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An Innovation Market Approach to Analyzing Impacts of Mergers and Acquisitions in the Plant Biotechnology Industry

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This paper provides some insights into the impacts of firm concentration on research output by analyzing data on research output in the form of United States patents and field trials by private firms and merger activity over the last fourteen years (1987–2001). In recent antitrust cases and rulings, the US Federal Trade Commission (FTC) is more frequently assessing the impacts of mergers on the basis of innovation competition as well as product market competition. Results of Herfindahl-Hirshfield Index and Four-Firm Concentration Ratio analyses show that there is evidence of firm concentration in innovation markets. Analysis of new firm entry and mobility in innovation market share confirm this diagnosis. Given what appears to be the beginning of a trend towards negative impacts on innovation and competition, the FTC should monitor field trials, patents, and deregulations, as well as other measures of research activity and output and prices, for signs that industry concentration is having an adverse effect on research and development activities.

Key words: agriculture, biotechnology, concentration, innovation market, mergers and acquisitions, patents, research and development.

Introduction

The groundswell of mergers and acquisitions in the plant biotechnology industry over the last decade has been driven by the research assets required to develop new biotechnology products and by the strong patent system of the United States. These mergers generate concern that the concentration of patents, plant germplasm, and markets for biotechnology among a few firms may be causing a decline in the level of research and innovation in the industry (Barton, 1998). Patents on enabling technology, such as transformation techniques, and the large number of patents on specific crops held by major companies may be reducing the incentive and ability of other companies to perform research. In addition, the cost of obtaining permission to use patented technology or genetic material may prevent some firms, particularly smaller ones, from participating in innovative research (Graff, Wright, Bennett, & Zilberman, 2004).

Several policy alternatives are available to the government for preventing excessive levels of concentration: The US Patent and Trademark Office (USPTO) can reconsider its policies on issuing broad patents; the Federal Trade Commission (FTC) and US Department of Justice can use their antitrust powers to prevent abuse; and public research institutions can develop and license technologies that prevent private firms from obtaining a monopoly at any stage of the research and development process. This paper focuses on one of these policy instruments—the antitrust activities of the FTC and Department of Justice—as a basis for assessing the competitiveness of the plant biotechnology literature.

This paper makes two contributions to the literature. First, we bring the FTC concept of innovation markets to bear on agricultural biotechnology in general and the development of new crop varieties in particular. Second, we present empirical evidence related to the performance of the innovation market in this industry. Our empirical evidence, based on the newly available US Department of Agriculture Economic Research Service (USDA ERS) agricultural patent database (Pray, Oehmke, & Naseem, this issue) and our concept of industrial mobility, are new to the agricultural biotechnology literature.

The paper proceeds with a description of the conceptual framework underlying the innovation markets approach and the FTC approach to regulation of mergers and acquisition (M&A) activity in innovation markets. Although the FTC applies the innovation market approach to evaluate specific mergers or acquisitions, the concepts are adapted to the agricultural biotechnology industry as a whole. The paper then moves to empirical evidence on the innovation market in plant biotechnology. The final section draws conclusions.

Conceptual Framework

Traditional analyses of concentration focus on market share and the ability of a company to manipulate price in an output market. The most commonly used merger models based on existing market shares result in a static analysis of competition in a particular industry (Dahdouh & Mongoven, 1996). This is an appropriate method of analysis in industries with homogeneous products that change little over time. Agricultural biotechnology does not produce a homogeneous product nor is the product the same over time—biotechnology is instead a dynamic industry characterized by large investments in research and development (R&D) in an attempt to differentiate products by developing a new and better product—herbicide-resistant crop varieties, for example. Indeed, pricing analyses such as those of Falck-Zepeda, Traxler, and Nelson (1998), Oehmke and Wolf (2004), or Kesan and Gallo (this issue) suggest that despite a near monopoly, herbicide-tolerant cotton and soybeans are priced so that farmers and/or consumers get the largest portions of the benefits from innovation. However, examinations of the output market reveal little about whether these prices are sufficient to assure that the industry generates a flow of socially beneficial innovations, or whether market leaders are engaged in other behavior that slows the development of competing innovations, for example creating barriers to engaging in R&D.

Innovation is a dynamic process and requires a dynamic analysis to capture adequately the future impacts of mergers and acquisitions. This has raised questions about the ability of the current system of antitrust analysis effectively to evaluate the impacts on innovation that these mergers and acquisitions may be having (Jorde, 1995). Antitrust agencies have recently begun to recognize that innovation warrants a more central role in antitrust analysis due to its crucial role in generating economic growth and in enhancing global competitiveness (Gilbert & Sunshine, 1995; Whalley, 1995).

In the past decade the FTC began to analyze the impacts of potentially noncompetitive R&D-based industries in terms of the innovation market—the market for new innovations in the industry—emphasizing the speed of developing, producing, and marketing improved products (US Federal Trade Commission [FTC], 1996). For example, the approval of Monsanto's purchase of DeKalb was conditional on Monsanto making available to competitors their patented technology on agrobacterium transformation of corn and their stock of corn germplasm that was obtained from their earlier purchase of Holden's Foundation Seed company (US Department of Justice [DOJ], 1998). To ignore the effects of a merger on innovation, in particular, would understate the importance of future competition (Scotchmer, 1991).

