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# INTELLECTUAL PROPERTY AND MARKET STRUCTURE IN AGRICULTURE

by

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ABSTRACT. In the past several years, the seed industry worldwide has been dramatically restructured, mostly through mergers and acquisitions. We argue that the restructuring has been technologically driven, and has also resulted in the transformation of several chemical conglomerates into life-sciences firms. We discuss why the restructuring has mostly occurred through mergers rather than contractual relationships such as licensing, and investigate its efficiency implications, both as it concerns anticompetitive effects and the joint use of complementary assets.

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# 1. Introduction

Over the past decade the structure of the plant breeding and agricultural biotechnology industries has been radically transformed. Through dozens of mergers, acquisitions and strategic alliances, there has been a rapid and dramatic concentration of control over value-generating assets. As assets have been reshuffled, and in many instances newly created, much controversy has arisen. The content of the controversy has ranged from regulatory concerns about the exercise of market power, academic researchers' concerns about freedoms to operate, competitors' concerns about litigation threats, consumer concerns about genetically altered foods, and environmental concerns about insect resistance build-up.

Our goal in this paper is to shed light on this history of industrial consolidation. Consolidation is only one way among many of accomplishing the purposes served by vertical integration. The pharmaceuticals industry, for example, has witnessed a proliferation of exclusive licensing agreements. Why, then, has the trend towards consolidation in recent years has been so much more dramatic in agricultural biotechnology than in other, comparably knowledge-intensive industries? This topic is an important one for policy-makers and regulators responsible for safe-guarding competitive forces. An obvious concern is that this trend may reflect a relentless quest for market power. Other, less sinister motivations for consolidation include the mitigation of contractual hazards and the exploitation of asset complementarities. While regulators are naturally unwilling to sanction the accumulation and exercise of market power, if this power results directly from innovation, U.S. patent and intellectual property policies allow such power to be exercised. Most analysts agree that consolidation should not be impeded if it allows synergies to be exploited, either in the realms of production or of innovation. However, if the pursuit of such synergies leads to an effective cartelization of the research and development process, a public policy response must be formulated that disperses access to the innovation market more broadly.

Our paper focuses particular attention on two striking developments in the industries under consideration and on the connection between these developments and the observed transformation in industrial structure. The first development is the evolution of more clearly articulated intellectual property rights to certain critical assets. The second is the transformation of traditional agriculture from a *commodity* business to a *differentiated product* business. In the former, products are homogeneous, and markets are anonymous and clearly delineated; moreover, from the perspective of a supplier, the value of a product is more or less exogenously fixed. In the latter, distinctions between products and boundaries between markets are blurred; moreover, value, to a large extent, must be "created" through the efforts of producers. There are intimate and complex relationships between these two developments, i.e., in intellectual property and product differentiation. As these developments unfold, regulators are navigating in uncharted territory. The analysis typically conducted to evaluate pre-consolidation conduct and behavior in a world of commodities provides little if any insight into conduct and behavior in a differentiated product world.

To motivate the formal analysis that follows, we report the following "true story," with company names suppressed. Prior to the technological transformation of agriculture, there was a clear division between the roles played by farmer/dealers and agricultural chemical companies. The former sold seed to farmers and maintained close relationships with retail seed companies; the latter sold herbicides and insecticides to farmers, as well as providing them with technical counsel. Farmers tended to heed the advice they received from chemical companies, partly because of their acknowledged technical expertise, and partly because they were known to be well protected by insurance in the event that their advice proved illfounded. Then a certain trait developer ($T$) invented a trait that was resistant to a certain kind of insect. Under a licensing agreement, the trait was inserted into a seed company's germplasm, and the seed company ($S$) was responsible for marketing the augmented seed to farmers. Naturally, $S$ began marketing this new product in its traditional way, through its traditional channels, i.e., the farmer/dealers. Company $T$ argued that

their technology could be more efficiently disseminated if it were marketed through the chemical companies whose traditional insecticide products were now substitutes for the new innovation. After all, the chemical companies had the acknowledged technical expertise as well as the liability coverage; moreover, why would they be marketing a direct substitute for their own product lines unless it were a credible alternative? Company $S$ staunchly resisted this iconoclastic marketing proposal for an extended period, delaying market penetration. Eventually, $T$'s marketing strategy was adopted, with resounding success. Rather than fight the same battle over and over again, $T$ shortly afterwards acquired control of $S$.

Several aspects of this conflict over marketing strategies are particularly salient for our purposes. First, the conflict would never have arisen without the revolutionary biotechnological innovations that overturned traditional marketing relationships. Second, the new product we refer to—insect resistant seed—is a prime example of a "differentiated product" in the sense described above: ultimately, demand for it was vigorous, but this demand had to be "created," then "nurtured" through an intensive marketing campaign. In particular, it was necessary to convince farmers that the product was indeed insect-resistant would be cost-effective. Third, there was much uncertainty and disagreement about how best to "capture the value" of the innovation. Company $T$ and company $S$ each had confidence in its own ability to market the product, but neither had much faith in the other's ability. Fourth, biotechnology alone would not have been sufficient to generate market value: the process of value creation and capture took several years, and without the benefit of the newly secured property rights over this kind of innovation (see section 3 below), neither company could have been induced to spend the time and resources required to overcome all of the obstacles that lay in their path.

After presenting the empirical evidence, we introduce a simple analytical framework that enables us to explore the causal relationships between intellectual property, technology and industrial structure. The model tracks rather closely the story we have just told, and formalizes several of the salient features listed above. In particular, we formalize the distinction between commodities and differentiated products. The analysis we present should be viewed as a thought experiment. It demonstrates that the observed pattern of industrial consolidation can be explained using the most basic economic principles, with the addition of a few, quite natural enhancements. The explanation we propose invokes none of the factors that are conventionally invoked to explain why consolidation may dominate contracting: incomplete contracts, transactions costs and contractual hazards. This does not mean that we view these factors as unimportant in the present context. We offer no judgment about the empirical significance of these modern economic explanations relative to the simpler ones that we propose. The point of this paper is to demonstrate that it is not *necessary* to invoke these explanations in order to explain the empirical facts about the evolution of the biotechnology industry.

The paper is organized as follows. The structure of the industry and the recent pattern of mergers and acquisitions are presented in section 2. Section 3 outlines the evolution of intellectual property in agriculture over the course of this century. In section 4, we catalog the economic forces driving consolidation in agricultural biotechnology. Section 5 develops the analytical model. The paper is summarized in Section 6.

## 2. Consolidation in the Agricultural Seed Industry

This section chronicles the rapid consolidation that has occured within the agricultural biotechnology knowledge industry, especially during the last three years. We also report some of the surprisingly high valuations that have been assigned as acquisitions have occured. Table 1 provides

a list of the key consolidations in the industry since June 1995. There are, however, a number of notable omissions from the table. One is the formation of Novartis approximately two years ago through a merger between Ciba Geigy, Sandoz, Ciba Seeds and Northrup-King. Ciba Geigy was a major trait developer and agricultural chemical concern. Ciba Seeds was one of the top seed companies in the world. Sandoz was a very large agricultural chemical company and Northrup-King Seeds was another major natural cornseed retailer. Another omission is the merger between Rhone-Poulenc and AgrEvo to form Aventis.

At the time of many of these acquisitions and mergers, the recorded valuations were surprising. In August of 1996, the announced purchase of Plant Genetics Systems (PGS) for $730 million was made at a time PGS's market capitalization was $30 million. According to AgriEvo, $700 million of the purchase price was assigned to the valuation of the patent-protected trait technologies owned by PGS. The acquisition of Holden's Foundation Seeds by Monsanto may have been even more surprising. Here, a privately owned company, Holden's, with gross revenues of only $40 million, was acquired for a purchase price of $1.1 billion. A principal regulatory issue in this merger was the potential effect that might arise for germplasm access by Monsanto's competing trait developers. Holden's germplasm is widely disbursed throughout the industry and at least one of its elite lines is present in most commercial corn pedigrees. In the case of Monsanto's acquisition of DeKalb Genetics, Monsanto paid not only a control premium of 122% for the 60% of DeKalb that they did not already own, but also indemnified DeKalb against any disapproving regulatory action. At the time of writing this paper, DuPont and Pioneer Hybrid International announced a definitive agreement for DuPont's acquisition for $7.7 billion of the 80% of Pioneer that it did not already own. In this instance, the control premium was only 14%, while the initial premium paid for 20% of Pioneer (purchase price of $1.7 billion) was significantly higher.

These mergers and acquisitions are reflected in the current structures of the cotton, soybean and corn industries. Summaries of these structures are depicted in, respectively, Charts 1, 2 and 3 below. All of the components refer to shares for current commercial activities. There are other trait developers in each of these industries, but they are not currently involved in any commercial transactions. For soybeans and corn, the vertical structure has four components: traits, foundation seed, retail seed and distribution. In the case of cotton, the foundation seed component does not exist, since the foundation seed component of the cotton industry is integrated with retail seed activities.

The chart for cotton (Chart 1) includes Monsanto's proposed divestiture of Stoneville and a Sure-Grow Equivalent Without this divestiture, Monsanto's acquisition of Delta & Pine Land would have meant that Monsanto would control 88% of the current commercial retail seed business. In the distribution component, the introduction of genetic engineering has resulted in competition between agricultural chemical distributors and farmer/dealers. This competition arises, of course, because although some of the new innovations (e.g., Round-Up Ready traits) complement traditional chemistry (herbicides), other innovations (e.g., Bt traits) compete with traditional chemistry (insecticides).

Chart 4 provides further details about the evolution of the corn industry over the last three decades. Note that considerable consolidation has taken place, with Monsanto, Dupont (Pioneer), and Novartis currently representing the dominant retail seed companies. These transformed life science companies are spending huge resources on research and development efforts. In 1997, Monsanto spent almost $1 billion on R&D and had preliminarily planned to spend well over $2 billion if their announced merger with American Home Products had been consummated. In the case of Novartis, their research and development expenditures in 1997 were over $2.5 billion, and they announced

a $50 million initiative on plant genomics alone in 1998. AgriEvo allocated $295 million in 1997, while Rhone- Poulenc spent a similar amount, $219 million.[1]

According to the conventional wisdom, the acquisitions reported in Table 1 were motivated by considerations such as exploiting asset complementarities, mitigating contractual hazards, and/or seeking market power (Graff, Rausser and Small (1998)). The acquirer in virtually all of these transactions was able to demonstrate substantial synergies and efficiencies between agricultural chemicals, biotechnology research, germplasm development and seed retailing. There is, of course, much speculation also about the motivations of the acquirees. In the case of Cargill's exit from the international and domestic retail corn seed industry, two hypotheses have emerged. Some suggest it relates to their lack of research and development and thus their capacity to create and capture value from genetic engineering. Others assert the exit was tied to their litigation risk emanating from new DNA fingerprinting. In the case of DeKalb Genetics, it is hypothesized that simliar concerns of litigation risk as well as the validity of their intellectual property portfolio may have prompted an exit. A lack of many of the complementary assets outlined in Section 3, and the loss of a major trade secret lawsuit to Pioneer provided Holden's with some incentive for merger with Monsanto.

