t-2}$ | Own institutional funding                             | 18.219 | 18.470    | 0       | 95.653  |
| $OTH_{t-2}$ | Other funding   | 7.950  | 9.228     | 0       | 59.587  |
| $AS_{t-2}$  | Agricultural science graduate students                | 36.84  | 67.27     | 0       | 280     |
| $BS_{t-2}$  | Biological Science graduate students                  | 189.95 | 157.07    | 1       | 741     |
| $AF_{t-2}$  | Average faculty salary                                | 50.49  | 10.45     | 29.03   | 107.76  |
| $NF_{t-2}$  | Number of faculty                                     | 819.62 | 470.45    | 37      | 3258    |
| $EFFOTT_t$  | Ratio of patent applications to invention disclosures | 0.35   | 0.20      | 0       | 1       |
| $OTT_t$     | Number of FTE's in the office of technology transfer  | 5.26   | 5.63      | 0       | 33      |
| $BEFORE_i$  | Number of ag-biotech patents (1971-1990)              | 1.54   | 3.14      | 0       | 19      |
| $G_{t-1}$   | Dynamic patent accumulation (for all ag patents)      | 4.89   | 9.34      | 0       | 82      |

Note: For university data and patents per university: N = 565, for 128 universities;  $FED$ ,  $STA$ ,  $IND$ ,  $INS$ , and  $OTH$ , are measured in \$1,000,000 and  $AF$  in \$1,000. For citations N=1552.

**Table 4**  
**Random Effects Negative Binomial Estimation Results**  
 (Dependent variable  $Y_{it}$ , the count of types of agricultural patents)