The concept of *innovation markets* was developed to deal with antitrust claims focused on R&D efforts and where the definition of a product market was not applicable (Gilbert & Sunshine, 1995; Starek, 1996). According to the FTC intellectual property licensing guidelines (US DOJ/FTC, 1995), an innovation market

> consists of the research and development directed to particular new or improved goods or processes, and the close substitutes for that research and development. The close substitutes are research and development efforts, technologies, and goods that significantly constrain the exercise of market power with respect to the relevant research and development, for example by limiting the ability and incentive of a hypothetical monopolist to retard the pace of research and development. (§3.2.3¶2)

Innovation markets analyses measure the level of innovation competition that is occurring and are analogous to the product market analyses that are used in antitrust analysis to measure price and other competitive variables. Innovation market analysis takes a forward-looking perspective and recognizes the possibility that future competition can be harmed by mergers that result in a reduction in R&D activities (Dahdouh & Mongoven, 1996).

Innovation markets are delineated only when the capability to engage in relevant R&D can be associated with specialized assets or characteristics of specific firms (US DOJ/FTC, 1995). In addition, they are characterized by several key features: There are no products yet in existence; there are very small numbers of R&D programs; and high entry barriers preclude reliance on easy entry to remedy a likely reduction in innovation competition (FTC, 1996). Research and development activities in the plant biotech industry provide an excellent example of the definition of innovation markets.

Antitrust guidance on assessing possible anticompetitive reductions of innovation competition is still evolving. In the National Cooperative Research Act (NCRA) of 1984, Congress directed that registered ventures be reviewed for their "effects on competition in properly defined, relevant, research, development, product, process, and service markets. Competition is as important in R&D as it is in any other commercial endeavor" (National Cooperative Research and Production Act, 1993). The FTC and Department of Justice have provided guidelines regarding the assessment of innovation issues only with regard to licensing agreements and their treatment under the FTC and Sherman Acts (US DOJ/FTC, 1995). The 1992 Horizontal Merger Guidelines (FTC, 1992) provide direction in assessing whether a proposed merger is likely to create, enhance, or facilitate the exercise of market power, but no one has fully specified how those guidelines could be used in assessing the likelihood that a merger or acquisition will reduce innovation below "competitive levels" and thereby violate Section 7 of the Clayton Act (FTC, 1996).

The FTC's criteria for taking action under the innovation markets concept is to look at the impact of a merger on R&D activities of competitors of the merged firm, the impact of the firm's own in-house R&D, and the ability of new firms to enter the market. Along the same lines, Gilbert and Sunshine[1] (1995) state that an analysis of the effects of a change in market structure on innovation involves answering the following three questions: First, does the merged firm have the ability to decrease total market investment in R&D? This is analogous to the determination of a merged firm's share of the relevant market in a horizontal product merger. Second, does the new combination have the incentive to reduce innovative effort? The ability to reduce significantly the total amount of R&D does not mean that a merged firm has the incentive to reduce innovation. Ex post econometric studies of mergers and acquisitions in US industry find that R&D typically declines immediately after a merger (Ravenscraft & Scherer, 1987). Finally, does the merger have any consequences for the efficiency of R&D expenditure?

In this paper, we focus on the first two issues, at the industry level. That is, for the first question we examine the degree of concentration at the industry level and whether this concentration provides market leaders with the ability to decrease total industry R&D activity. We also examine whether recent merger and acquisition (M&A) activity in the plant biotechnology industry leads to an industry structure that undermines the incentives for innovation.

1. *At the time this article was written, Gilbert was Deputy Assistant Attorney General for Economics and Sunshine was Deputy Assistant Attorney General for Mergers in the US Department of Justice Antitrust Division.*

Empirical Analysis of the Crop Biotechnology Innovation Market

Methodology

In this section we use US field trial and patent data for private firms to evaluate the impacts of industry concentration on innovation in the plant biotech industry. (See Pray, Oehmke, & Naseem, in this issue, for a discussion of the advantages and disadvantages of various datasets.) An analysis of concentration in the industry is conducted using two standard measures: the *Herfindahl-Hirshfield Index* (HHI) and the *Four-Firm Concentration Ratio* (CR-4). Each of these measures is based on the assumption that market power is related to market share—in this case market share being the proportion of patents owned or field trials conducted by a firm. The HHI yields a better reflection of anticompetitive impacts and is more comprehensive than concentration ratios. (See Rhoades, 1995, for a discussion of the HHI and Lopez, Azzam, & Lirón-España, 1997, for an application to agricultural industries.)

The field trial data is further evaluated to provide information that may be useful in testing the more common theories and hypotheses about the impact of concentration on ease of entry into the market; research output of merged firms, smaller firms, and the industry as a whole. It is also subjected to a mobility test, with mobility occurring when one firm increases its market share at the expense of other firms. This measure is developed in more detail below.

Concentration in the Innovation Market

The field trial data indicates a trend in concentration in innovation markets over time. Figure 1 shows that the concentration of research as measured by share of the top four firms increased, with Monsanto clearly the driving force behind the increases. After 1994, concentration went up and the number of firms conducting research declined until 1996. 1996–2002 saw a slight increase in the total number of firms conducting research, accompanied by an even greater increase in research concentration by the top four firms.