## 3. The Evolution of Intellectual Property

In order to appreciate the relationship between industrial consolidation and research and development, it is necessary to provide some historical perspective on the evolution of intellectual property. (For related discussions see (Moschini and Lapan, 1997) and (Wright and Koo, 1999).) During much of this century, conflicts and disputes have continuously arisen between farmers' and breeders' rights. Up until the 'thirties, farmers' rights generally prevailed. Prior to the development of

[1] Audited data for 1998 is not currently available.

hybrid corn varieties, farmers had direct access to any germplasm that was developed. Attempts to secure premiums or differentiable pricing for new germplasm were generally unsuccessful. Annual crops had short reproductive cycles, and their seeds could easily be saved by farmers. Until the introduction of hybrid corn, these saved-seeds bred true and maintained their productivity. In the case of corn, however, the introduction in the 1930's of hybrid varieties meant that saved-seed was no longer a viable option for farmers. As a result, the biological science of the time allowed private breeders to protect their discoveries and innovations through trade secrecy. Initially, private breeders used public "inbred lines" to develop the parents of their proprietary hybrid varieties. As a result, hybrid corn was the first significant example of intellectual property in the agricultural industry.

The first legislation in the United States to protect the investment of plant breeders came through the Plant Patent Act of 1930. The act protects asexually reproduced varieties, i.e., those that are reproduced by cutting, layering, budding or grafting. The legislation specifies that in order to qualify as intellectual property, the variety must be "distinct" and "new." These requirements are much weaker than those that apply to utility patents. Both kinds of patents are administered by the US Patent and Trademark Office.

It was not until 1970 that protection was provided to sexually reproduced varieties through the Plant Variety Protection (PVP) Act. This act is administered by the USDA, which offers certificates to breeders on the basis of distinctiveness, uniformity, and stability. Infringement covers selling, importing, or sexually multiplying a protected variety. There are, of course, several exemptions allowed under this act. In particular, there is a research exemption, which allows anyone to use a protected seed variety to breed a new variety. Moreover, another exemption allows farmers to save seed for reproductive purposes as well as to sell seed to other farmers whose primary

occupation is growing crops for consumption or feed. The PVP Act was amended in 1994 to eliminate controversial provision allowing the sale of "saved-seed" to others for reproductive purposes. Under this amendment, a farmer can use saved-seed only for his own replantings, and can sell his purchased seed only for purposes other than reproduction. The subsequent court decision "Asgrow Seed Company v. Winterboer" (115 USC 788, 1995) established that agents who sell any amount of seed for reproductive purposes now violate the rights of certificate holders.

With the introduction of modern biotechnology, utility patents have provided stronger intellectual property protection for plant-related innovations. A utility patent is a property right granted by the U.S. Government to inventors to exclude others from imitating, manufacturing, using or selling the invention over a specified period of time. In exchange for this exclusive right, the public receives a detailed description of the invention, so that others can use it after the patent-specified term has expired. To obtain a utility patent, the subject matter must meet certain criteria: it must be novel, non-obvious, useful and amenable to the descriptive requirements of the law.

Until the land-mark Supreme Court ruling in the matter of Diamond v. Chakrabarty (447 U.S. 303 (1980)), plant-related inventions based on genes or cells from nature or applied to living organisms were viewed as natural phenomena and were thus deemed unpatentable. In this case, however, the court held that "anything under the sun that is made by man" is patentable subject matter. Specifically the court found that

> "the patentee has produced a new bacterium with markedly different characteristics from any found in nature and one having the potential for significant utility. His discovery is not nature's handiwork, but his own; accordingly it is patentable subject matter under the section 101."[2]

[2] Diamond v. Chakrabarty (447 U.S. 303 (1980)).

This decision broadened the narrow reach of utility patent laws to encompass living organisms. Accordingly, utility patents are now granted in the U.S. for genetically engineered organisms, for processes that transform cells and express proteins, and for the genes themselves.

Advances in biotechnology have also increased the effectiveness of utility patent enforcement. For example, "bag label contracts" can be better enforced using modern molecular biology techniques for reverse engineering. Pioneer Hybrid International, in a recent suit against its competitors, supported its case with these techniques, alleging that the defendants selected self-pollinated seeds from bags of Pioneer hybrid corn and used them for breeding competitive hybrids. Pioneer alleged that use of seed for breeding violated an implicit contract described on the bag label. In the case of trade secrets, genetic DNA finger-printing was the source of credibility in a case involving Pioneer Hybrid International and Holden Foundation Seeds Incorporated. A 1994 Supreme Court decision found that Holden had violated an Iowa trade secrecy law and required them to pay $48 million to Pioneer.

On the international front, a number of conventions have attempted to rationalize plant-related intellectual property rights. One of the goals of the International Union for the Protection of New Varieties of Plants is to promote the international harmonization of plant breeders' rights by creating a set of uniform and well articulated principles. These principles were first codified in 1961 and subsequently revised in 1972, 1978, and 1991. Current plant breeders' rights in most countries are based on either the 1978 act or the 1991 act.

The 1992 Convention on Biological Diversity focuses on the sovereign rights of genetic resources, arguing that sovereign rights supercede the "common heritage of mankind". This convention offers some protection of farmers' and sovereign rights to plant genetic resources. It does not, however, explicitly recognize such rights. Nor does it specify mechanisms by which right holders will be compensated. In contrast, the trend toward stronger protection for biological innovation is reflected

in the adoption in 1994 by GATT of the Trade Related Intellectual Property Standards agreement (TRIPs). This agreement sets a minimum standard for the protection of living organisms. It also contains a provision protecting trade secrets relating to inbred lines of hybrid varieties. In spite of these provisions, biological processes are not patentable in most countries and the TRIPs agreement is silent in this regard.

The Bayh-Dole Act of 1982 is another piece of legislation which has become important in the formation of plant intellectual property. Supporters of this legislation successfully argued that unless universities have the right to license patentable inventions, many discoveries from federally funded research would never become commercialized. It has been argued that the historical significance of this act is comparable to that of the Land Grant Act that established public universities in each and every state.[3]

The increasing importance of utility patents is revealed in Figure 1. Note also that the protection provided by PVPC certificates has fallen significantly over the course of this decade, from a high of over 300 awarded certificates in 1992 to less than 70 awarded in 1998. Over the same period, the number utility patents issued rose from 48 to almost 500. Further evidence of increased activity and associated R&D efforts is provided by Figure 2, which reports on transgengic releases and notices.

## 4. Economic Forces Driving Consolidation

In this section we focus on the forces in agricultural biotechnology that have led to the consolidation of firms providing basic gene research, transgenic manipulation, germplasm development and seed development. At the end of the section we comment on possible anticompetitive effects of these developments.

[3] Etzkowitz (1998)

4.1. **Changes in the Industry Structure.** The biotechnology revolution has both expanded the assets used in plant breeding and altered the structure of complementarities among more traditional assets. The new market structure of agro-biotechnology can be understood, to a substantial degree, as a response to this new web of asset relationships.

Classical breeding, as practiced from approximately the 1920s through the 1970s (and is still practiced extensively), was undertaken in a technological environment quite different from the current one. The only way to improve traits in a germplasm was to cross elite lines. The hybrid method is a lengthy, tedious process of crossing and back-crossing, utilizing traditional plant breeding skills. Although Mendelian genetics assisted in selecting the varieties to cross, direct use of molecular and cell biology was limited. Commercial firms focussed on the creation and development of elite germplasms, which were separately articulated for different climates and growing conditions.

Classical breeding did not require the profusion of complementary assets, particularly intellectual property, that is required in the current environment. Plant breeders focused on the observable characteristics of plants. These breeders could gain little by joining forces with the scientists working at chemical, pharmaceutical, or other life science companies. Hence seed companies existed substantially as independent corporate entities.

Prior to biotechnology, there were basically two ways of distributing seeds. Some companies (e.g. Holden's Foundation Seed) focused solely on the development of elite lines of foundation seed, which they licensed to independent "mom and pop" distributors, who handled the tasks of multiplying, marketing, and distributing the seed. Several large firms (Pioneer, De Kalb, Garst) integrated breeding and distribution of their own released varieties, leaving only a portion of the final marketing to independent but exclusive sales agents. For crops that could not be crossed to form sterile hybrids, commercial breeding was inhibited by the lack of reliable guarantees against unauthorized

replication. For these crops, private sector activity focused on the distribution of public-domain varieties, typically following minor breeding enhancements

At the present stage of the industry's evolution, creation of varieties depends on general tools of molecular and cell biology. Genetic engineering has increased the complementarity between capacities in plant breeding and capacities in other life sciences. (For an extended discussion of these ideas, see Goodhue (1997) and Goodhue and Rausser (1997)). Tools for plant transformation shorten the time lags associated with plant breeding, increase their precision, and make new breeding programs possible. Thus, legal access to process technologies increases the productivity of an installed research capacity. Conversely, the larger and more sophisticated is a firm's research operations, the greater is the derived benefit from its enabling technologies. Thus, legal access to biotech process technologies and research capacity are complements.

Since the marginal cost of incorporating a trait into a seed is essentially zero, the earnings from licensing the trait are almost entirely a function of market size. Thus, a large marketing network strongly complements a portfolio of traits. Conversely, a marketing network is more valuable (and will be maintained with more confidence), if it is distributing the best available technologies. Thus traits and germplasm complement a network for marketing seeds.

As agriculture became more "information intensive," a complementarity developed between marketing networks and a certain cluster of research-related assets. An expert sales force can collect soil samples and other farm-specific information to aid recommendations about the package of varieties and chemicals that will be optimal for a local growing environment. These data can, in turn, be utilized by a research organization to assist the development of the next generation of technologies. Moreover, under the new regime, traits can be engineered into varieties that confer tolerance to a specific herbicide. These traits then increase the value of a capacity to produce a complementary chemical.

Yet another asset that complements the preceding ones is an installed legal and regulatory capacity. Until the 1980's, legal issues were (relatively) straightforward. Since then, innovators are required to file and defend intellectual property claims over a set of technologies that continually increases in breadth and complexity. They must also interact with government at other levels, such as the agencies that govern releases of transgenic organisms. Moreover, they increase both the number and the complexity of contracts, joint ventures, and strategic alliances with other firms in the industry, and with universities and other non-profit research institutions. All these considerations tend to increase the benefit of legal and regulatory competencies.

4.2. **The *Ex Post* Motive for integration: Complementary Assets.** Motives for integration can loosely be categorized into *ex post* and *ex ante* motives. The former, discussed in this subsection, arise from a desire to use complementary assets efficiently once they have been developed (Milgrom and Roberts, 1995). The latter, discussed in subsection 4.3 below, arise from a desire to avoid ex post "holdup" for licensing fees (Scotchmer, 1991). While these motives to capture value are private ones, they may also result in social benefits. However there is also an anticompetitive motive to create market power beyond that which naturally inheres in intellectual property rights. After tracing the motives for integration and its benefits, we outline some anticompetitive implications which could be masked beneath the rhetoric of enhancing efficiency.

Following Graff et al. (1998), complementary assets include, at a minimum:

1. Research capacity, including the skills and experience of a company's scientists, the competence of its technicians, the power and precision of its laboratory equipment, and so on.
2. Access to research or process technologies for plant transformation, such as techniques for transferring genes into plants (including agrobacterium and bioprojectile methods) and techniques for identifying useful genes (sequencing, molecular markers, etc.).

