Transitions in Agbiotech: Economics of Strategy and Policy

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PART TWO: Industry Issues

12. Structural Change in the Biotechnology and Seed Industrial Complex: Theory and Evidence

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Chapter 12

Structural Change in the Biotechnology and Seed Industrial Complex: Theory and Evidence

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Introduction

After fifteen years in research and development (R&D), crop biotechnology has recently entered its commercial phase. First generation products have been crops with herbicide tolerance and resistance to particular insect pests. Second generation products, transgenic plants with enhanced quality traits, are fast approaching commercialization (Kalaitzandonakes and Maltsbarger 1998).

Even the optimists among biotechnology proponents have been caught off guard by the extremely fast adoption rates of first generation biotechnologies. In 1999, just four years from commercial introduction, an estimated 50 percent of the total U.S. corn, soybean and cotton acreage has been planted with transgenics. The "coming of age" of crop biotechnology, however, has triggered dramatic structural changes in the seed/biotechnology complex over the last five years. Through a wave of mergers and acquisitions (M&As) the biotechnology and seed industries have quickly consolidated around a small number of diversified multinational firms with significant capabilities in discovery, product development and distribution.

In this paper, we briefly summarize the structural changes in the seed and biotechnology industries and the reasons underlying this merger/acquisition boom. Drawing on developments in evolutionary economics and transaction costs theory we conclude that the ongoing industry consolidation is a predictable phase in the innovation's lifecycle. Furthermore, we find that the consolidation has proceeded in ways that are consistent with the innovation's level of appropriability and market value.

Structural Change in the Biotechnology/Seed Complex

After years of promises and large R&D investments crop biotechnology finally reached commercialization in 1995. Unlike market introduction, however, market penetration in US agriculture has been very fast (Table 1). Product introductions in the corn, soybean and cotton markets have included plants resistant to selected insect pests and to specific herbicides like Roundup, Liberty and Buctril. Despite supply constraints, adoption of transgenic technologies has been faster than any other agricultural technology on record, including hybrid corn (Kalaitzandonakes 1999).

TABLE 1 Estimated Transgenic Crop Acreage

	Percent of planted acres				
Crop	**1995**	**1996**	**1997**	**1998**	**1999 (est.)**
Corn					
• Bt		1	7	20	25-40
• RR				1	4
• LL			1	7	
Soybeans					
• RR		1	14	37	50+
Cotton					
• Bt		14	17	21	
• RR			6	28	50+
• BXN				8	

Bt is *Bacillus thuringiensis* (insect resistant), RR is Roundup resistant, LL is Liberty resistant, BXN is Buctril tolerant.

Source: Industry Estimates.

Large R&D investments in crop biotechnology have been recently topped, however, by investments in M&As in the seed and biotechnology industries. Monsanto and DuPont have led the way in such investments. Novartis, Dow Agrosciences, AgrEvo (Hoechst/Schering), Zeneca and Rhone Poulenc are all involved in similar efforts, albeit on a reduced scale (Table 2). Through horizontal integration, these diversified firms have merged their capabilities with those of specialist biotechnology startups and have consolidated intellectual property rights of key biotechnologies. Through vertical integration into the seed business, they have coupled their significant research and product development capacity with leading positions in distribution.

Pioneer Hi-Bred International has been the leading branded seed merchandiser in the corn and soybean markets. Pioneer's market was near 40 percent in corn and 16 percent of purchased soybean seed in 1998 (Table 3). Monsanto's purchases of Asgrow and DeKalb resulted in a branded seed corn market share near 15 percent. In addition, Monsanto's purchase of Holdens allows some influence over germplasm sold to other companies but also encourages competition in the branded seed market. Holdens' germplasm is estimated to be part of an additional 30-40 percent of branded seed sales. With Monsanto's acquisitions of Asgrow and DeKalb, and DuPont's acquisition of Pioneer, these two companies combined will either own or influence some 80 percent of the North American seed corn market.