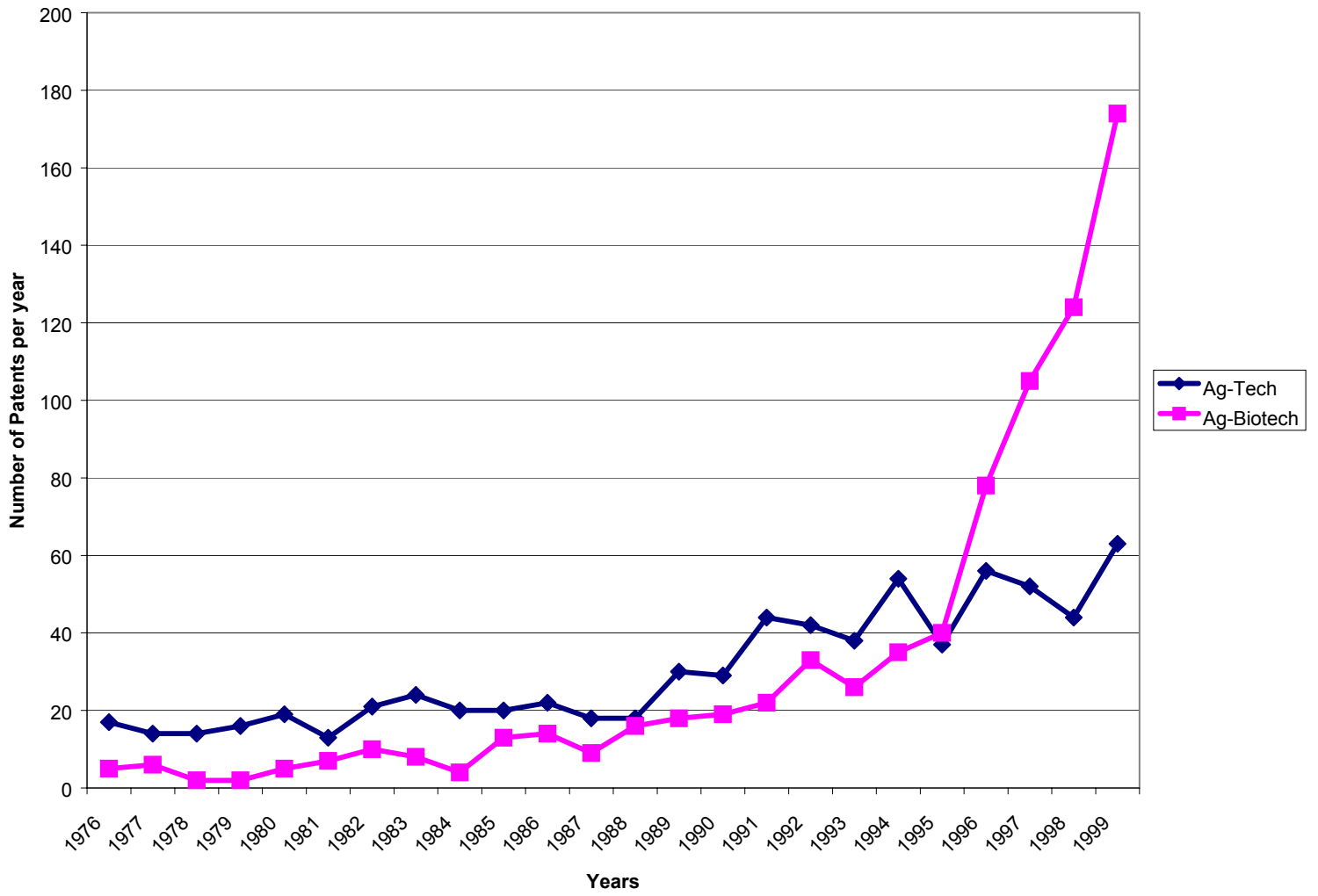
| Variable       | Definition  | Ag-Biotech Patents | Ag-Tech Patents    | Total Ag-Patents   |
|----------------|---|--------------------|--------------------|--------------------|
| $FED_{t-2}$    | Federal funding                                       | .0007<br>.0018     | -.0079**<br>.0037  | -.0009<br>.0016    |
| $STA_{t-2}$    | State funding   | .0202**<br>.0093   | .0206***<br>.0076  | .0183**<br>.0077   |
| $IND_{t-2}$    | Industry funding                                      | -.0176<br>.0176    | .0072<br>.0167     | -.0082<br>.0143    |
| $INS_{t-2}$    | Own institutional funding                             | .0081<br>.0052     | .0207***<br>.0050  | .0126***<br>.0043  |
| $OTH_{t-2}$    | Other funding   | .0125<br>.0146     | .063***<br>.0174   | .0282**<br>.0130   |
| $AS_{t-2}$     | Agricultural science graduate students                | .0064***<br>.0019  | .0058***<br>.0016  | .0060***<br>.0016  |
| $BS_{t-2}$     | Biological Science graduate students                  | .0004<br>.0010     | -.0032***<br>.0009 | -.0005<br>.0009    |
| $AF_{t-2}$     | Average faculty salary                                | .0227**<br>.0109   | .0011<br>.0132     | .0165*<br>.0094    |
| $NF_{t-2}$     | Number of faculty                                     | .0001<br>.0002     | .0002<br>.0001     | .0002<br>.0002     |
| $EFFOTT_t$     | Ratio of patent applications to invention disclosures | 1.458***<br>.3553  | -.3343<br>.4849    | .7778***<br>.2943  |
| $OTT_t$        | Number of FTE's in the office of technology transfer  | .0102<br>.0219     | .0320**<br>.0189   | .0116<br>.0189     |
| $YrDum$        | 1997-1998   | -.7840***<br>.1955 | -.2641<br>.2305    | -.6007***<br>.1509 |
| $G_{t-1}$      | Dynamic patent accumulation, within type              | .0232**<br>.0117   | .0494***<br>.0076  | .0157**<br>.0064   |
| Constant       |   | -1.69***<br>.7088  | -.7354<br>.8423    | -.3622<br>.7965    |
| Log-likelihood |   | -461.32            | -302.99            | -567.46            |

N = 565, Number of universities = 128, standard errors in parentheses, \*\*\*, \*\*, \* significant at greater than a 1%, 5%, 10% level respectively.