3. Access to traits and enhancements (Bt corn-borer resistance, herbicide tolerance, longer shelf life, etc.).
4. Elite germplasm, i.e., "the rest of the plant," into which gene technologies are introduced to create genetically engineered crop varieties.
5. Crop varieties. Each variety is bred from elite lines, adapted to local conditions of soil and climate, and possibly includes traits introduced through genetic engineering.
6. The capacity to produce non-biological agricultural inputs, particularly chemical fertilizers, herbicides and pesticides. These inputs may be complementary to seed-embodied traits (such as the herbicide that crops are engineered to tolerate); or may be stand-alone inputs (biopesticides, soil treatments, etc.)
7. A distribution network for seeds and other inputs, which provide the point of contact with farmers.
8. Farms, which convert the inputs into commodities and/or differentiated products.
9. Capacities for processing, marketing, and distributing agricultural output, including brand name products (e.g. FlavrSavr).
10. Legal and regulatory competencies. This category encompasses the expertise and relationships needed to deal with the complex requirements of the several government agencies that regulate agricultural biotechnology.[4] It also includes the capacity to litigate intellectual property infringement claims, and to negotiate advantageous contractual relationships.

Some of these assets are physical or human capital. Others, however, depend for their existence and tradability on and made tradable by the existence of intellectual property rights. For example, asset classes 2 and 3 are often patentable, while class 5 may be protected under the PVPA.

[4] These include, in the United States, the Food and Drug Administration, the Environmental Protection Agency, the Patent and Trademark Office, and several agencies within the Department of Agriculture.

Figure 4 indicates the steps that must be followed from gene discovery to capturing market value. Each of these steps needs formidable assets for implementation. For example, "field test" refers to the extensive corn breeding programs at multiple stations that are operated by the national companies. Pioneer has 50 seed research stations in the United States and Canada, 28 of which conduct research on corn. It has 43 research locations outside the U.S.[5] DeKalb has 36 research locations in the United States and Canada.[6] In addition to the national seed company breeding programs, approximately 25-30 regional seed companies have breeding programs. These are smaller than the national programs (involving 1-3 breeding stations) but each company each year produces several proprietary inbreds which can be manipulated with inbreds from other sources to produce a proprietary hybrid product.

In agricultural biotechnology, the tasks of basic gene research, transgenic manipulation, commercial germplasm development, and hybrid seed production are in some cases integrated into single firms, but are mostly separated. Mycogen pursues all four, but until recently, DuPont was mostly involved in basic gene research and transgenic manipulation. Transactions to share assets can either be coordinated within the boundaries of a single firm, accomplished through mergers, or facilitated by licenses.

4.3. **The *Ex Ante* Motive for Integration: Spillover Benefits.** Research into molecular genetics, including gene mapping and molecular markers, might lead to improved methods of traditional plant breeding, as well as trait development. When an innovation has spillover benefits for other innovations—for example, it could reduce their cost or provide a necessary foundation—then from a social perspective, the first innovator should share in the profits from subsequent inventions. Otherwise the earlier innovator will have deficient incentives to invest. Only if the second invention

[5] Pioneer (1996)
[6] DeKalb (1996)

infringes the first patent will the second party be induced to share his profit with the original innovator. On the other hand, if the later innovator knows he will infringe a prior patent, he may be dissuaded from investing by the threat of ex post holdup for high licensing fees. This hazard, which might otherwise stifle second-generation products, can be at least partially overcome if, before the second firm invests, the firms have already established a licensing agreement. The hazard can be overcome even more efficiently if the potential sequential innovators actually merge. This is the ex ante motive for integration mentioned above.

4.4. **Consolidation versus Licensing.** Intellectual property rights do not, by themselves, assure the capture of value. This can be either because complementary assets are not combined efficiently (Teece, 1986), or because the joint profit available from a cumulative line of research is not divided such that the R&D cost of each innovator is covered (Green and Scotchmer, 1995). Both problems can arise in agricultural biotechnology. Even if a new and valuable trait is protected by an intellectual property right, it cannot generate value without being incorporated in commercial seed lines, which are produced and sold to farmers. The trait developor will be unwilling to invest if he expects that most of the value will be captured by the seed lines instead of his own company.

Integration helps the firms capture rents from an innovation. Theoretically, integration could occur either through merger or licensing. However, the cost and limitations of licensing are not trivial, and they increase dramatically in rapidly changing environments. In environments characterized by substantial uncertainty and infrequent contract negotiations, it is impossible to write complete, contingent contracts and very costly to write incomplete, but reasonably comprehensive contingent contracts. As a result, contracts written in such environments often give rise to poorly aligned incentives to undertake R&D investments, and may result in costly renegotiations. In this respect, the agricultural biotechnology industry is a textbook example of a case in which the efficiencies of consolidation dominate the benefits derivable from contracts. The problems are compounded by

difficulties of monitoring effort and by long delays between investments and results. In addition, there are the usual problems of finding terms that satisfy all parties. When a new trait is introduced, the germplasm supplier may prefer licensing with a low royalty in order to expand the market share of the germplasm supplier. The trait developer may prefer a higher royalty (and thus higher price) in order to maximize trait revenues. A fixed fee in addition to royalties might mediate this conflict, but the trait developer might resist a fixed fee until he knows the extent of the market.

4.5. **Anticompetitive Effects of Integration.** So far we have taken the view that integration is economically healthy because it allows the joint use of complementary assets, and mediates conflicts in intellectual property. However, a concern of the antitrust authorities is that market power should not be extended beyond that which was intended by the Congress in granting intellectual property protection.

A potential anticompetitive effect arises when firms have intellectual property on traits and research tools that are *substitutes* rather than *complements*. Examples of substitutes are the many patents that have issued on herbicide-tolerant traits and on the several competing technologies for inserting genes into germplasms. Integrating ownership of substitute traits or substitute research tools would surely result in the kind of anticompetitive effect that the antitrust authorities seek to avoid. A natural question is whether such integration has occured in agri-biotechnology.

Although there is no empirical evidence to support this assertion, there is potential for anticompetitive effects in certain industry practices. One possibility concerns no-stacking licenses, whereby a trait developer licenses his trait to a germplasm company with the restriction that the germplasm company cannot "stack" the traits of other developers onto the same germplasm. With the no-stacking provision, each trait developer ties up the germplasm company as his exclusive customer. The no-stacking provision prevents the germplasm company from shopping around for the cheapest

price on, say, a Bt license, with the result that the license price for Bt is no longer kept low by competition. The no-stacking provision does not create the same kind of mischief with complementary traits as with substitute traits, since complementary traits would not compete away each other's profits even with free entry. Further, the no-stacking provision can be renegotiated with the consent of all parties when it is convenient to combine complementary traits of several developers in a single germplasm. Nevertheless, a reason to introduce the no-stacking provision when licensing complementary traits is that the provision looks innocuous, but carries over to *substitute* traits, where it is not innocuous.

Similar anticompetitive effects might alternatively arise from vertical merger, which is sometimes also thought innocuous. Suppose that there are two vertically merged firms, each consisting of a trait developer and a germplasm company, and each owning one complementary trait (sweetness, protein) and one substitute trait (two versions of the same herbicide resistance). The two vertically integrated firms can cross license their complementary traits at high enough royalties to overcome the restraint on profit that might otherwise arise due to competition on the substitute traits. The market outcome would likely be different if, for example, the trait developers licensed their traits unbundled and nonexclusively at royalty rates of their own choosing.[7]

Finally we notice that entry is limited for reasons other than intellectual property, and that all restrictions on entry can lessen competition. Three other types of entry barriers are technical, regulatory, and economic. Each of these corresponds to a different type of market power, and creates a different policy challenge.

On the technical side, a firm might control a "bottleneck" asset that cannot independently be developed by competitors through normal capital investment. The bottleneck could be an inelastically supplied input, such as, for example, the supply of plant biologists. If their wages are bid

[7] These thoughts should be regarded as preliminary. The authors intend to develop them in subsequent drafts of the paper.

up, the market supply can only respond with a lag. Regulatory barriers include health and safety regulation and field testing permits, the absence of which can retard the introduction of new varieties. Economic barriers arise from increasing returns to scale. With increasing returns, the market may have a sole provider, since a sole provider can supply the market more cheaply than several firms. Obviously, the problem with a sole provider is that it is not disciplined by competition. The welfare benefits of efficient production are compromised by the ability of a sole provider to exploit monopoly power.

Scanning down the list of ten assets that are used in the agronomic systems industry, at least five pose no significant barriers to entry for a firm with sufficient incentive and capital. These include research capacity; legal/regulatory capacity; access to a marketing network for inputs; production capacity on farms; and access to processing, marketing and distribution networks for agricultural outputs. All can be built up through appropriate investment. Accumulation of the other five assets - access to process technologies; access to individual patented plant traits; use of elite germplasm; ability to market a diversity of enhanced crop varieties; and capacities in the manufacture of other agricultural inputs - are all restricted by intellectual property laws.

The remaining classes of assets - process technologies; elite germplasm lines; and capacity in other agricultural inputs - are therefore places to look for possible monopolization. Fundamentally new process technologies appear only rarely. Elite germplasm lines can only be developed through slow processes of breeding; their supply can be treated as nearly fixed in the short run.[8]

[8] Pioneer Hybrid recently took fifteen years to develop a single new elite line of corn germplasm, adapted to tropical conditions (Salhuana, pers. comm.)

## 5. A Model: Merger with Complementary Assets

A striking characteristic of the trend towards integration in the agricultural biotechnology industry has been that firms have tended to buy each other outright. Alternative forms of integration include profit sharing arrangements, equity swaps and licensing arrangements with royalties, in which one firm cedes its intellectual property to another in return for a percentage of sales. Our objective in this section is to investigate the predominance of buyouts over other alternatives. In a very stylized, abstract model, we compare two extreme forms of integration, which we refer to as "licensing" and "merger." A licensing contract specifies that the licensor will receive a fixed percentage of revenues earned by the licensee. In a cash buyout, the acquiring firm pays the acquiree an amount that does not depend on future profits earned by the consolidated firm.

Since most of the objectives for consolidation discussed above can be accomplished with either form of contract, these objectives should therefore not be the focus in an explanation of why firms prefer mergers to licensing. However there is one feature of the industry that does, in fact, lead to a preference for merger. That feature is the salient characteristic of the vignette reported on page 2, in which two firms disagreed about which of them could more successfully manage their combined assets. When such disagreements arise, there may be circumstances under which firms can agree to merge through a cash buyout, but cannot agree to integrate based on a licensing arrangement.

Such circumstances may arise whenever firms have heterogeneous beliefs about their respective management abilities. In particular, suppose that each firm has a great deal of faith in its own abilities, while suspecting that the other firm is managerially incompetent. In this case, the two firms will have very inconsistent beliefs about the future performance of the firm under alternative management teams. The licensor (irrespective of which firm it is) may be so pessimistic about the likely future revenue stream of the firm under the licensee's management that it will demand a very

high royalty rate as a precondition for agreement. This rate may prove to be prohibitively high. Now consider the possibility of a merger through cash buyout. Provided that the buyer's faith in *its own* abilities to generate future profits is sufficiently high that a merger seems profitable even after the seller's reservation price has been paid, then there will be joint surplus to be divided, regardless of whether the seller believes that the buyer's optimism is warranted. Provided the seller is paid on a lumpsum basis, it's own beliefs are completely irrelevant to whether or not a deal can be reached.