HHIs were calculated from the field trial data, without and with correcting the data for M&A activity. The postmerger HHIs were calculated using data on all mergers that took place in each year (Table 1 and Figure

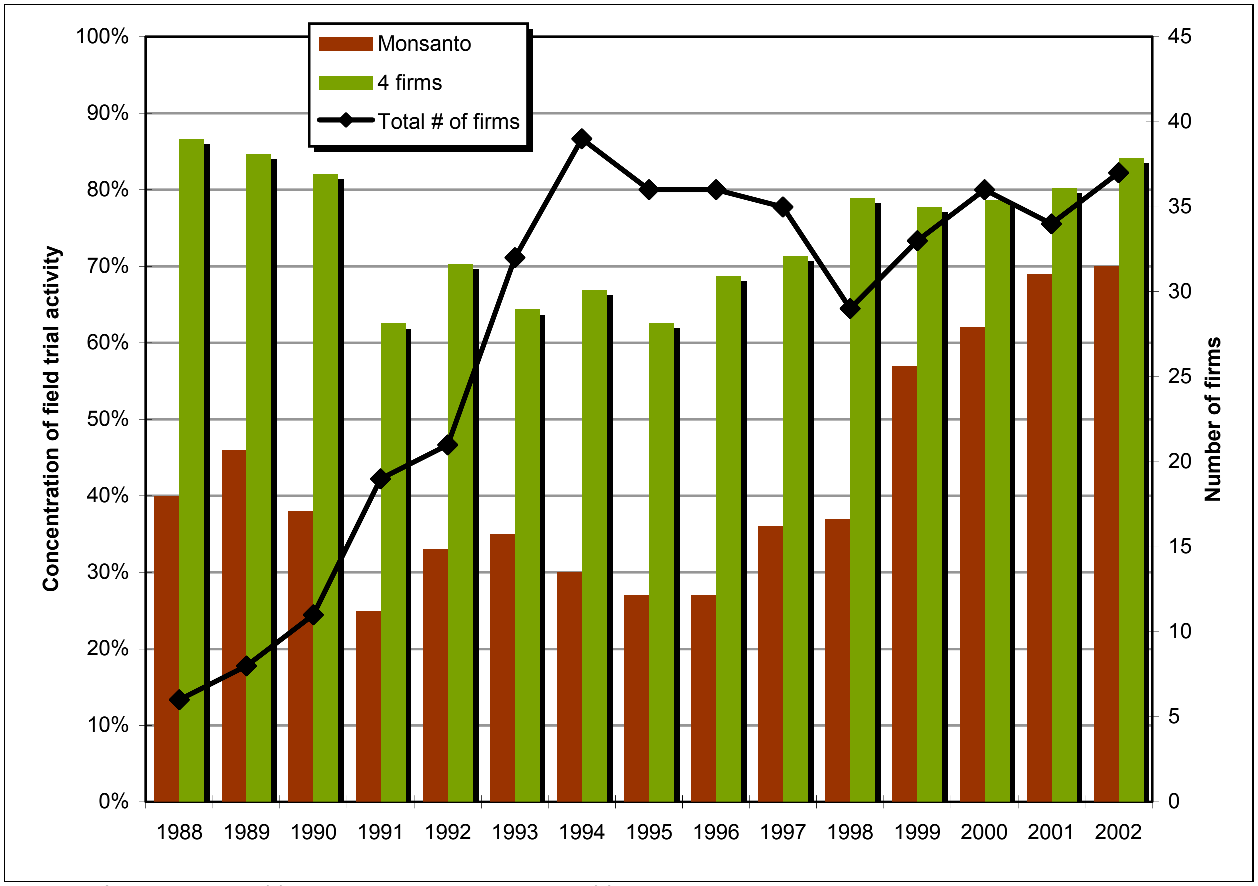

Figure 1. Concentration of field trial activity and number of firms, 1988–2002.
Note. Data from USDA APHIS (2002).

Table 1. Analysis of market concentration in field trials.

Year	CR-4[a] (postmerger)	HHI[b] (premerger)	HHI[b] (postmerger)	Number of mergers	Number of firms
1988	87%	2444	2444	0	6
1989	85%	2840	2840	1	8
1990	82%	2387	2387	1	11
1991	63%	1235	1240	0	19
1992	70%	1639	1645	0	21
1993	64%	1632	1635	0	32
1994	67%	1517	1521	2	39
1995	63%	1143	1310	3	36
1996	69%	894	1290	7	37
1997	71%	1327	1862	5	35
1998	79%	1608	2182	4	29
1999	78%	2954	3405	5	33
2000	79%	3575	3948	7	36
2001	80%	4453	4828	3	34

Note. Data from USDA APHIS (2002).
[a] *CR-4 = four-firm concentration ratio.*
[b] *HHI = Herfindahl-Hirschman index.*

2). Thus, the indices may be particularly high, because this calculation is usually conducted looking at the merger activity of just one firm. During the late 1980s and early 1990s, field trials in the industry were highly concentrated among a few firms, with CR-4s exceeding 60% (in some years over 80%) and HHIs exceeding 1800. During the mid-90s, these indicators dropped into a moderately concentrated range. It was during that time that increases in merger and acquisition activity were accompanied by increases in new firms entering the market. Indicators for the last few years of this decade reveal a dramatic increase in concentration. The CR-4 increased to 80% and the (postmerger) HHI increased to 4828.