TABLE 2 Selected Acquisitions in Crop Biotechnology and Seed Industries, 1993-1998

Company 1	Country 1	Company 2	Country 2	Cost ($Millions)
DuPont	US	Pioneer	US	9,400
Monsanto	US	DeKalb	US	2,300
Monsanto	US	Delta & Pineland (pending)	US	1,900
Monsanto	US	Cargill Seed International	US	1,500
Monsanto	US	Holdens	US	1,000
AgrEvo	Germany	PGS	Belgium	770
Monsanto	US	Calgene	US	700
Monsanto	US	PBI	UK	550
Dow	US	Mycogen	US	622
Monsanto	US	Asgrow Agronomics	US	240
Monsanto	US	Agroceres	Brazil	220
Monsanto	US	Agracetus	US	150
Zeneca	UK	Mogen	Netherlands	70
Mycogen	US	Dinamilho	Brazil	12
DuPont	US	Dalgerty	UK	N/A
DuPont	US	Hybrinova	UK	N/A
DuPont	US	Cereals Innovation Center	UK	N/A

Source: University of Missouri Agrobiotechnology Database.

TABLE 3 Seed Corn Market Shares in the US, 1998

Company	**Percent**
DuPont / Pioneer Hi-Bred	39
Monsanto	**15**
DeKalb	*11*
Asgrow	*4*
Novartis	9
Dow Agrosciences / Mycogen	4
Golden Harvest	3
Cargill	4
Advanta	3
Others	20

Source: Industry Estimates.

Other companies have also been involved in the restructuring of the seed industry. In 1996, the merger of Ciba-Geigy and Sandoz formed Novartis and combined Ciba Seed and Northrup King into a significant competitor in the global seed industry. Novartis then capitalized upon the early market introduction of its Bt products and expanded its corn seed market share from about 6 percent in 1995 to 9-10 percent in 1998. Dow Agrosciences recently acquired Mycogen. Mycogen has a 4 percent market share in corn seed. In addition, Dow Agrosciences recently acquired part of Illinois Foundation Seeds, which provides foundation seed for another 11 percent of branded seed corn sales by regional companies.

The soybean market has long been considered the low margin part of the seed business. In the soybean seed market there is no hybridization to differentiate products, and a significant amount of farmer-saved seed. In addition, public varieties from universities provide low priced competition that has limited branded soybean seed profit margins (Kimle and Hayenga 1993). Pioneer's entry into the soybean seed market in the early 1980s, and their very large corn market shares and strong dealer system, resulted in their emergence as the leading soybean seed company in the early 1990s. Asgrow and DeKalb were strong competitors. Asgrow has capitalized on the Roundup Ready soybean demand and increased its market share (16 percent) in 1998, partly at Pioneer's expense (Table 4). Monsanto seed brands accounted for 24 percent of purchased soybean seed in 1998, up five points from 1997.

TABLE 4 Purchased Soybean Seed Market Shares in the US, 1998

Company	Percent
Monsanto	**24**
DeKalb	*8*
Asgrow	*16*
DuPont / Pioneer Hi-Bred	17
Novartis	5
Dow Agrosciences / Mycogen	3
Stine	4
Other brands	39
Public varieties	10

Source: Industry Estimates.

Delta and PineLand has long dominated the cottonseed market (Table 5). Monsanto became a competitor when it bought Calgene and Calgene's cottonseed subsidiary Stoneville. Monsanto's bid for the purchase of Delta and PineLand (71 percent of the cotton seed market) has not yet been approved by the Justice Department, but Monsanto has agreed to divest itself of the Stoneville cottonseed business (16 percent of the market).

TABLE 5 Cotton Seed Market Shares in the US

Company	1997	1998
Delta & Pine Land	*72*	*71*
Stoneville	*12*	*16*
Other	16	13

Source: Agricultural Marketing Service. (1997; 1998). Cotton Varieties Planted. Washington, DC: United States Department of Agriculture.

Innovation Lifecycles and Industry Consolidation

Clearly, recent M&As have quickly consolidated the biotechnology/ seed complex. Consolidation in innovation industries, however, is hardly unique. Rather it is a phase frequently observed in typical innovation lifecycles.

Utterback, and Abernathy and Utterback describe the basic characteristics of innovation lifecycles and the associated industry dynamics through an evolutionary process. Following a technological discontinuity, barriers to entry are lowered and new entrants gain easier access to affected industries. During this early phase of innovation, firms engage in product innovation. A great deal of experimentation with product design and operational characteristics takes place among competitors during this "fluid" phase. Several distinct product concepts and designs may be brought forward at one time. Over time, specific new product concepts become the standard through broad market acceptance. Then product innovation subsides. The pace of process innovation quickens and some industries may enter a “specific phase” in which the rate of innovation dwindles for both product and process innovations as firms focus on cost, volume, and capacity.