**Table 5**  
**Negative Binomial Citation Regressions:**  
*(Dependent variable  $C_i$ : number of citations per patent)*

|  | <b>Model 1</b>  | <b>Model 2</b>  | <b>Model 3</b> |
|--|-----------------|-----------------|----------------|
|  | <b>N = 1552</b> | <b>N = 905</b>  | <b>N = 674</b> |
| <i>Patent age</i>  | 0.569***        | 2.004***        | 1.953***       |
|  | 0.024           | 0.162           | 0.242          |
| <i>Patent age</i> <sup>2</sup>                               | -0.017***       | -0.132***       | -0.130***      |
|  | 0.001           | 0.014           | 0.024          |
| <i>class47 : Plant Husbandry</i>                             | -0.113          | -0.884***       | -0.346         |
|  | 0.197           | 0.386           | 0.479          |
| <i>class119 : Animal Husbandry</i>                           | -0.486***       | -0.755          | -0.537         |
|  | 0.177           | 0.367           | 0.448          |
| <i>class424 : Biocides, Pesticide</i>                        | -0.093          | -0.470**        | 0.008          |
|  | 0.137           | 0.230           | 0.299          |
| <i>class426 : Food</i>                                       | 0.128           | -0.008          | 0.438          |
|  | 0.113           | 0.208           | 0.273          |
| <i>class435 : Ag-biotech/chemistry</i>                       | -0.307**        | -0.504**        | -0.128         |
|  | 0.120           | 0.199           | 0.254          |
| <i>class504 : Plant protection</i>                           | -0.577***       | -0.950***       | -0.562         |
|  | 0.173           | 0.288           | 0.367          |
| <i>class514 : Bio-affecting compositions</i>                 | 0.422**         | 0.337           | 0.853**        |
|  | 0.184           | 0.297           | 0.367          |
| <i>class530 : Chemical processes</i>                         | 0.224           | 0.438           | 0.886*         |
|  | 0.245           | 0.474           | 0.528          |
| <i>class536 : Ag-biotech compounds</i>                       | 0.011           | -0.404          | -0.168         |
|  | 0.272           | 0.417           | 0.507          |
| <i>class800 : Ag-biotech organisms</i>                       | 0.130           | -0.196          | -0.002         |
|  | 0.127           | 0.199           | 0.248          |
| <i>Patents owned at grant year</i>                           | 0.0005          | 0.006*          | 0.006          |
|  | 0.002           | 0.003           | 0.005          |
| <i>USDA co-ownership</i>                                     | -1.269***       | -2.106***       | -2.163***      |
|  | 0.381           | 0.669           | 0.719          |
| <i>Business co-ownership</i>                                 | -0.249          | -0.306          | -0.351         |
|  | 0.177           | 0.270           | 0.314          |
| <i>Total University funding<sub>t-2</sub></i>                |                 | 0.0002          | 0.0005         |
|  |                 | 0.0007          | 0.0009         |
| <i>Agricultural Grad Students<sub>t-2</sub></i>              |                 | -0.001          | -0.001         |
|  |                 | 0.001           | 0.001          |
| <i>Ratio of patent applications to invention disclosures</i> |                 |                 | -0.270         |
|  |                 |                 | 0.411          |
| <i>Number of FTE's in the office of technology transfer</i>  |                 |                 | 0.029*         |
|  |                 |                 | 0.016          |
| <i>Constant</i>  | -2.061***       | -5.755***       | -5.777***      |
|  | 0.171           | 0.480           | 0.658          |
| <b>Log Likelihood</b>  | <b>-3010.95</b> | <b>-1140.20</b> | <b>-794.74</b> |

### The Growth of University Agricultural Patenting



Citation Rates of University Ag-Patents