The above idea can be illustrated by a simple numerical example. The example is completely symmetric: each agent has the same reservation profit level and the same beliefs about expected performance, depending whether or not the agent itself is in control. For $i = 1, 2$, suppose that party $i$ believes that expected annual profits will be \$9m per year if $i$ itself controls the management of the joint enterprise, but only \$6m per annum if $j \neq i$ is in control. Suppose also that $i$'s reservation profit level is \$4m. In this case $i$ will be willing to cede control of the joint process to $j$ in exchange for royalty revenues only if it can negotiate a sharing arrangement in which $i$ receives at least 2/3 of every dollar of profit earned. In this case, $i$ will earn at least 2/3 of \$6m p.a., which is at least $i$'s reservation profit level of \$4m p.a.. This leaves 1/3 of every dollar earned for $j$. Even though $j$ expects the much higher annual profit of \$9m per year, 1/3 of this amount (\$3m) is an insufficient incentive for $j$ to accept the agreement. In sum, because $i$ is so pessimistic about $j$'s ability to deliver, the minimal *share* of profits that $i$ will accept is so great that the residual share is insufficient to satisfy $j$, even given $j$'s more optimistic assessment of the future. Hence a royalty arrangement will not be consummated. Now consider a consolidation in which $i$ cedes control over its asset in exchange for an up-front, lump-sum payment. Any payment over \$4m will be sufficient to induce $i$ to sell out, while $j$ will be willing to pay up to \$5m in order to acquire $i$. In this case, the necessary conditions for an agreement to emerge are satisfied. Thus, the difference between

royalty and buy-out agreements is that for royalties but not buyouts, what matters to each $i$ is $i$'s own evaluation of how well $j$ can perform.

5.1. **The "commodity" world.** To relate the above ideas to the developments described in the preceding sections, we develop a very stylized model. Our analysis starts by formalizing the distinction introduced on page 1 between a world of "commodities" and a world of "differentiated products." In the latter world, but not the former, a manager can create a market for its newly differentiated product, but the extent of this market depends on managerial skill. In this context, different agents can reasonably have different beliefs about the relative effectiveness of different management teams. Within these two worlds, we will explore the different relationships between intellectual property, beliefs and industry structure.

We consider a two-tiered production process and three alternative ways of structuring it. Two of these involve vertical integration—between a trait developer and a seed producer—and the third does not. Vertical integration can be accomplished either by contracting (i.e., exclusive licensing) or by consolidation (i.e., mergers and acquisitions). If the two tiers are *not* integrated, then they are linked together through non-exclusive licensing agreements. In each of the proposed industry structures, we consider a regime in which intellectual property rights are clearly articulated (the *IP*-regime) and one in which they are not (the *NIP*-regime). (Of course, this distinction is unnecessarily stark. More realistically, think of the *NIP*-regime as representing the period when agricultural intellectual property was weakly protected under the PVPA, and of the *IP*-regime as representing the later period when property rights were more clearly articulated through utility patents.) In the differentiated product world, and within the *IP*-regime, we further distinguish between two cases, depending on the nature of agents' beliefs about the critical endogenous variables which determine profitability: in one case, these beliefs are homogeneous; in the other, they are heterogeneous. The tree of different possibilities we consider is represented schematically in Figure 5.

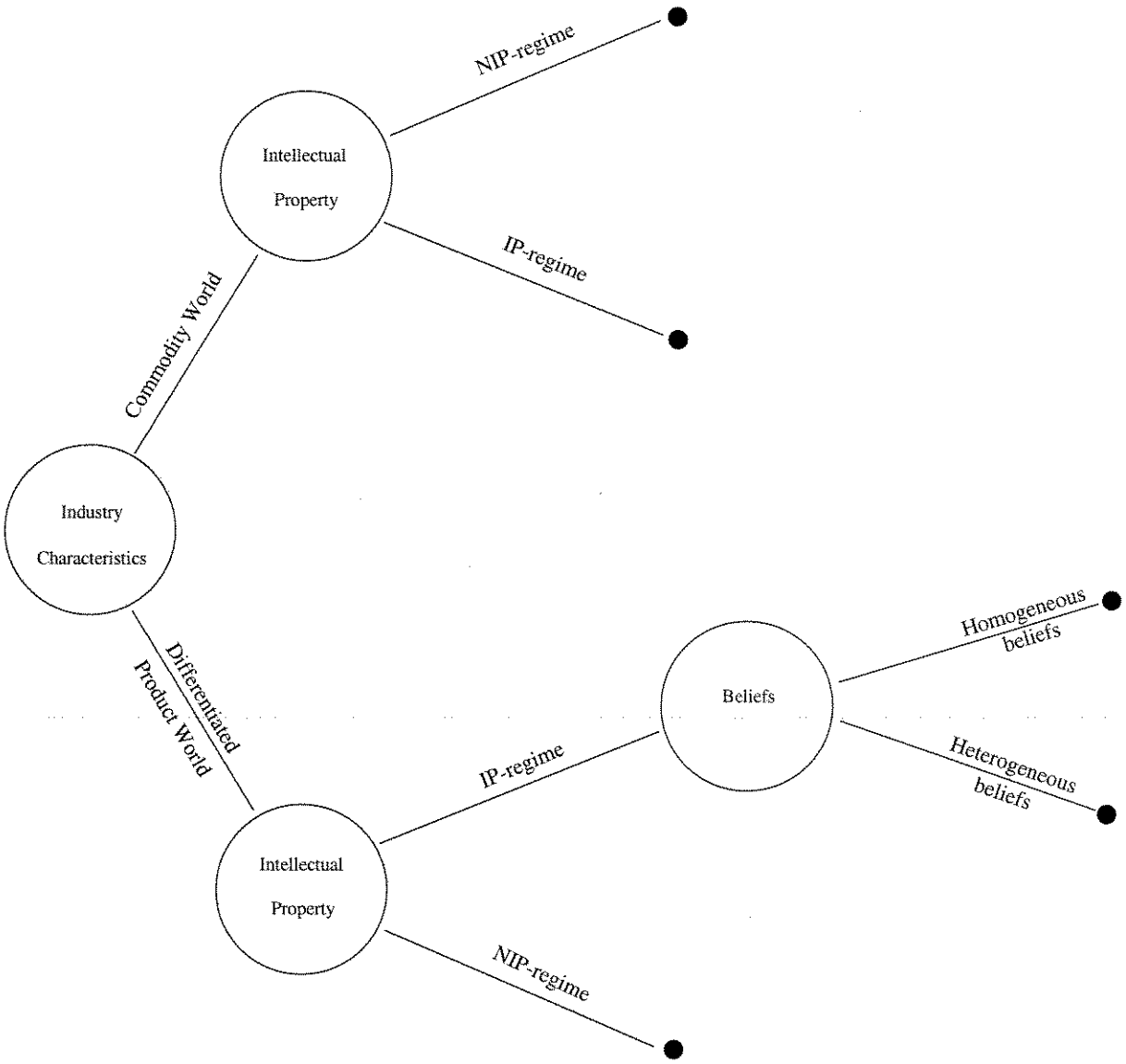


FIGURE 5. Tree of Possibilities

We focus our attention narrowly on two questions: (a) what "drives" vertical integration in this industry and (b) if integration occurs, does it occur through contracting or consolidation? We have designed our model to investigate whether there is anything which consolidation can achieve which contracting cannot. We consider a model in which markets are open for two periods. In the commodity world, all market parameters are identical in each period. In the first period, a single agent develops an R&D product called a *trait*, incuring a fixed cost of $\tilde{F}$ and zero marginal cost.

(Throughout this and the next subsection, symbols adorned by tildes (˜) are associated specifically with the "commodity" world while symbols adorned by hats (ˆ) are associated specifically with the "differentiated product" world.) What happens in the second period depends on whether or not intellectual property rights are clearly articulated. If they are (the *IP*-regime) the trait developer attains a patent and retains his monopolistic status in the second period; if they are not (the *NIP*-regime) other suppliers will imitate the trait developer's product in the second period, and price competition will drive the equilibrium price of licenses, and hence equilibrium profits for the trait developer, to zero.

Two agents produce *seed* according to the supply function $s_1 q$, where $s_1 > 0$. (To minimize notation, we assume that the trait development incurs no marginal costs and that seed producers incur no variable costs. The fundamental properties of the model would remain the same if we included these additional cost factors.) This product is sold directly to growers, either as *augmented seed*, which has the trait inserted, or as *basic seed*, which does not. Demand for basic seed is perfectly elastic at a price of $\bar{p}^{\mathcal{B}} > 0$.[9] Each producer who supplies this market earns a profit of $\bar{\pi}^{\mathcal{B}}_{\mathsf{sd}} = (\bar{p}^{\mathcal{B}})^2/(2s_1)$ per period. The demand for augmented seed is given by given by $\tilde{d}_0 - d_1 p^{\mathcal{A}}$, where $d_1, \tilde{d}_0 > 0$. (Except that in fact seed is sold to growers by independent distributors, the structure we model matches reasonably closely the actual structure of the cotton seed industry (see Chart 1).)

In order to sell augmented seed, suppliers must obtain a license from the trait developer. We assume initially that licenses are *non-exclusive*, i.e., available on the same terms to all seed suppliers. As is the current practice in the industry, we assume that the per-unit license fee, $\ell$, is passed on directly to growers. That is, the supply function for agumented seed is $\ell + s_1 q$.

[9] This is, obviously, not representative of reality, but, once again, we justify the assumption on the grounds that it simplifies our arithmetic.

We assume that if both seed producers participate in the market for augmented seed, they will compete-by-price and the equilibrium in this market will coincide with the competitive equilibrium.[10] The competitive equilibrium price of the augmented product, given that non-exclusive licenses are priced at $\ell$, is $\bar{p}^{\mathcal{A}}(\ell) = \frac{\tilde{d}_0 s_1 + 2\ell}{2 + d_1 s_1}$. Each producer produces the quantity $q^{\mathcal{A}}(\ell) = \frac{\tilde{d}_0 - d_1 \ell}{2 + d_1 s_1}$ and earn profits of $\bar{\pi}^{\mathcal{A}}_{\mathsf{sd}}(\ell) = \frac{s_1}{2}\left(\frac{\tilde{d}_0 - d_1 \ell}{2 + d_1 s_1}\right)^2$.