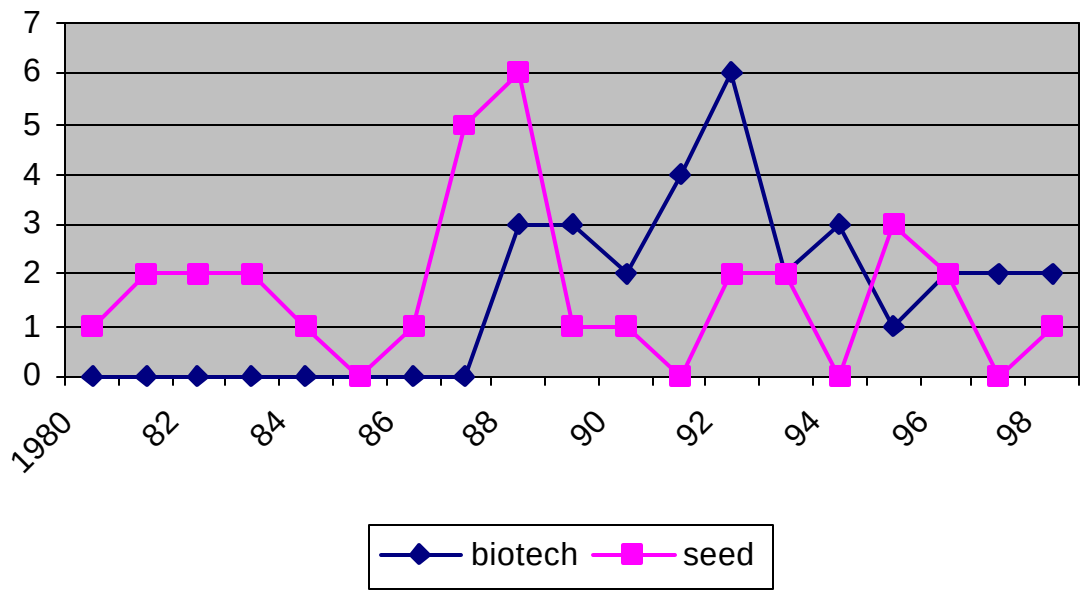
Industry dynamics parallel those of the innovation. Firm entry is at its peak during the fluid phase of the product innovation where new entrants and incumbents alike compete for the dominant product design. Once the dominant design becomes established the total number of firms drops off as the industry consolidates around a few dominant players. These remaining firms emulate the features of the dominant product concept and compete on efficiency.

A dominant design and the resulting industry structure are not predetermined. Rather, they are endogenous to the innovation process and emerge from a complex interplay of technical possibilities, strategic maneuvering of firms, the occasional configuration and ownership of assets, history and sheer inertia.

Innovation in the crop biotechnology industry follows closely such patterns of innovation and industrial dynamics (Kalaitzandonakes and Bjornson 1999). Firm entry in the crop biotechnology industry peaked in the early 1980s. Product innovation continued throughout the 1980s where various product forms, including transgenic plants and genetically engineered microorganisms, competed for technical dominance (Kalaitzandonakes and Marks 1999). The dominant design in the first generation biotechnologies--transgenic plants with pesticidal action--emerged in the early 1990s. Consolidation began shortly thereafter with biotechnology startups leading the way (Figures 1 and 2).

