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Mergers, Acquisitions, and Stocks of Agricultural Biotechnology Intellectual Property

John L. King and David Schimmelpfennig
United States Department of Agriculture Economic Research Service

A subset of patents owned by six large agricultural biotechnology companies is analyzed from the new Initiatives for Future Agriculture and Food Systems (IFAFS) Agricultural Biotechnology Intellectual Property database. These patents account for over 40% of US agricultural biotechnology patents issued 1976–2000 held by US and European firms. We describe the quantity, quality, and technological composition of these patent stocks, especially noting differences between these firms and their subsidiaries. Subsidiary firms contributed more patent stocks, although parent firms contributed better patents by one measure of patent quality. Patent stocks developed or acquired by these firms exhibited technological focus in one or more areas of agricultural biotechnology, and parent and subsidiary were not always focused on the same technological area.

Key words: agricultural biotechnology, intellectual property, technology classifications, utility patents.

Introduction

Mergers and acquisitions (M&As) are an important method for companies to acquire technological capabilities, such as knowledge and expertise, business experience with the technology, and intellectual property (IP) rights. An alternative to M&As is the internal development of these technological capabilities. Internal development might take longer and cost more than acquisition of an existing technology through change in company ownership and control. Intellectual property rights can be licensed, but technology licensing can be difficult when the owner is a competitor or when licensing transactions are slow or expensive to negotiate. If timely development of a complex technology requires integration within one firm, M&As are a mechanism through which firms can assemble the necessary components.

Agricultural biotechnology is a good area in which to study changes in ownership of technology through M&As. Agriculture has been using biotechnology for research and development of new products for over a decade. The use of biotechnology to develop new crops that create value for producers, processors, and consumers has made use of extensive knowledge of plant breeding and agronomic practices in addition to new abilities to correlate beneficial traits to particular genes, insert the genes into cultivars with a transformation technology, and select and preserve the genes in the transformed variety.

Perhaps because of the need to assemble so many different technologies owned by numerous separate firms, the agricultural biotechnology sector saw a large amount of M&A activity in the 1990s. During this period of rapid technological change and the creation of new technologies and products, ownership changes of these technologies were frequent. Firms began to use biotechnology in agriculture for different reasons: Some had experience in agricultural inputs (especially seeds and chemicals) and sought to apply new technologies, others were seeking applications for innovations in which they possessed cutting edge ability, and still others were startup companies formed to commercialize new biotechnology discoveries. Observing the different technological capabilities of these firms and their decisions to merge or acquire can provide some insight into the role of M&A activity in the creation of new technologies.

This paper compares technology stocks held by firms involved in major agricultural biotechnology M&As. By observing different aspects of the technology portfolios held by each firm, we can infer some of the technological results of agricultural biotechnology M&As. Our measurement of technology stocks relies mainly on patents, about which a great deal of information is available in the recently released United States Department of Agriculture Economic Research Service (USDA ERS) Agricultural Biotechnology Intellectual Property Database (ABIP) discussed in the next section (see also Pray, Oehmke, & Naseem, this issue).

Because so many financial, strategic, and other factors influence the decision to merge or acquire, this paper will not claim to identify the specific role of technology in M&A events. However, by describing the

quantity, quality, and technological composition of intellectual property stocks of combining firms, we hope to highlight the potential importance of this topic.

Agricultural Biotechnology Patent Data

The data for this paper are mainly drawn from the Agricultural Biotechnology Intellectual Property database developed by ERS and collaborators, which is publicly searchable at http://www.ers.usda.gov/Data/AgBiotechIP/ (as of July 2005). The primary data for this database are a set of utility patents issued by the US Patent and Trademark Office between 1976 and 2000 identified as relevant to agricultural biotechnology and biological processes in food and agriculture. An advantage of using this database is that it includes detailed annual histories of patent ownership between 1988 and 2002. This feature allows us to collect data on M&A activity. Another advantage of the database is that the patents are categorized according to a technology classification system. This categorization plays a significant role in our analysis. The classification system includes patents on genetically engineered agricultural plants and animals, the processes used to produce genetically engineered varieties, research approaches (such as tissue culture), research tools with potential applications to agriculture, patents on nongenetically engineered species (such as other new crop varieties), and other biological processes used in the food and nutrition industries (such as fermentation).