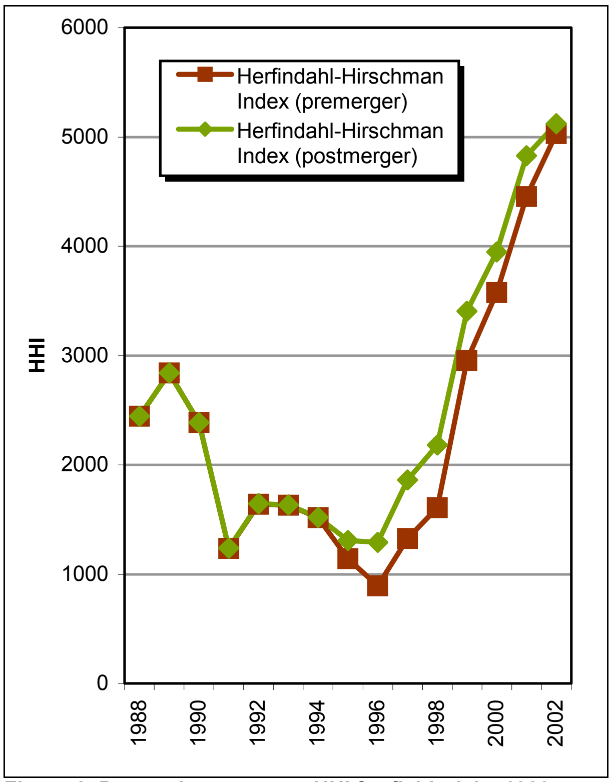

Figure 2. Pre- and postmerger HHI for field trials, 1989–2002.

Note. Data from USDA APHIS (2002).

For most industries, a change in the HHI (based on shares of market sales and number of firms) of more than 50 points due to a merger is sufficient to raise the curiosity of regulators (Pilloff & Rhoades, 2002). The data presented in Table 1 show changes greater than 50 points for 1995 and every year thereafter, although it should be noted that these changes are cumulative over a number of M&A events. Oehmke and Wolf (2003) show that in some cases different firms are using the same genetic event (e.g., *Cry* gene) and present a GR-4 measure that is comparable to the CR-4 but takes into account ownership of the underlying intellectual property. Their finding from the GR-4 is that the industry is even more concentrated than indicated by the CR-4 measure.

An analysis of patents provides additional evidence of concentration of research assets. Figure 3 shows changes in patent ownership resulting from mergers, acquisitions and divestitures in the agricultural biotechnology industry from 1988–2000 (USDA ERS, 2004). The large numbers of mergers and acquisitions have resulted in an increase in concentration in patent ownership. When M&As are taken into account, the top 10 patent assignees controlled over half of agricultural biotech patents issued through 2000. If acquisitions were not taken into account, the top 10 patent assignees as designated on the original patents would have controlled only about one third of the agricultural biotech patents (USDA ERS, 2004).

To measure the impact of mergers on the research activities of merging firms, we compare the number of patents held by the top four firms to the number they would have held if there were no M&A activity (*ceteris paribus*). Figure 4 shows the number of patents held by the top four firms before and after mergers. In patents, the top four firms over the last ten years have consistently included Monsanto, Pioneer, Novartis, and DuPont. Since 1997, the number of patents held by merged firms increased dramatically, so that by 1999 the top four firms held almost 49% of the agricultural biotech patents. The upward trend in both lines suggests that most of this increased concentration would have occurred had the M&A activity not occurred, although it is possible that in the absence of M&A activity, other firms might have been more active in research and patenting.

Patents on key transformation technologies for grains are held by three firms: DuPont, Monsanto, and Syngenta. DuPont controls the gene-gun technology through an exclusive license. Monsanto and Syngenta hold key patents on the use of *agrobacterium* for transforming crops, but the FTC forced Monsanto to give control of one *agrobacterium* method for transforming corn to the University of California at Berkeley. Monsanto also controls the 35S promoter, which has proved critical in some technologies such as herbicide resistance (Charles, 2002). Patents on the most important genes for insect resistance (Bt) at first blush do not appear to be very concentrated. Jenkins (1998), relying