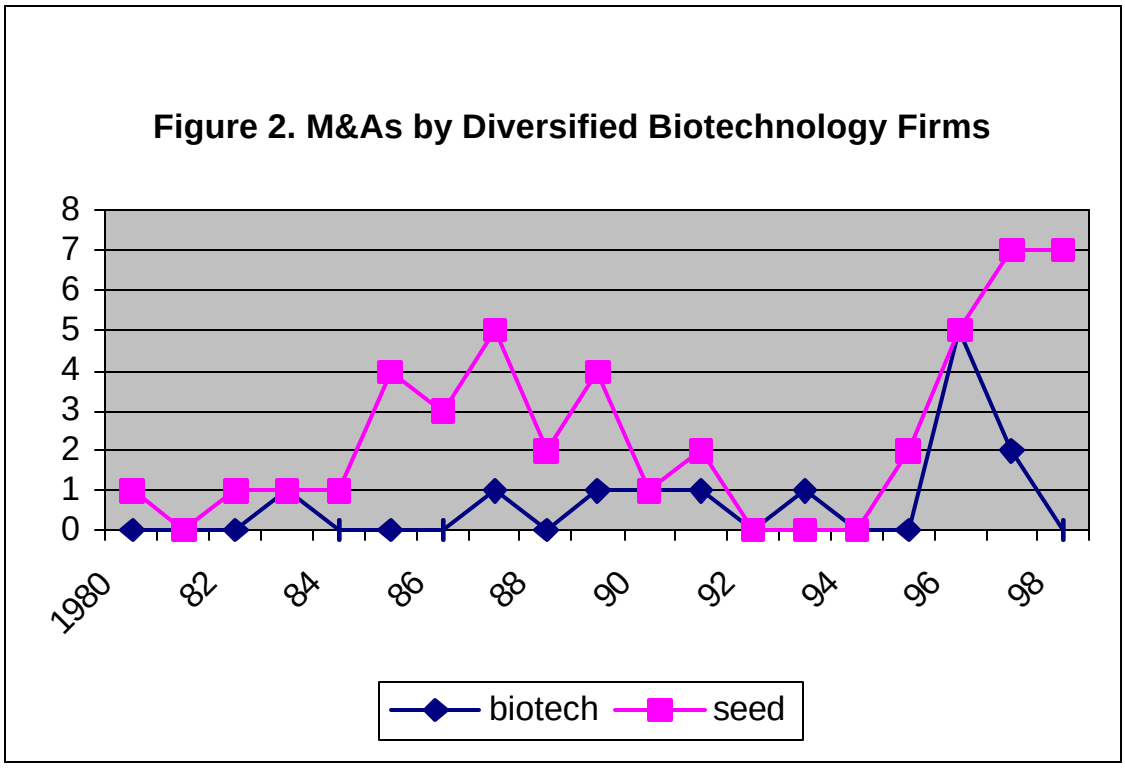
Still, while this evolutionary process describes the fundamental dynamics of innovation and the horizontal consolidation in the biotechnology industry, it does not explain the factors that have led to the observed patterns of vertical integration and consolidation in the seed industry. Transactions costs do.

Figure 1. M&As by Biotechnology Startups



Industry Consolidation: A Transactions Cost Explanation

Since the advent of the agro-biotechnology research in the mid-1970s, transforming plants was considered the optimal way for delivering such technologies (Kalaitzandonakes 1997). Superior germplasm, was therefore an essential complementary asset for agro-biotechnology. For commercial introduction, (bio) technological know-how, strong intellectual property position and a broad proprietary germplasm base had to be coordinated through contracts, joint ventures or ownership of all three types of assets.



For biotechnology firms, strategies to vertically integrate seed and biotechnology assets have been as old as the agrobiotechnology industry itself. Industry pioneers like David Padwa, founder of the early biotechnology startup Agrigenetics, began acquisitions of regional seed companies in 1976 in order to finance biotechnology research and deliver its products to the market. Other leading biotechnology startups, such as Calgene, Biotechnica International and Mycogen but also diversified biotechnology firms like Ciba Geigy and ICI, had similar strategies and carried out a number of acquisitions in the seed industry in the 1980s and 1990s (Figures 1 and 2).

But vertical ownership was not the only strategy used to coordinate technology, intellectual property and germplasm. Over the years, there have been numerous contracts between biotechnology and seed companies for joint product development and distribution. It is interesting to note that Monsanto and DuPont, the top two acquirers of the last three years, are latecomers in the seed industry. In the mid-1990s, both of these companies reversed their long-standing strategies to become technology specialists in favor of becoming fully integrated.

Why should biotechnology companies opt for vertically integrating into the seed business instead of choosing among other forms of coordination between technology and germplasm? The weak appropriability of biotechnology and the high costs for coordinating such assets in the absence of ownership should account for most of the interest shown by biotechnology companies in vertical integration in the last few years.

The Weak Appropriability of Agro-biotechnology

The ability of biotechnology firms to capture (appropriate) profits from their innovation depended on their strength of intellectual property coverage and the ease of imitation (Teece 1987). Firms could more readily profit from unique, non-imitable biotechnologies with strong intellectual property coverage. Complementary assets necessary to bring biotechnologies to the market were also important. Scarce and specialized complementary assets could command a larger share of the innovation profits.