The data from the ABIP database are supplemented with data on patent citations available from the National Bureau of Economic Research (NBER). Patents vary widely in their technological and commercial significance. To measure differences in these aspects of private-sector patents, we examine data on forward and backward citations. Forward citations indicate the number of times that a particular patent is cited by subsequent patents, with more forward citations associated with patents having greater impact. Backward patent citations indicate the number of citations made to prior patents, with more backward citations associated with patents that integrate more innovations from the past. The usefulness and potential pitfalls of patent citations data, including the significant changes over time that have occurred in the rate of patenting and therefore in the number of citations made, are discussed by Hall, Jaffe, and Tratjenberg (2001). Our data include patents through 2000, and the NBER citation data extend only through 1999, so we address the effects of truncation in citation data later in the paper. The NBER citations database is available online at http://www.nber.org/patents/ (as of July 2005).

Table 1. US agricultural biotechnology utility patents in private sector, 1976–2000.

Company	Total	Parent patents	Subsidiary patents	Subsidiary % of total
Dow	234	11	223	95%
Dupont	565	109	456	81
Monsanto	674	294	380	56
BASF	228	89	139	61
Bayer	516	158	358	69
Syngenta[a]	425	142	283	67
Total Big Six	2,642	803	1,839	70
Other US	2,826	2,826	—	—
Other European	943	943	—	—
Total US private-sector agbiotech patents	8,245	6,406	1,839	29

[a] Syngenta patents reflect Novartis patents only; total includes patents from subsidiaries and merger with AstraZeneca.
Note. Data from USDA/ERS/ABIP.

Six Firms Account for 40% of Agricultural Biotechnology Patents

Since the first regulatory release for planting of a genetically engineered crop was granted in 1983 (Wrubel, Krimsky, & Anderson, 1997), the market for agricultural products developed with biotechnology has become dominated by a relatively small number of suppliers. Since 1998, just six firms have accounted for over 80% of genetically modified crop field trials for regulatory release in the United States—an indication that the quantity of research being done has become quite concentrated.

By 2002, these same six firms also controlled over 40% of private-sector agricultural biotechnology patents issued in the United States through 2000 (Table 1). These firms—US firms Dow, Dupont, and Monsanto and European firms BASF, Bayer, and Syngenta—dominate the ownership of agricultural biotechnology utility patents. Consolidation of agricultural biotechnology seems to fit with the idea that centralization of technology ownership facilitates successful commercialization of complex technology product development.

One remarkable aspect of the data presented in Table 1 is that in all cases, subsidiary firms accounted for a majority of the patented technology of the "Big Six." Overall, subsidiaries contributed 70% of the patent stocks that Big Six firms eventually controlled.

Although the parent companies had significant agricultural biotechnology patent holdings (with the exception of Dow; see below), these holdings did not constitute even a majority of the patented inventions of the consolidated agricultural biotechnology firm. Even though the Big Six came to dominate agricultural biotechnology patent stocks, it is clear from the patent stocks of their acquired subsidiaries that much innovation also originated outside these firms. M&A of patent ownership represents an important avenue through which the technologies underlying the Big Six patent holdings were assembled.

Patterns of Technology Stock Acquisition

The Big Six firms demonstrated three different patterns by which parent firms acquired patent stocks of subsidiaries. In two cases (Dow and Dupont), subsidiary agricultural biotechnology patent stocks represented a vast increase over existing agricultural biotechnology stocks of the parent firms. In three other cases (Monsanto, Bayer, and BASF), the parent firm held the largest number of agricultural biotechnology patents, but the sum of subsidiary patents was nonetheless larger than the parent stock of patents. This represents an "accretion" of smaller individual patent stocks around the large individual patent stocks held by the parent firms. In a final case, agricultural biotechnology patent stocks of the resulting firm were built up from a series of mergers involving companies with roughly equal patent stocks.