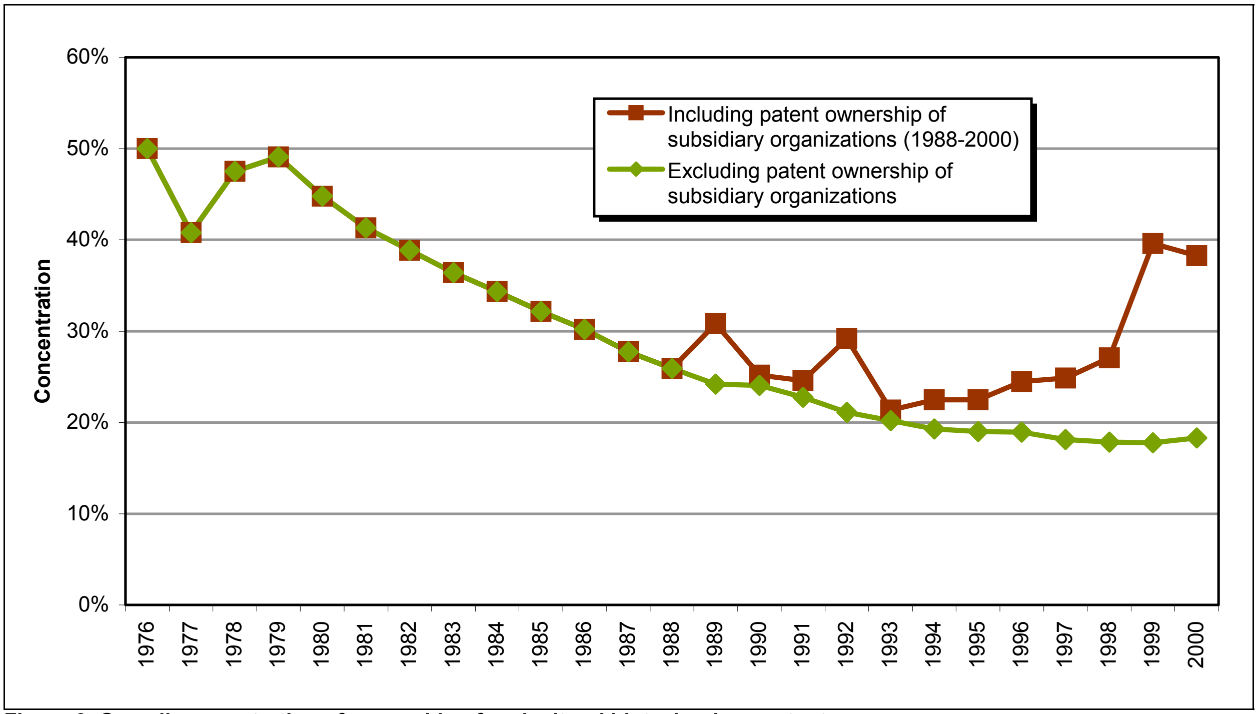

Figure 3. Overall concentration of ownership of agricultural biotechnology patents.

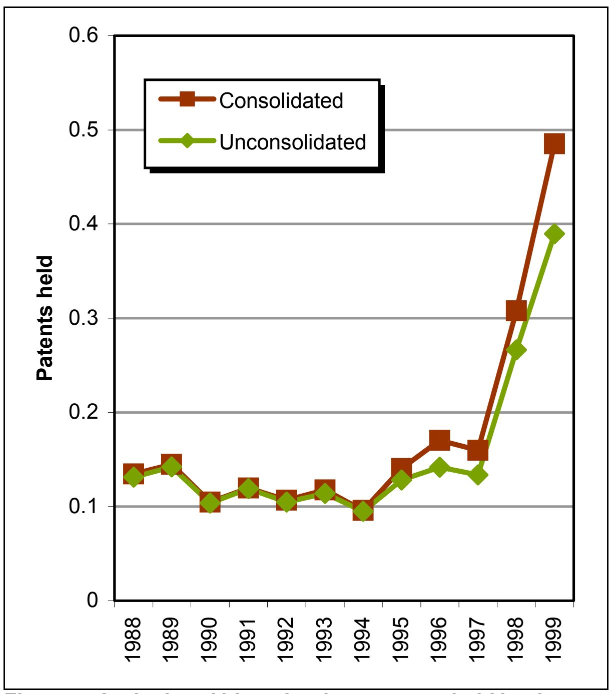

Figure 4. Agricultural biotechnology patents held by the top four firms, 1988–1999.

Note. Data from USDA ERS (2004).

on the Derwent Biotechnology Abstracts, found that the top four firms controlled 39% of Bt patents, and the top firm, Dow, controlled 20% of the Bt patents. However, not all *Cry* genes from Bt control the same kinds of insects, nor do they provide the same degree of control. A relatively small number of *Cry* genes are actually used in current insect-resistant crops, with anecdotal evidence of control by the major firms. Further analysis of the patent dataset is needed to determine if there are a few *Cry* genes that are critical for insect resistance, and whether these genes are controlled by the major biotechnology companies.

Figure 5 shows the evolution of enabling technology patents and other agricultural biotechnology patents from 1970 to 2000. In the early 1990s through 1995, there was a dramatic increase in patent applications for enabling technologies. It is difficult to determine the true level of patent activity after that time due to the nature of the data set because many patents were still pending. The pattern of other agricultural biotechnology patents mirrors that of enabling technology patents, peaking in 1995 and declining to a 1999 level of about 15% of the peak level. It is unclear whether there was a decline in inventive activity due to the delays in granting patents; if there was a decline, it is unclear how much of it was due to an inability to access the necessary enabling technologies for commercial production.