Most crop biotechnologies that reached the market over the last few years demonstrated significant degree of technical imitation and low degree of appropriability (Kalaitzandonakes and Bjornson, Joly and deLooze 1996). Intellectual property rights for fundamental technologies overlapped and were heavily contested. The very same companies that have led consolidation have also been involved in lawsuits controlling patent rights or contractual rights to use key biotechnologies over the last few years (Hayenga 1993). The companies claiming patent rights to specific genes, specific processes, or general concepts like insect resistance in corn, include Monsanto, DeKalb, Mycogen, Novartis, AgrEvo, Rhone Poulenc and Pioneer. The court decisions in some of these lawsuits are instructive.

- In February 1998, Mycogen lost a patent infringement suit against Monsanto, DeKalb, and Delta and PineLand. A jury decided that Mycogen did not prove that it was the first to invent the Bt technology and considered its patent invalid.

- Monsanto sought damages and injunctive relief against Mycogen and Ciba-Geigy (Novartis) for infringement of a Bt insect resistant patent. A jury verdict in June 1998 found that while the patent was literally infringed by the defendants the patent was not enforceable. Thus, the use of the Bt genes by Mycogen and Novartis could continue in competition with Monsanto's licensed products.

- In yet another court case, Novartis lost a patent-infringement lawsuit it had filed against Monsanto Company and co-defendant DeKalb, over a patent for genetically engineered corn. In November 1998, a jury decided Monsanto and DeKalb did not infringe the patent held by Novartis since January 1997, and that the Novartis patent was invalid.

- In the most recent court decision Monsanto lost rights to glyphosate resistant technology. In 1997, Monsanto commercially introduced corn containing a gene from DeKalb providing glyphosate resistance. Rhone Poulenc Agro filed suit against Monsanto and DeKalb contending that they did not have a right to license, make or sell corn products using Rhone Poulenc Agro technology for glyphosate resistance. DeKalb had sublicensed to Monsanto glyphosate tolerant technology previously licensed from Rhone Poulenc Agro.

These conflicting claims, but more importantly the relevant outcomes, demonstrate the lack of definitive intellectual property rights among biotechnology leaders. Under these circum-

stances, high quality proprietary germplasm, a key complementary asset for commercialization, proved to be in stronger position than biotechnology know-how and intellectual property rights. In short supply and subject to significant development lags, germplasm could command a significant share of the innovation profits forthcoming from weakly appropriable agro-biotechnologies. Under such conditions, vertical integration into the seed business and ownership of germplasm became a primary strategy of agro-biotechnology firms for profiting from their innovation. Of course, a part of the prospective profits from biotechnology were transferred to seed assets, capitalized in lofty prices paid in recent M&As (Bjornson and Kalaitzandonakes 1999).

The High Costs of Coordinating Biotechnology and Germplasm

The low appropriability position of agro-biotechnology relative to complementary germplasm assets provides a strong economic argument for biotechnology firms taking ownership positions and vertically integrating into the seed business. The relatively high transaction cost for coordinating biotechnology and germplasm through contracts provides another.

There were significant impediments to structuring complete contracts that would distribute value appropriately among contracting parties and would motivate appropriate behavior. Because of the significant time lags involved in genetically engineering and developing commercial amounts of germplasm with desirable traits, contracts that coordinated biotechnology and seed assets were constructed years before reaching market. Such contracts were necessarily incomplete, as it was impossible to predict all relevant technological and commercial possibilities being created. Accurate valuation of the individual contribution of the interdependent technology and germplasm to the final technological advance (e.g. higher yields) were difficult to assess. Such jointness typically leads to indeterminate quasi rent sharing schemes and incomplete contracts (Alchian and Demsetz 1972).

Incomplete contracts would predictably lead to costly renegotiations and delays. Accordingly, firms would draw their boundaries so that such costs are minimized (Pisano, Williamson 1975). Ownership of both technological and seed assets bypassed high transaction costs providing additional economic reasoning for vertical integration of such assets.

Some Concluding Comments

The recent restructuring and consolidation of the seed/biotechnology complex has been broadly discussed and issues of concentration and control have been raised. While control positions in the consolidated biotechnology/seed industry may be feasible, we have argued that low technology appropriability and incomplete contracts are the primary motives behind recent horizontal and vertical integration in these industries.

Factors similar to those experienced in the first generation agrobiotechnologies will likely continue to dictate future industry structure. Hence the ownership and distribution of key technical, intellectual property, and distribution assets relevant to second generation biotechnologies could provide a preview on future industry restructuring.

Endnote

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