Dow Agroscience represents an asymmetric case in which a parent with few agricultural biotechnology patents acquired a large number of agricultural biotechnology patents. Subsidiary patents contributed nearly all (95%) of the firm's agricultural biotechnology patents. The subsidiary firm Mycogen alone contributed 87% of the total patent count. Dow's core technology was mostly in agricultural chemicals rather than in agricultural biotechnology per se; Mycogen, on the other hand, had a large number of patented agricultural biotechnologies. Similarly, the Dupont acquisition of Pioneer Hi-Bred brought in 81% of the agricultural biotechnology patents of the combined firm. Many of the Pioneer patents were for germplasm in the form of patented cultivars and inbred lines. Although it did not have a large number of patents, Dupont had a significant holding of patents in the important area of genetic transformation.

In three examples of accretion around a parent firm, the acquiring firm had the largest individual patent stock, even though the subsidiary firms together contributed more patents to the acquiring firm. For instance, Monsanto itself accounted for the largest number of patented agricultural biotechnology inventions of the combined firm (44% of the combined firm total), but Monsanto obtained significant patent stocks through acquisitions of Dekalb Genetics (17%), Calgene (14%), and Holden's Foundation Seeds (9%). A similar pattern holds true for BASF and Bayer. This pattern of accretion around a large patent holder is distinct from the asymmetric pattern of Dow and Dupont.

The Syngenta case was a special instance of multiple mergers of firms with similarly sized agricultural biotechnology patent stocks. In 2000, Novartis agribusiness and Zeneca agrochemicals merged to form Syngenta. Zeneca had merged with Astra in 1999 and acquired Mogen, a plant biotechnology company based in the Netherlands in 1997. Novartis itself was formed by the merger of Ciba and Sandoz in 1996. Each of these subsidiaries had significant holdings.

Technological Focus and the Decision to Acquire

Besides the absolute magnitude of agricultural biotechnology patent stocks added through acquisition, it is instructive to examine their specific technological focus. One important aspect is the composition of technologies found within the stock of utility patents held by parent and subsidiary firms. The numbers across the top of Table 2 represent the technologies represented in the ABIP classification system (available at http://www.ers.usda.gov/Data/agbiotechip/Technologies.htm, as of July 2005). Each number represents a main technology heading from this classification scheme. (See the footnote for Table 2 for explanations of the technology headings.) The numbers in the body of the table are counts of patents in a given technology classification divided by the total number of patents held by that parent or subsidiary (not both). Note that columns within a row do not sum to 100% because some patents are cross-classified.

Table 2 shows the technological focus of the patent holdings of the Big Six parent and subsidiary companies. Cells of companies (and groups of companies) that had greater than 40% of their technology stocks in a particular technology are shaded for easy identification. Because of cross-classifications, some companies had multiple technology foci.

Big Six firms differed in both the degree and choice of technology focus compared to non-Big Six firms. Table 2 shows that each of the Big Six patent stocks had at least one (shaded) technological focus, either in the

Table 2. Technological focus of patenting activity.

	Technology[a]								
Company	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Dow	.18	.00	.18	.00	.27	.09	.18	.09	.00
Dow subsidiaries	.74	.16	.10	.00	.74	.03	.31	.14	.00
Dupont	.33	.09	.11	.04	.07	.08	.50	.32	.07
Dupont subsidiaries	.83	.01	.06	.01	.04	.00	.82	.15	.03
Monsanto	.52	.05	.27	.08	.13	.04	.22	.20	.00
Monsanto subsidiaries	.76	.01	.14	.00	.03	.02	.59	.22	.01
BASF	.10	.03	.73	.01	.09	.03	.07	.10	.04
BASF subsidiaries	.15	.06	.18	.24	.17	.30	.19	.14	.04
Bayer	.11	.05	.64	.03	.06	.09	.08	.10	.00
Bayer subsidiaries	.29	.09	.30	.03	.18	.12	.33	.23	.02
Syngenta-Novartis	.35	.08	.47	.03	.21	.08	.23	.13	.05
Syngenta-AstraZeneca	.61	.09	.20	.01	.22	.04	.45	.32	.10
Other US	.22	.12	.14	.10	.16	.16	.47	.16	.07
Other European	.21	.20	.16	.07	.21	.18	.40	.19	.05