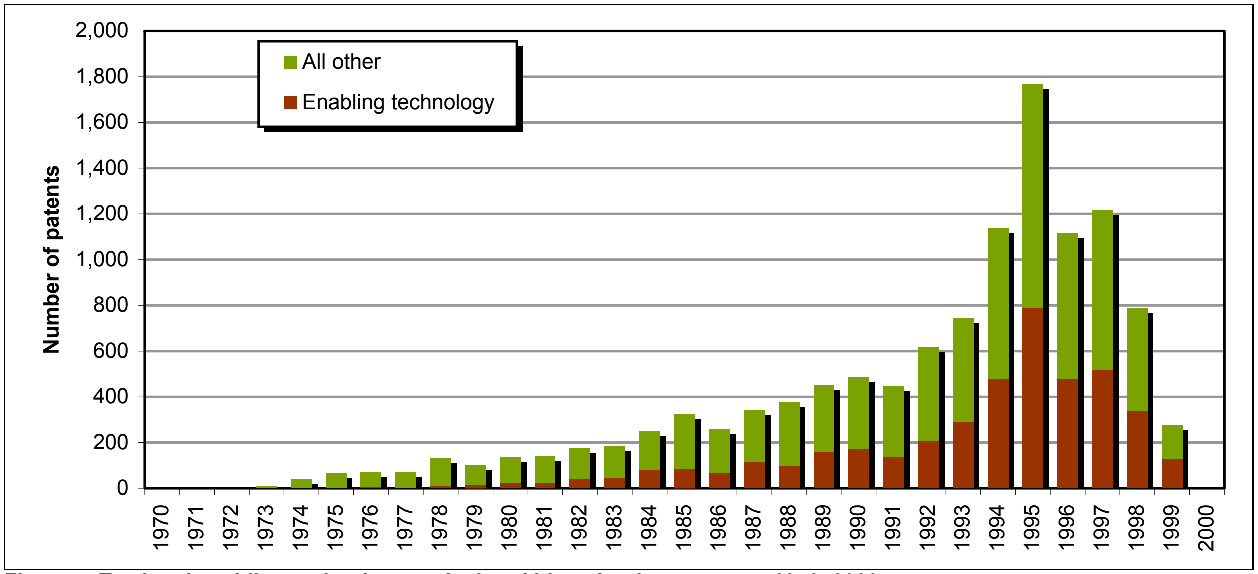

Figure 5. Total and enabling-technology agricultural biotechnology patents, 1970–2000.
Note. Data from USDA ERS (2004).

New Firm Entry into the Innovation Market

The number of new firms entering an industry is an important measure of whether there are important barriers to entry, such as too much concentration or lack of access to patented technology. The number of new firms (i.e., firms that have never before conducted a field trial) receiving permits and notifications to conduct field trials is shown in Figure 6. In the late 1980s and early 1990s, the number of new firms conducting field trials slowly increased from two in 1987 to a peak of 11 in 1994. 1995 saw a drop to six firms followed by an increase to 10 firms in the following two years. 1998 again showed a drop to five firms—the lowest level since 1990. 2000–2002 showed a dramatic increase in the number of new firms participating in field trials. By 2002, the number of new firms receiving permits and notifications doubled the 1995 figure. Oehmke, Wolf, and Raper (2005) model this as cyclical industry evolution.

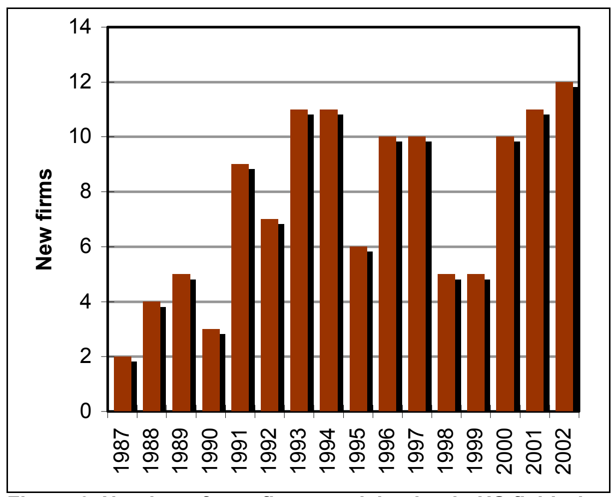

Figure 6. Number of new firms participating in US field trials, 1987–2002.
Note. Data from USDA APHIS (2002).

Mobility in the Innovation Market

Mobility is a measure of changes in firm leadership in an industry. Changes in leadership can occur when an existing firm takes market share from another or when a new firm enters the market and captures significant market share (often on the basis of an innovative product). Simply looking at concentration ratios will not reveal this change in market leadership. For example, when IBM was selling its operating system for the first generation of personal computers, it had essentially the entire market. Microsoft is now the dominant firm in personal computer operating systems, and except for a scattering of Apple (which is phasing out its operating system) and Linux users, Microsoft has essentially the entire market. An examination of simple concentration ratios will not reveal this change in market leadership; an examination of the mobility index will.

To construct the mobility index, let $m_{i,t}$ denote the share of firm i at time t. We are interested in the change in market shares over time. Because the market shares sum to one, simply adding the changes across firms

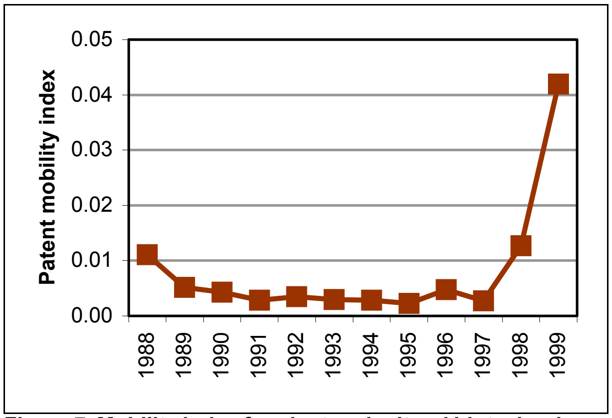

Figure 7. Mobility index for plant agricultural biotechnology industry, patent data, 1988–1999.
Note. Data from USDA ERS (2004).

reveals nothing. Consequently we define the mobility index to be

$$M_t \equiv \sum_i (m_{i,t} - m_{i,t-1})^2. \quad (1)$$

(Cable, 1997, provides a useful discussion of the construction and application of the mobility index.) The mobility index takes on values from zero (when there is no change in any firm's share) to two (when one monopolist is replaced by another). We apply the mobility index to patent data, calculating share as the proportion of all patents approved in year t that are owned by firm i (i.e., $m_{i,t} \equiv n_{i,t} / \Sigma(n_{i,t})$; $n_{i,t}$ is the number of patents approved in year t that are owned by firm i).