We assume that $\tilde{d}_0$ is sufficiently large that if the price of licenses is sufficiently low, it is more profitable to sell augmented seed than basic seed. That is, we assume $\bar{\pi}^{\mathcal{A}}_{\mathsf{sd}}(0) > \bar{\pi}^{\mathcal{B}}_{\mathsf{sd}}$. Define $\ell^* > 0$ by the condition that $\bar{\pi}^{\mathcal{A}}_{\mathsf{sd}}(\ell^*) = \bar{\pi}^{\mathcal{B}}_{\mathsf{sd}}$. That is, $\ell^* = \frac{\tilde{d}_0}{d_1} - \bar{p}^{\mathcal{B}}\left(1 + \frac{2}{d_1 s_1}\right)$. Clearly, it will be more profitable to produce for the augmented market than the basic market if and only if $\ell < \ell^*$. Thus, the derived demand schedule for the trait, $x^d(\ell)$, is zero if $\ell > \ell^*$. Otherwise, $x^d(\ell) = q^{\mathcal{A}}(\ell) = \frac{\tilde{d}_0 - d_1 \ell}{2 + d_1 s_1}$. We assume that the sole trait developer is a monopolistic supplier of licenses, and hence sets the license price at $\bar{\ell}^{\mathcal{A}} = \min\left[\frac{\tilde{d}_0}{2d_1}, \ell^*\right]$.[11] The seed providers' outside option of supplying the basic market will be binding, provided that $\bar{p}^{\mathcal{B}} \geq \frac{\bar{p}^{\mathcal{B}}}{2(d_1 + 2/s_1)}$. We assume that this inequality is satisfied. In this case, each seed provider supplies $q^{\mathcal{A}}(\ell^*) = \frac{\bar{p}^{\mathcal{B}}}{s_1}$ and earns profits of $\bar{\pi}^{\mathcal{A}}_{\mathsf{sd}}(\ell^*) = \frac{(\bar{p}^{\mathcal{B}})^2}{2s_1}$. The trait developer's profit from selling non-exclusive licenses is

$$\bar{\pi}^{\mathcal{A}}_{\mathsf{tr}} \quad = \quad 2\bar{\ell}^{\mathcal{A}} q^{\mathcal{A}}(\bar{\ell}^{\mathcal{A}}) - \tilde{F} \quad = \quad \frac{2\bar{p}^{\mathcal{B}}}{d_1 (s_1)^2}\left(\tilde{d}_0 s_1 - \bar{p}^{\mathcal{B}}(2 + s_1 d_1)\right) - \tilde{F} \tag{1}$$

Intellectual Property: In an *intellectual property* regime (*IP*-regime), the analysis of the second period will be exactly the same as in the preceding subsection. In particular, the supplier will earn

[10] In this context, with upward-sloping supply, the Nash equilibrium for the classical Bertrand price-competition model does *not* coincide with the competitive equilibium. However, several authors ((Dubey, 1982), (Simon, 1984) among others) have constructed strategic market games in which price competition delivers competitive outcomes, provided there are at least two active agents on each side of the market.

[11] That is, the trait developer's (*untruncated*) marginal revenue function is $\frac{\tilde{d}_0 - x^d}{d_1}$. Since the supplier's marginal cost is zero, the untruncated output solution is $\tilde{d}_0$, for which the market clearing license fee is $\frac{\tilde{d}_0}{2d_1}$, provided of course that this fee is no greater than the fee $\ell^*$ at which seed providers can do equally well supplying the market for basic seed.

profits of $\bar{\pi}^{\mathcal{A}}_{\mathsf{tr}}$ in each period, if it sells licenses on a non-exclusive basis. In a *no intellectual property* regime (*NIP*-regime), other suppliers will imitate the trait developer's product in the second period, and price competition will drive the equilibrium price of licenses, and hence equilibrium profits for the trait developer, to zero.

Integration through exclusive licensing: As an alternative to marketing its product nonexclusively, the trait developer can negotiate an exclusive arrangement with one of the seed providers. In this case, augmented seed will be monopolistically supplied in the final market. Since we are in an IP-regime, monopoly power will be retained in the second period.

We do not attempt in this paper to model the negotiation process by which the *level* of the exclusive license is determined. Our narrower objective is to identify the range of parameters for which the incentives for integration are sufficient to warrant an exclusive arrangement. We assume that when considering an exclusive agreement, the two parties first determine the price and output levels that maximize their joint profits $\tilde{\pi}^{\mathcal{M}}_{\Sigma}$ (i.e., the monopolistic outcome). An agreement will be negotiated if and only if there is a division of profits, $(\lambda_{\mathsf{tr}}\tilde{\pi}^{\mathcal{M}}_{\Sigma}, \lambda_{\mathsf{sd}}\tilde{\pi}^{\mathcal{M}}_{\Sigma})$—where $\lambda_{\mathsf{tr}}$ is the trait developer's share and $\lambda_{\mathsf{sd}}$ is the seed producer's share—such that each party's share exceeds its *reservation share* level.

The trait developer's reservation share is determined by its profit $\bar{\pi}^{\mathcal{A}}_{\mathsf{tr}}$ from licensing nonexclusively to both seed providers. The seed provider's reservation level is the profit $\bar{\pi}^{\mathcal{B}}_{\mathsf{sd}}$ from supplying the basic (non-augmented) product or, equivalently since $\bar{\pi}^{\mathcal{B}}_{\mathsf{sd}} = \bar{\pi}^{\mathcal{A}}_{\mathsf{sd}}$, its profit in the augmented market under a nonexclusive licensing agreement, when the license fee is set at $\bar{\ell}^{\mathcal{A}}$, defined above (page 26). For $i = \mathsf{tr}, \mathsf{sd}$, define $\tilde{\lambda}_i$ by $\tilde{\lambda}_i\tilde{\pi}^{\mathcal{M}}_{\Sigma} = \bar{\pi}^{\mathcal{A}}_{i}$. Clearly, party $i$ will weakly prefer integrating to not integrating, provided that its share of joint profits is at least $\tilde{\lambda}_i$. Hence a necessary condition for an exclusive licensing agreement to emerge is that $\tilde{\lambda}_{\mathsf{tr}} + \tilde{\lambda}_{\mathsf{sd}} \leq 1$. Note that in the present, perfect information, context, this condition will be satisfied if and only if $\bar{\pi}^{\mathcal{A}}_{\mathsf{sd}} + \bar{\pi}^{\mathcal{A}}_{\mathsf{tr}} \leq \tilde{\pi}^{\mathcal{M}}_{\Sigma}$. In a

commodity world, the joint monopoly price for the augmented product is $\tilde{p}^{\mathcal{M}} = \frac{\tilde{d}_0(1+d_1 s_1)}{d_1(2+d_1 s_1)}$. Joint monopoly output is $\tilde{q}^{\mathcal{M}} = \frac{\tilde{d}_0}{2+d_1 s_1}$ and joint monopoly profits are $\tilde{\pi}_{\Sigma}^{\mathcal{M}} = \frac{\tilde{d}_0^2}{2d_1(2+d_1 s_1)} - \tilde{F}$. Combining this expression with the expressions for $\bar{\pi}_{\mathsf{sd}}^{\mathcal{A}}$ and $\bar{\pi}_{\mathsf{tr}}^{\mathcal{A}}$ on page 26, we obtain:

$$\tilde{\pi}_{\Sigma}^{\mathcal{M}} - (\bar{\pi}_{\mathsf{sd}}^{\mathcal{A}} + \bar{\pi}_{\mathsf{tr}}^{\mathcal{A}}) = \frac{(x-y)(3x-y) + 2(\bar{p}^{\mathcal{A}})^2(2+d_1 s_1)}{(2d_1(s_1^2)(2+d_1 s_1)}$$

$$\text{where } x = \bar{p}^{\mathcal{A}}(2+d_1 s_1) \text{ and } y = \tilde{d}_0 s_1.$$

Clearly, then, a sufficient (but not necessary) condition for integration to occur is that either $x > y$ or $3x < y$. {Explain what this means in terms of relationship between $\bar{p}^{\mathcal{A}}$ and $\tilde{d}_0$.}

*NB*

We now address the question of whether or not in the present framework, the decision to integrate via licensing is driven by intellectual property. In the *NIP*-regime, an exclusive licensing agreement can be sustained only in the first period; in the second period, competition between trait developers will dissipate monopoly rents. In the *IP*-regime, the exclusive arrangement can be maintained for both periods. However, in the present context, the second period is a mirror image of the first. The trait developer will weakly prefer an exclusive arrangement in the first period if and only if it prefers it in both periods. We have established, therefore, that

**Proposition 1.** *In a* commodity world, *the choice between licensing exclusively vs non-exclusively does not depend on intellectual property considerations.*

Integration through Consolidation: So far in the model, whatever can be accomplished by an exclusive licensing agreement can also be accomplished through consolidation. By construction, if the trait developer merges with one of the seed producers, the two parties can exactly duplicate the outcome and sharing arrangement obtained under the exclusive licensing arrangement. Thus

**Proposition 2.** *In a* **commodity world**, *integration via consolidation and integration via exclusive licensing yield identical outcomes.*

5.2. **The "differentiated product" world.** We now move from a world in which augmented seed is viewed as "commodity" to one in which it are viewed as a "differentiated product." We use these terms in an highly specific way. For our purposes, the sole distinction is that in the former, the demand for, and the technology for providing, the object is exogenously fixed, while in the latter, both demand and technology are at least to some extent are dependent on the actions taken by producers. For a commodity—for example "Number 2 Red Winter Wheat"[12]—a well-defined demand schedule is already in place. There is no need to develop, say, a marketing plan for Red Winter Wheat, since demand is what it is: it does not respond to efforts by market participants to change it. For a differentiated product, however, significant resources must be devoted to "developing a market for" or "capturing the value of" the product. It is not enough simply to supply the product; one must also create a demand for it. By the same token, for a commodity, the fixed operating costs that a producer faces are truly fixed, while for a differentiated product, the magnitude of these fixed costs can be modified by management effort. In particular, in the production of augmented seed, there are production complementaries that may or may not be exploited, depending on the nature of the relationship between the trait developer and the seed provider and the expertise of the managers that oversee the relationship.

We formalize these distinctions in a very specific way. We will represent both the demand intercept for augmented seed, and the fixed cost of producing the trait, as random variables governed by "subjective" distributions. Specifically, both the trait developer and seed provider hold beliefs about these variables, and these subjective beliefs may vary, depending on which party's management controls production and marketing operations. We first consider the case of homogeneous beliefs:

[12] Debreu (1959)'s example of a commodity in the Theory of Value

both parties agree upon the relationship between their respective management skills and the random variables under consideration. We then introduce heterogeneity: specifically, we consider what happens when each party views its own management team as better equipped than the other to realize the differentiated product's market potential.

The primary conclusion of this section is that under homogeneous beliefs, consolidation and exclusive licenses remain equivalent routes to integration while under sufficiently heterogeneous beliefs, the consolidation route will dominate the licensing route. Party $i$ (either the trait developer or the seed producer) may be unwilling to cede control over its component of the joint product (i.e., augmented seed) to party $j$ through a licencing agreement, because it lacks the faith that $j$ will be able to "capture the value" inherent in the joint relationship. If party $j$ is to manage the production and marketing process, party $i$'s subjective expectation of its royalty revenues may be sufficiently pessimistic that no licensing agreement will be feasible. If $i$ is absorbed by $j$ through a merger, on the other hand, then $i$'s expectations about $j$'s management skills will no longer matter. Party $i$'s compensation will be based on $j$'s confidence about $j$'s own abilities: $i$ may not believe that the performance of the consolidated company will live up to $j$'s expectations, but $i$ will no longer care about performance, since it will have been already been compensated.

Modelling differentiated products: To model the ideas discussed above, we introduce two modifications to the basic structure presented on page 24. Under certain circumstances, we will replace the exogenously specified demand intercept $\tilde{d}_0$ and fixed cost parameter $\tilde{F}$ with the variable intercept $\hat{d}_0(\theta;t)$ and variable fixed cost $\hat{F}(\theta;t)$, where $\theta \in [0,1]$ is a random variable measuring *management quality* and $t \in \{1,2\}$ indicates the period. The two parameters vary with $\theta$ only in period two. That is, for all $\theta$, $\hat{d}_0(\theta;1) = \tilde{d}_0$ and $\hat{F}(\theta;1) = \tilde{F}$. On the other hand, we assume that $\hat{d}_0'(\cdot,2) > 0$ and $\hat{F}'(\cdot,2) < 0$. That is, higher quality management of the integrated operation can do a better job of

"creating a market" for augmented seed, and can better exploit synergies and complementarities in its production. These benefits, however, take time to materialize.