[a] *Key to technologies: (1) plant technologies; (2) patented organisms, nonplant; (3) metabolic pathways and biological processes in plants; (4) metabolic pathways and biological processes in animals; (5) protection, nutrition and biological control of plants and animals; (6) pharmaceuticals; (7) genetic transformation; (8) metabolic pathways and biological processes, DNA-scale; (9) genomics. Note. Data from USDA/ERS/ABIP. Cells greater than 40% are shaded.*

parent holdings, the subsidiary holdings, or both. Outside their areas of specialization Big Six firms have fewer patents than non-Big Six firms, which were more evenly distributed across technologies. In terms of choice of technology focus, genetic transformation (technology 7) was the technological focus of non-Big Six agricultural biotechnology firms in the United States and Europe. Although Dupont specialized in this area, the rest of the Big Six firms focused in areas besides genetic transformation.

Other than Dow, which had only 11 patents exclusive of its subsidiaries (Table 1), each Big Six parent company had a technological focus. By contrast, the subsidiaries as a group were more dispersed across technological areas. When subsidiaries did have a technological focus (Monsanto, Dupont, and Dow), that technological focus was in multiple areas due to cross-classification of patents.

Turning to the technological focus of the combined firms, most had multiple areas of technological focus. Dow, Dupont, Monsanto, and Syngenta all coupled focus in technology 1 (plant traits) with another focus, either technology 7 (genetic transformation) or technology 5 (protection, nutrition, and biological control of plants and animals). Bayer and BASF, which did not have multiple areas of technological focus after acquiring firms, did acquire firms with holdings in a wide breadth of technologies. Both of these outcomes accord with the discussion of M&A activity as a means of combining complementary technologies in Graff, Rausser, and Small (2003).

Acquiring Quantity or Quality?

Some patents are more useful than others. Patents on obsolete technologies or technologies that never proved marketable are less valuable than patents for a profitable new product or an important technology platform in widespread industry use. Patent citations are a widely used measurement that attempts to capture differences in patent quality. We constructed our index of patent quality from data provided by the NBER patent citations database discussed previously. We compare the average number of forward (cited by a subsequent patent) and backward (citing earlier patents) citations for parent and subsidiary patent stocks. We use this index to add a quality component to our description of the patent stocks of Big Six parents and subsidiaries.

Patent citations have a skewed distribution. Most citations occur in just a few patents with hundreds of citations; most patents have few or even no citations. This reflects differences in applicants, technologies, and even patent examiners. To minimize the resulting distortion in this measure of patent quality, we use a logarithmic index of patent citations. As a result, additional patent citations have a positive but decreasing marginal impact on the index.

A discrepancy in the ABIP and NBER datasets is that ABIP includes patents issued as late as 2000, whereas the NBER data extends only through 1999. This leads our index to understate the importance of more recently issued patents, especially forward citations. However, because each Big Six firm suffers from the same problem to a similar degree, the citation indices allow comparison across these companies.

In addition to patent citations, the ability to cut across different technological areas is another aspect of patent quality. Other things being equal, a patent that combines disciplines might be more valuable to firms in areas of complex technology. Patents that are cross-classified in different technological areas might indicate a more applied patent, that is, closer to a commercialized product. Of course, patents within a single technological area can be very valuable, but in general, cross-classified patents might be another positive indicator of patent quality.

Table 3 presents a mixed picture of the patent quality of Big Six patent stocks. Both forward and backward citation measures are typically higher for Big Six parent firms than for their subsidiaries, but Big Six subsidiary firms have a higher average number of cross-classifications.