Figure 7 shows the mobility index in the agricultural biotechnology innovation market. The mobility index shows a marked upturn after 1997. However, the magnitude of the values is so small that even this upturn is insufficient to generate any meaningful level of mobility. In other words, using patent counts, there is no indication that different or new firms are stepping in to provide new leadership in the innovation market. Coupled with the evidence on declining patent numbers over the late 1990s, this raises questions about the rate of invention in the crop biotechnology industry.

Figure 8 shows the mobility index for the five major genetically modified crops in the United States, based on field trial numbers and shares. Until 1994 there was quite a bit of mobility in each crop. Since 1997 there has been relatively little mobility in any crop, with the exception of potato in 2001. The timing of this decline in mobility—coincident with the high M&A activity in the industry—suggests that the M&A activity has acted to limit changes in innovation industry leadership. Whether this limiting effect is a characteristic of stability or stagnation cannot be determined without looking at the flow of new products from the industry. This decline coincides with the fewer number of new firm entrants in the late 1990s, but the mobility index fails to rise again with the increased number of new firm entrants from 2000 to 2002. This indicates that new firms may be entering the industry, but they are either not interested in or incapable of challenging for leadership at the stage of the R&D process represented by the field trial data.

New Product Measures

The ultimate goal of the innovation market is to generate products that can be commercialized; the ultimate goal of regulators is to insure that the innovation market works to generate commercial products in an orderly fashion. An agricultural biotechnology (transgenic) research product is legally ready for commercialization when the USDA grants it deregulated status. Figure 9 shows the number of requests for deregulation that have been approved or are pending before the USDA's Animal and Plant Health Inspection Service (APHIS). The annual number varies quite a bit; in some cases this variance is due to a low number of requests, in others to a low number of approvals, or on the high side it is due to a large number of requests and approvals. Despite this variance, the number of deregulations from 1992 to 1998 is markedly higher than the number of deregulations from 1999 to 2004. Although this output measure is not perfect, it provides clear evidence that the increasing concentration noted in the late 1990s is contemporaneous with a decrease in the number of new genetic modifications available for commercial use. This is prima facie evidence that the effects of M&A activity in the innovation markets on the flow of new commercializable products warrants further investigation to understand more precisely the causes of the decline in deregulations.

Summary and Conclusions

This paper applied the innovation markets approach to the analysis of the plant biotechnology R&D industry. Two questions are relevant to this paper: (a) In the existing market structure, do the market leaders have the ability to decrease total market investment in R&D? (b) In the new market structure, do firms have the incentive to reduce innovative effort? The paper has addressed