Obviously, like any other input, management effort is costly. For simplicity we will ignore these costs. Moreover, the costs and benefits of creating value through shifting the demand intercept will vary depending on market structure. In particular, management's incentives to create value will be sharply diminished under a non-exclusive licensing agreement, since in this case the benefits of each producer's efforts will partially accrue to the other producer. Opportunities to exploit production synergies will similarly be diminished unless integration occurs, because the degree of cooperation required to develop these synergies would be difficult to maintain without exclusive arrangements.

In reality, the effect of market structure on the role played by management will be quantitative rather than qualitative. To focus our analysis more sharply, however, we will model this effect as binary. We assume that in the absence of integration, the demand intercept and fixed cost parameter remain constant at $\tilde{d}_0$ and $\tilde{F}$. The modifications described above apply only if integration occurs, either through consolidation or exclusive licensing.

Party $i$'s beliefs about $\theta$ when party $j$ controls the management are given by the probability distribution $g_{ij}(\theta)$. Under *homogeneous beliefs*, $g_{ij}(\cdot) = g_{jj}(\cdot)$, i.e., both parties agree on the (random) quality of party $j$'s management ability. We will assume that in this case, the common belief is that management can improve matters on average, i.e., that $E^2_{ii}\hat{d}_0 = \int_{[0,1]} \hat{d}_0(\theta;2)g_{ii}(\theta)d\theta > \tilde{d}_0$ and $E^2_{ii}\hat{F} = \int_{[0,1]} \hat{F}(\theta;2)g_{ii}(\theta)d\theta < \tilde{F}$. Under *heterogeneous beliefs*, we presume that each party has greater confidence in its own management team than in the other party's, i.e., that for each $i$, $E^2_{ii}\hat{d}_0 > E^2_{ij}\hat{d}_0$ while $E^2_{ii}\hat{F} < E^2_{ij}\hat{F}$. We assume that all parties are risk-neutral expected profit maximizers.

Incentives for integration under the *NIP*-regime: If the trait developer cannot obtain a patent for its product, then the distinction between the commodity world and the differentiated product world evaporates. In the second period competitition between the original producer of the trait and its imitators will drive license fees to zero. Neither an exclusive licensing agreement nor consolidation will extend market power into the second period, since each seed provider can integrate with a different trait developer. Hence whether or not integration occurs will depend only on first period market considerations.

**Proposition 3.** *In the* NIP*-regime, the differentiated product world yields exactly the same conclusions as the commodity world. In particular, the choice between licensing exclusively vs non-exclusively does not depend on intellectual property considerations. Moreover, integration via consolidation and integration via exclusive licensing yield identical outcomes.*

Incentives for integration under the *IP*-regime with homogeneous beliefs: When management quality affects market performance in the second period, intellectual property *may* affect the decision to integrate or not integrate, but once again, the effect of integration is the same, whether it occurs through consolidation or contracting. Specifically, in either case, expected monopoly profits are $E\hat{\pi}_{\Sigma}^{\mathcal{M}} = \frac{\tilde{d}_0^2 + E_{ii}^2 \hat{d}_0^2}{2d_1(2+d_1 s_1)} - \left(\tilde{F} + E_{ii}^2 \hat{F}\right)$. By assumption, management efforts both increase demand and lower fixed costs on average. Hence, expected second period profits will exceed first period profits. Recall that this profit increment arises only if integration occurs. Thus, there is a range of parameter values for which the necessary conditions for integration will not be satisfied based on first-period considerations alone, but when the additional second-period benefits of integration are taken into account, an exclusive arrangement will prove feasible. (The above argument clearly relies upon our rather blunt distinction between the roles of management with and without integration. The same result would apply, however, although for a narrower range of parameters, if management

incentives to create value and exploit synergies were merely diminished, rather than extinguished, in the absence of integration.)

As we have noted, these improved profits can be secured only if intellectual property rights extend the trait developer's status as the unique supplier into the second period. Hence whe have established that under the differentiated commodity world, intellectual property rights may drive integration.

**Proposition 4.** *In a differentiated product world, there are parameter values for which integration is feasible in the* IP*-regime but not in the* NIP*-regime.*

Up to this point in the analysis, there has been nothing in our model that distinguishes the incentives for integration via consolidation from the incentives for integration via exclusive licensing. Hence, so far, the *form* of integration does not depend on intellectual property, only the issue of whether or not integration occurs.

Incentives for integration with heterogeneous beliefs: Once heterogeneous beliefs about management are introduced, the equivalence between the two forms of integration breaks down. Recapitulating the argument, the distinction turns on the issue of control. Under an exclusive licensing agreement, both parties maintain a stake in the performance of the company, and if neither party has sufficient faith in the other's ability to deliver the requisite management skills, the subjectively evaluated surplus may be insufficient to warrant integration. For *consolidation* to occur, however, it is not necessary that both parties share an optimistic assessment of the acquiring party's management skills. Provided that at least one party has sufficient faith in its own management abilities to warrant consolidation, the other will be willing to cede control in exchange for compensation that does not depend on the subsequent performance of the integrated enterprise.

Under what conditions will integration arise? On page 27 we defined threshhold profit shares $\tilde{\lambda}_{\mathsf{tr}}$ and $\tilde{\lambda}_{\mathsf{sd}}$ and observed that a necessary condition for integration, either via licensing or consolidation, was that these shares summed to at most unity. With heterogeneous information, the analogous necessary condition applies. However, the threshhold shares will differ, depending on the form of integration, and on which party will ultimately control production and marketing activities. First, consider the case of integration via exclusive licensing. For $j = \mathsf{tr}, \mathsf{sd}$, suppose that $j$ obtains a license from $i$ to produce the augmented product. Now for $r = \mathsf{tr}, \mathsf{sd}$, define $\hat{\lambda}^{\ell}_{rj}$ by $\hat{\lambda}^{\ell}_{rj} E^2_{rj} \hat{\pi}^{\mathcal{M}}_{\Sigma} = \bar{\pi}^{\mathcal{A}}_{r}$. Since $r$ is risk neutral, it will be willing to consider a contract in which $j$ obtains a license from $i$, provided that $r$'s share of expected joint profits weakly exceeds $\hat{\lambda}^{\ell}_{rj}$. Hence a necessary condition for agreement to emerge is that $\hat{\lambda}^{\ell}_{\mathsf{sd},j} + \hat{\lambda}^{\ell}_{\mathsf{tr},j} \leq 1$. Now consider a consolidation proposal which leaves $j$ in control. In this case, for $j, r = \mathsf{tr}, \mathsf{sd}$ define the threshhold shares $\hat{\lambda}^{m}_{rj}$ by $\hat{\lambda}^{m}_{rj} E^2_{jj} \hat{\pi}^{\mathcal{M}}_{\Sigma} = \bar{\pi}^{\mathcal{A}}_{r}$. The key distinction here is that for $i \neq j$,

$$\hat{\lambda}^{\ell}_{ij} \quad = \quad \frac{\bar{\pi}^{\mathcal{A}}_{i}}{E^2_{ij} \hat{\pi}^{\mathcal{M}}_{\Sigma}} \quad > \quad \frac{\bar{\pi}^{\mathcal{A}}_{i}}{E^2_{jj} \hat{\pi}^{\mathcal{M}}_{\Sigma}} \quad = \quad \hat{\lambda}^{m}_{ij}$$

while

$$\hat{\lambda}^{\ell}_{jj} \quad = \quad \frac{\bar{\pi}^{\mathcal{A}}_{i}}{E^2_{jj} \hat{\pi}^{\mathcal{M}}_{\Sigma}} \quad = \quad \hat{\lambda}^{m}_{ij}$$

That is, the requirement that threshhold shares sum to at most unity is strictly more onerous for licensing than for consolidation. To recapitulate, the reason is that under a licensing agreement, $i$'s compensation depends on $j$'s realized performance, whereas under a consolidation agreement, it depends only on $j$'s expectation of *its own* ability to perform. By assumption, neither party's self-confidence is fully endorsed by the other. Hence

**Proposition 5.** *In a differentiated product world, there are, in the* IP*-regime, parameter values for which integration via consolidation is feasible but integration via exclusive licensing is not.*

## 6. Summary

Regulators, policy-makers and the general public have viewed with some alarm the dramatic transformation of the agricultural biotechnology industry that has taken place in recent years. This paper investigates the relationship between the trend towards industrial consolidation in this industry and two other important historical developments. The first is the evolution of more clearly articulated intellectual property rights to key agricultural biotechnology assets. The second is the unfolding transformation of traditional agriculture from a commodity business to a differentiated product business. For our purposes, the distinction is that commodities are clearly delineated objects that are traded on well-defined markets, whose parameters are exogenously determined. For a differentiated product, on the other hand, markets are blurry and in flux: in addition to producing a differentiated product, a supplier must first "create" and then "capture" its potential value. The paper focuses narrowly on two questions about these two developments: (a) how do they affect the incentives of firms in this industry to integrate vertically? and (b) how do they affect the relative attractiveness of integration via contracting or via consolidation?

Starting from the conventional wisdom that from an efficiency standpoint, anything which can be accomplished by consolidation can also be accomplished by contracting, a natural next step is to conclude that the trend towards consolidation reflects a relentless quest for market power. The paper highlights an alternative, exceedingly simple motivation for consolidation that deserves particular attention in a world of great uncertainty. The effects of this uncertainty have been compounded by revolutionary changes in technology and market relationships and by great divergences in beliefs. Under a contracting arrangement, in one party cedes control to a second in exchange

for royalty revenues, the returns to the first party depend on second's realized performance. In order to reach agreement, the first party must have sufficient faith in the second's ability to deliver. Such faith is *not* required, however, if a consolidation occurs in which the acquiree receives its compensation at the outset.

The empirical portion of the paper begins with a chronicle of all the consolidations that have taken place in the last five years. This is followed by a discussion of the change in the nature of intellectual property rights that has occured over the last century: in the early decades of the century, innovations in agriculture were afforded very little protection; in recent years, however, changes in both legislation, case law and enforcement technologies have contributed to a situation in which innovators are better able to appropriate some of the rents generated by their activities. The final empirical section discusses in detail the nature of agricultural biotechnology assets, focusing in particular on the steps that producers must take in order to create and capture value.

In the theoretical portion of the paper, we construct a simple model of the biotechnology industry, oriented narrowly towards answering the two questions we raise above. We demonstrate that in this very pristine setting, intellectual property does affect incentives to vertically integrate, either via consolidation or contracting, in a world of differentiated products, but does not in world of commodities. Moreover, provided that agents have heterogeneous beliefs about future values of the endogenous parameters that determine industry profitability, there is a range of parameter values for which integration via consolidation will be profitable but integration via contracting will not be.