So, instead of acquiring higher quality patents, the parents were getting more patents with multiple classifications, increasing their breadth if not the quality of their patent portfolios (for the technology classifications they acquired). Although this pattern emerges from the data on patent stocks, other strategic and financial considerations may have influenced M&A decisions. For instance, R&D funding among the Big Six varied quite widely. Monsanto was the top private agricultural biotechnology research spender in 2001 at $500 million, twice the second place Syngenta at $250 million. The company with the fewest agricultural biotechnology patents (11) spent one tenth of Monsanto's budget. Dow (and its subsidiaries) had a $50 million agricultural biotechnology research budget in 2001. In between Monsanto and Dow were Dupont at $230 million, Bayer at $75 million, and BASF at $70 million (Cavalieri, 2004). It might be possible that the financial resources available to Monsanto's management allowed the company to acquire the highest quality patents in its acquisitions, or at least to acquire patents that were upgrades to its existing portfolio.

Table 3. Intellectual property quality indicators.

Company	Cited (log of 1+ citations)	Citing (log of 1+ citations)	Cross-classifications
Dow	1.888	1.719	1.000
Dow subsidiaries	1.627	1.591	2.215
Dupont	1.903	1.459	1.624
Dupont subsidiaries	1.279	1.060	1.948
Monsanto	1.641	1.396	1.514
Monsanto subsidiaries	1.675	1.722	1.776
BASF	1.154	1.574	1.213
BASF subsidiaries	1.210	1.380	1.468
Bayer	1.545	1.322	1.165
Bayer subsidiaries	1.388	1.418	1.598
Syngenta-Novartis	1.476	1.478	1.526
Syngenta-AstraZeneca	1.124	1.381	2.046
Other US	1.704	1.650	1.440
Other European	1.370	1.392	1.460

Note. Data from ABIP, http://www.nber.org/patents/.

Conclusions

This paper introduces new evidence from an extensive collection at http://www.ers.usda.gov/Data/AgBiotechIP/ of 11,000 agricultural biotechnology utility patents issued between 1976 and 2000 by the US Patent and Trademark Office. We analyzed the quantity, quality, and composition of stocks of agricultural biotechnology intellectual property rights involved in mergers and acquisitions of the Big Six agricultural biotechnology firms. One clear result is that by 2002, Big Six firms had invented or acquired over 40% of agricultural biotechnology for which patents were issued to US or non-US firms.

Because these six companies are responsible for an even greater percentage of the commercial development required to create new products with biotechnology, it was somewhat surprising to discover that these firms did not invent a majority of the patent stocks they ultimately acquired. Merger and acquisition partners contributed a greater share of patents. In some cases, the Big Six firms contributed a very small share, while in other cases the Big Six contributed a sizeable (albeit minority) share of patent stocks. Moreover, although they were fewer in number, the patent stocks contributed by the parent firms were on average equivalent or better than those contributed by subsidiaries when measuring patent quality with a citation index.

Patent stocks of acquired companies included a high number of patents classified into multiple technology

areas relative to the stocks held by acquirers and other US and European firms. It is possible that the cross-cutting nature of these patents enhanced their appeal for the Big Six companies attempting to integrate complex technological steps.

The technological composition of patent stocks held by Big Six firms and their subsidiaries allowed fewer clear conclusions. In some instances, Big Six firms broadened the technologies available to them through acquisition of subsidiary patent stocks; in others, they deepened patent stocks in areas in which they were already focused. In still other cases, firms (acquirers and subisidiaries) had multiple areas of specialization and partial overlap of technological capabilities.

Authors often conclude papers by mentioning some possible extensions to their work but usually seem to imply that they believe that the most important work lies within. There should be no such implication in the mind of the reader here. The few empirical regularities that are presented here relate to a small subset of all agricultural biotechnology utility patents and comprise only the tip of the intellectual property iceberg. Fortunately for the reader, the larger portion of the iceberg lies waiting on the web in searchable databases for further exploration.

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