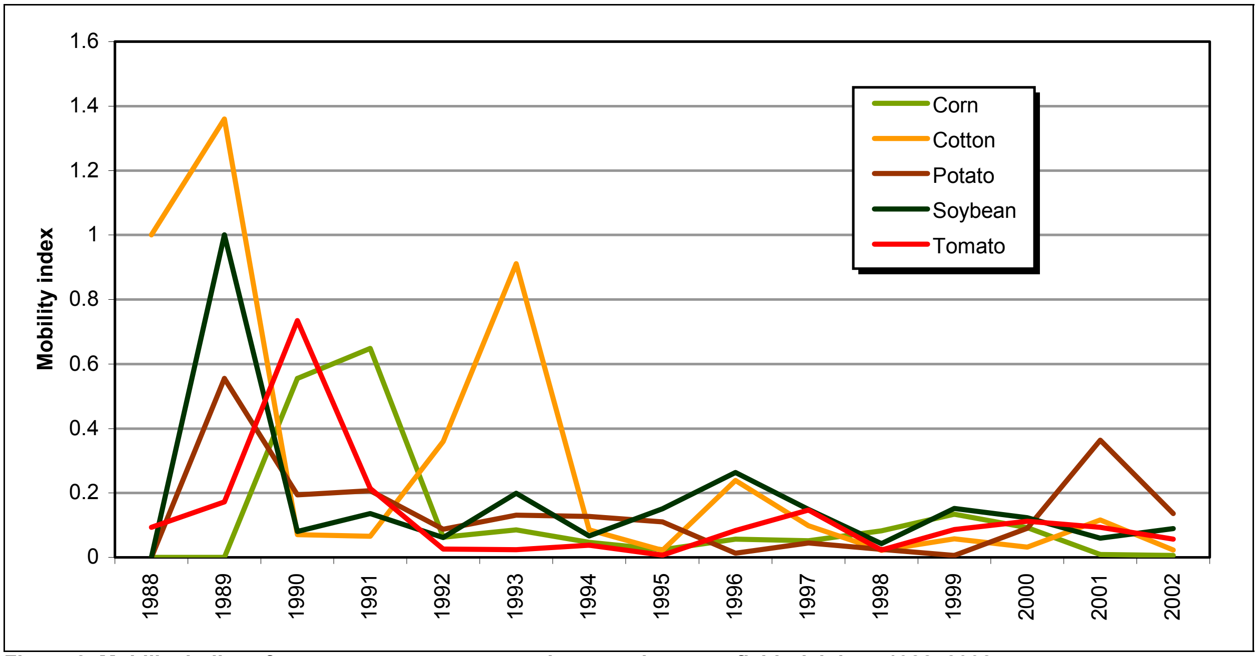

Figure 8. Mobility indices for corn, cotton, potato, soybean, and tomato, field trial data, 1988–2002.
Note. Data from USDA APHIS (n.d.).

these issues primarily by looking at concentration at various stages of the R&D process and the effects of this concentration.

Findings are summarized in Table 2. Concentration measures indicate that the industry is highly concentrated. Mobility indices indicate that this concentration is persistent, because the same few firms dominate the innovation market from year to year. The total number of field trials indicates that innovation concentration by a few firms has not reduced R&D activities for the industry as a whole but has adversely impacted the R&D activities for firms not in the top four. Entry by new firms into the market has increased, but not significantly compared to industry size. Deregulations show a diminished flow of new products forthcoming after 1998 relative to 1998 and before.

The answer to the first question is unambiguously yes: The leading plant biotechnology firms have the ability to reduce the industry level of R&D activity. This is clearly seen in the proportion of R&D activity undertaken by the market leaders. For example, with the top four firms holding almost 50% of the agricultural biotechnology patents, if these firms choose to diminish their efforts to obtain patents then the total patent count would fall, *ceteris paribus*. Similarly, Monsanto itself conducts nearly two thirds of all transgenic field trials conducted in the United States. If Monsanto chooses to decrease its efforts at field testing of new genetically modified crops, then the industry effort in this R&D activity would fall, *ceteris paribus*.

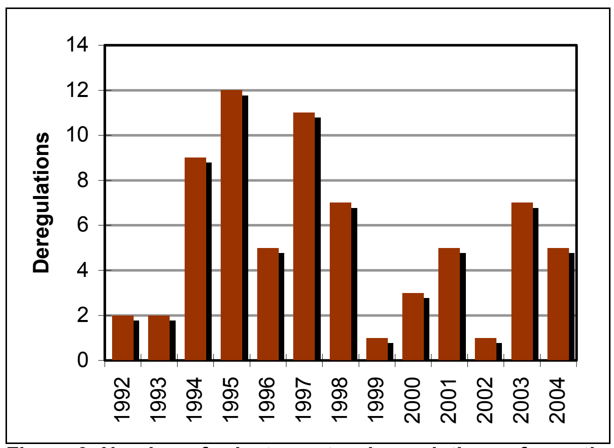

Figure 9. Number of private-sector deregulations of genetically modified crops approved or pending, 1992–2004.
Note. Data from USDA APHIS (n.d.).

More ominously, there is some degree of concentration in enabling patents that allow further research to go forward, particularly in transformation technologies, probably in promoter genes, and possibly in Bt genes. This may limit the ability of small or new firms to commercialize transgenic technologies. The fact that even though the number of new firms increased noticeably in

2000–2002, but the number of field trials conducted by these firms is negligible, is consistent with this view.

Table 2. Summary of results.

Impact of industry concentration	Results
Industry concentration	Increasing in recent years as measured by patent and field trial data. M&A activity has increased the growth rate in concentration measures.
Total industry level of R&D/inventive activity	Field trials increasing. Patents growing until 1996, then the trend is uncertain.
Merged firm research activity	Ambiguous.
Ability of new firms to enter innovation market	New firm entry increasing.
Ability for firms to compete for top spots	Increases in investments make it possible for larger firms to climb to top spots and harder for small firms to compete for top spots.
New products	Deregulations declined in mid-late 1990s.

It is unclear whether the new market structure is generating specific incentives to limit the level of inventive activity. Merged-firm research activity and patent activity provide ambiguous answers to this question (Table 2). Field trial activity is increasing and new firms are entering the industry, but investment requirements make it hard for new or small firms to compete for the top spots. It remains unclear whether this is a problem: The small or medium university-related firm that is founded by a research scientist and based on a novel gene construct is probably much better off being bought up by a large firm rather than trying to commercialize its own seed variety. However, the number of deregulations has clearly declined since 1998, coincident with the increasing industry concentration, indicating that commercialization of new crop varieties has decreased. This suggests that large firms are either not buying up small firms with novel genes or are not bringing those genes to market. A continued lack of new deregulations, even after the past few years of increased field trial activity, would be an important indicator of research inefficiency and/or noncompetitive behavior in the plant biotechnology innovation market.

We note that the answers to the two questions posed in this paper are phrased in a *ceteris paribus* fashion. However, in a concentrated industry, strategic behavior is regarded as the norm, so that other firms may respond by increasing R&D activity if, for example, Monsanto chooses to reduce its own R&D efforts. Determination and quantification of such strategic actions is an interesting task that is important to determinations of noncompetitiveness in the industry but requires detailed econometric analysis best left to future research.

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