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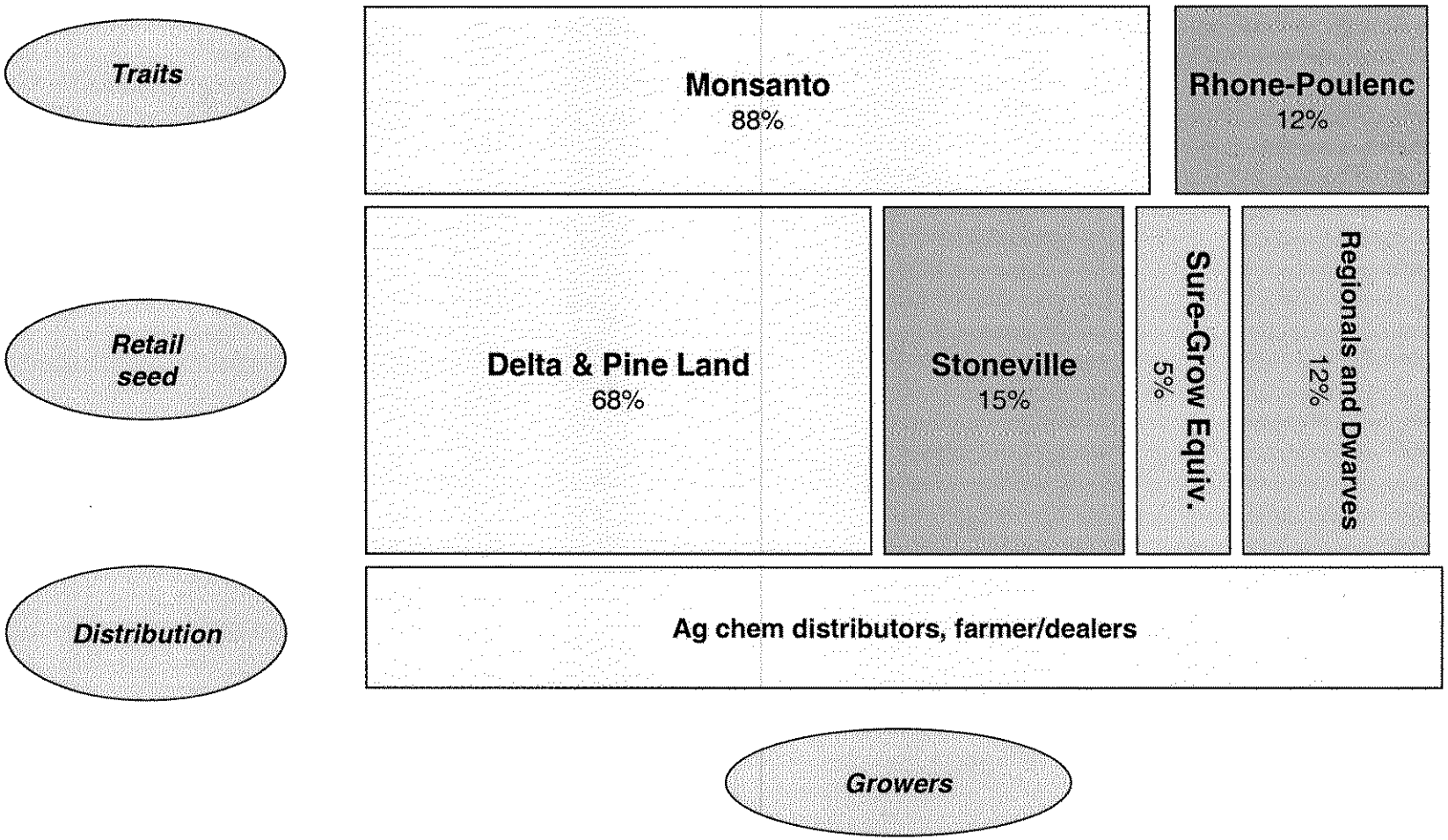
## Table 1: Key Consolidationions in the Agricultural Biotechnology Industry

| Date | Strategic Action | Description |
|---|---|---|
| Mar-99 | DuPont/Pioneer Hi-Bred | DuPont and Pioneer announce definitive agreement for DuPont to acquire the remaining 80% of Pioneer for $7.7 billion. |
| Nov-98 | DowAgroSciences/Mycogen | Dow AgroSciences completes acquisition of the remaining 21% of Mycogen. |
| Sep-98 | AgrEvo/Cargill Seeds (domestic) | AgrEvo announces an agreement to acquire Cargill's domestic seeds business for $650 million. (Agreement was set aside in February 1999.) |
| Jul-98 | Monsanto/Plant Breeding International | Monsanto announces an agreement to acquire PBI for $525 million. |
| Jun-98 | Monsanto/Cargill Seeds (intn'l ) | Monsanto announces an agreement to acquire Cargill's international seeds business for $1.4 billion. |
| May-98 | Monsanto/Cargill Joint Venture | Monsanto announces the formation of a joint venture with Cargill. |
| May-98 | Monsanto/Delta and Pine Land | Monsanto announces an agreement to merge with Delta and Pine Land for $1.9 billion |
| May-98 | Monsanto/DEKALB Genetics | Monsanto announces an agreement to acquire the remaining 60% of DEKALB for $2.2 billion. |
| Dec-97 | AgrEvo (51%)/Cotton Seed Internt'l. (49%) | AgrEvo and CSI form a cotton joint venture. |
| Nov-97 | Monsanto/Agroceres | Monsanto acquires Agroceres, a Brazilian seed corn company. |
| Sep-97 | AgrEvo/Nunhems (Sunseed) | AgrEvo acquires Sunseed, a U.S. vegetable seed company, for an estimated $88 million. |
| Aug-97 | DuPont/Pioneer Hi-Bred | DuPont acquires 20% of Pioneer and forms a strategic joint venture. |
| Apr-97 | Monsanto/Calgene | Monsanto acquires the remaining 45% of Calgene. |
| Feb-97 | Monsanto/Asgrow Agronomics (ELM) | Monsanto acquires Asgrow's agronomic seed business from ELM. |
| Jan-97 | Monsanto/Holdens Foundation Seeds | Monsanto acquires Holden's for $1.1 billion. |
| Nov-96 | Monsanto/Calgene | Monsanto increases ownership of Calgene from 49.9% to 54.6%. |
| Oct-96 | Mycogen/Morgan Seeds | Mycogen acquires Morgan Seeds, an Argentine seed corn company. |
| Aug-96 | AgrEvo/Plant Genetics Systems | AgrEvo acquires PGS for $725 million. |
| May-96 | Delta and Pine Land/SureGrow | Delta and Pine Land acquires SureGrow, a U.S. cottonseed company, for $70 million. |
| Apr-96 | Monsanto/Agracetus | Monsanto acquires Agracetus for $150 million. |
| Feb-96 | Delta and Pine Land/Hartz | Delta and Pine Land acquires Hartz from Monsanto. |
| Feb-96 | Monsanto/DEKALB Genetics | Monsanto acquires 40% of DEKALB and forms a strategic R&D relationship. |
| Feb-96 | Zeneca (50%)/Royal Vanderhave (50%) | Zeneca and Royal Vanderhave form a joint venture, Advanta, for their seeds businesses. |
| Jan-96 | ELM/DNA Plant Technology | ELM acquires 70% of DNA Plant Technology. |
| Jan-96 | DowElanco/Mycogen | DowElanco acquires 46% of Mycogen. |
| Jun-95 | Monsanto/Calgene | Monsanto announces an agreement to acquire 49.9% of Calgene. |

Note: The dates typically reflect announcement dates. Otherwise, the dates are completion dates for the transactions.

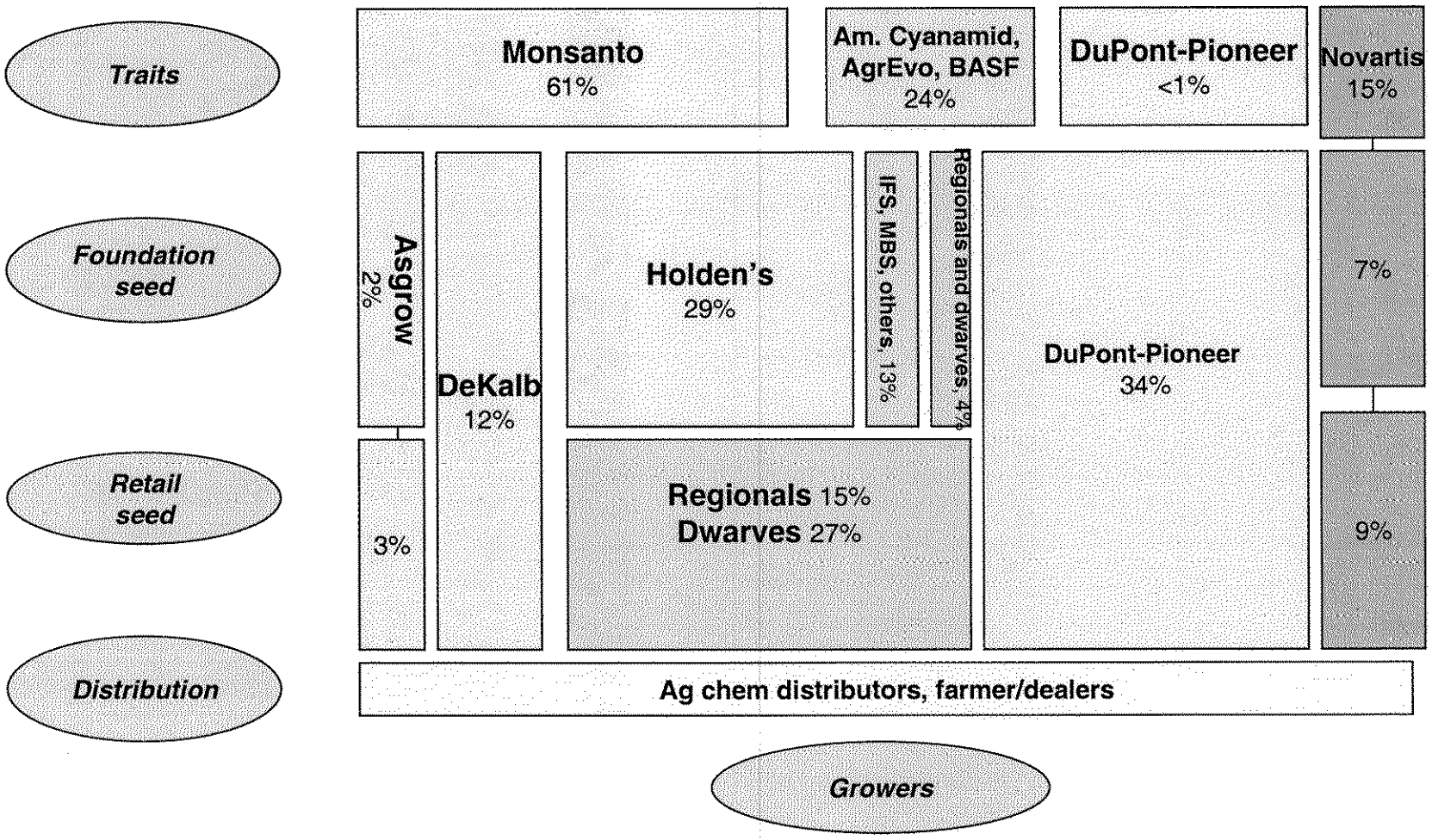
Data current as of March 15, 1999.
Source: BioScience Securities, Inc.

# CHART 1: STRUCTURE OF COTTON SEED INDUSTRY, POST-MERGER



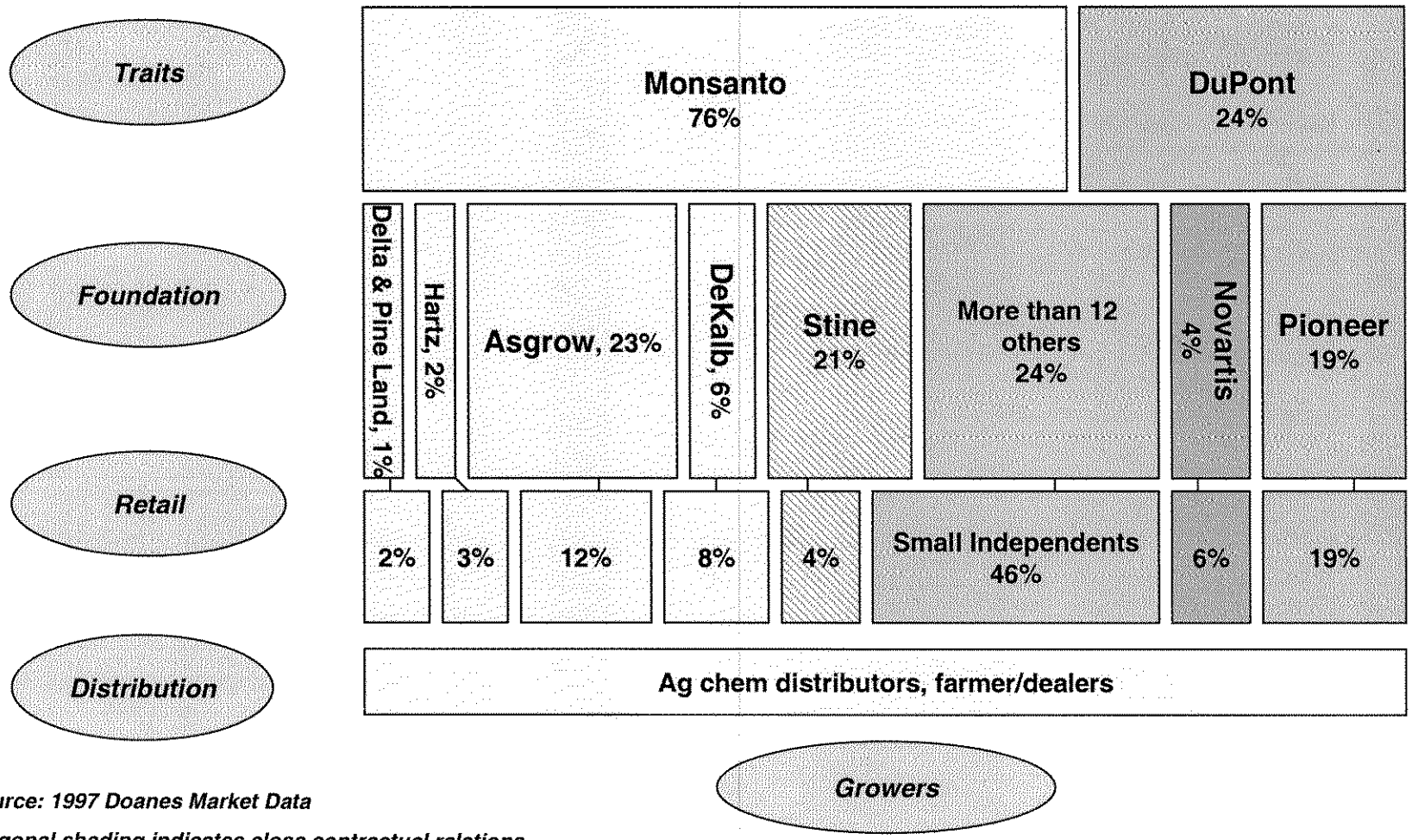

*Source: Industry reports, Estimates from 1998 USDA Study*

# CHART 2: STRUCTURE OF CORN SEED INDUSTRY




*Source: Industry reports, Estimates from 1998 Doanes Study*

# CHART 3: STRUCTURE OF SOY SEED INDUSTRY




*Source: 1997 Doanes Market Data*

*Diagonal shading indicates close contractual relations*

# CHART 4: SEED CORN BRAND CONSOLIDATION

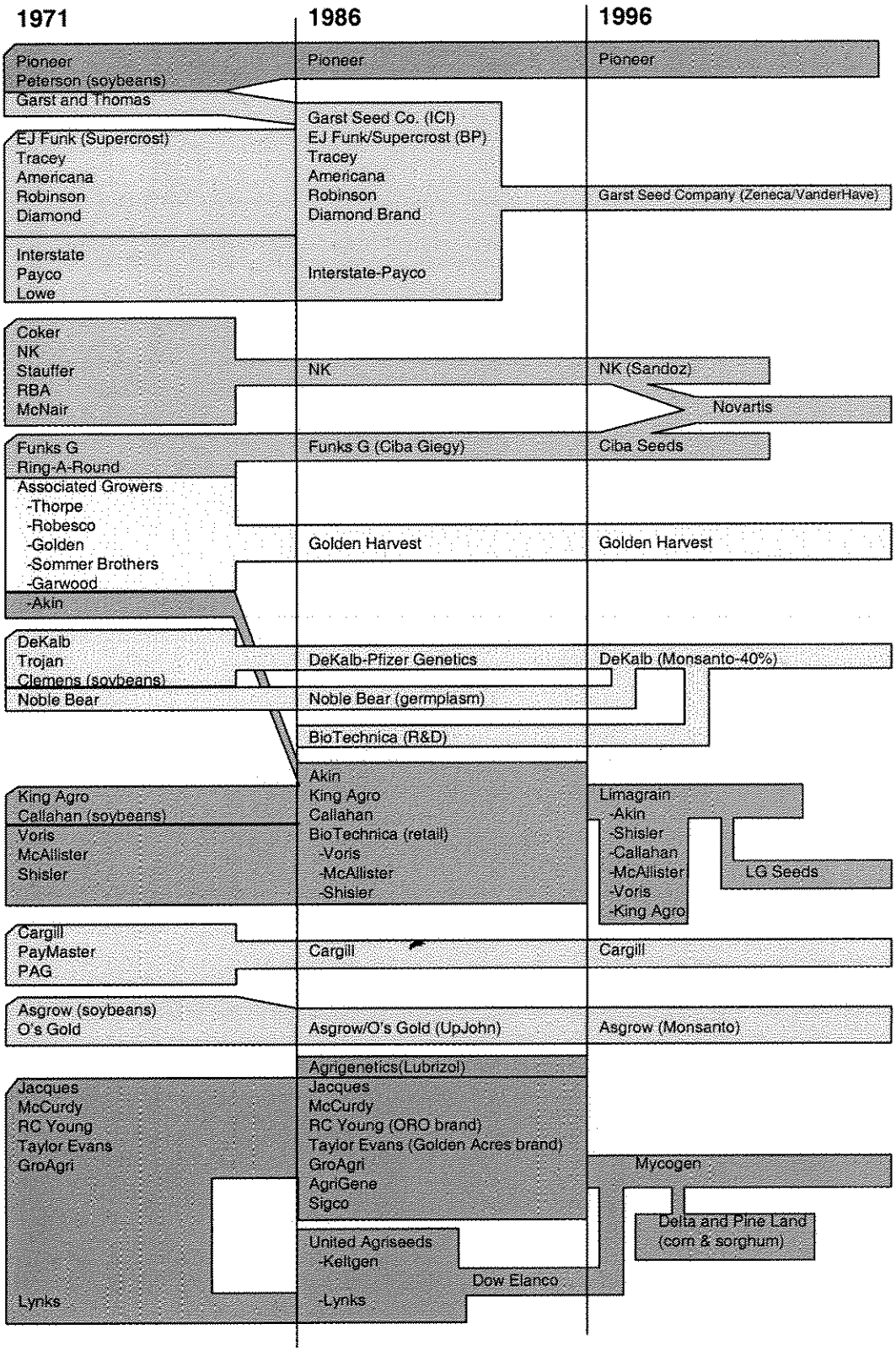
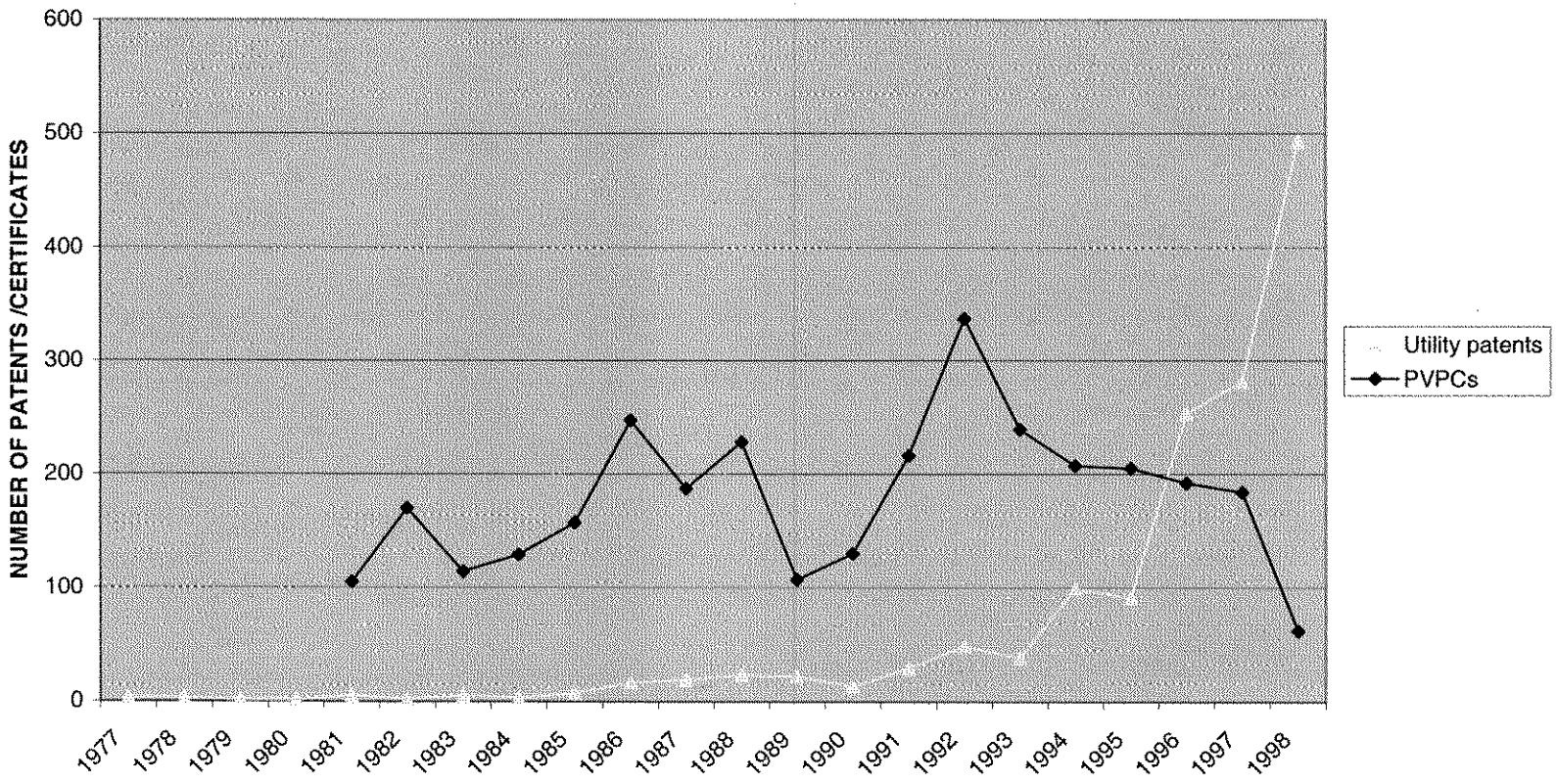
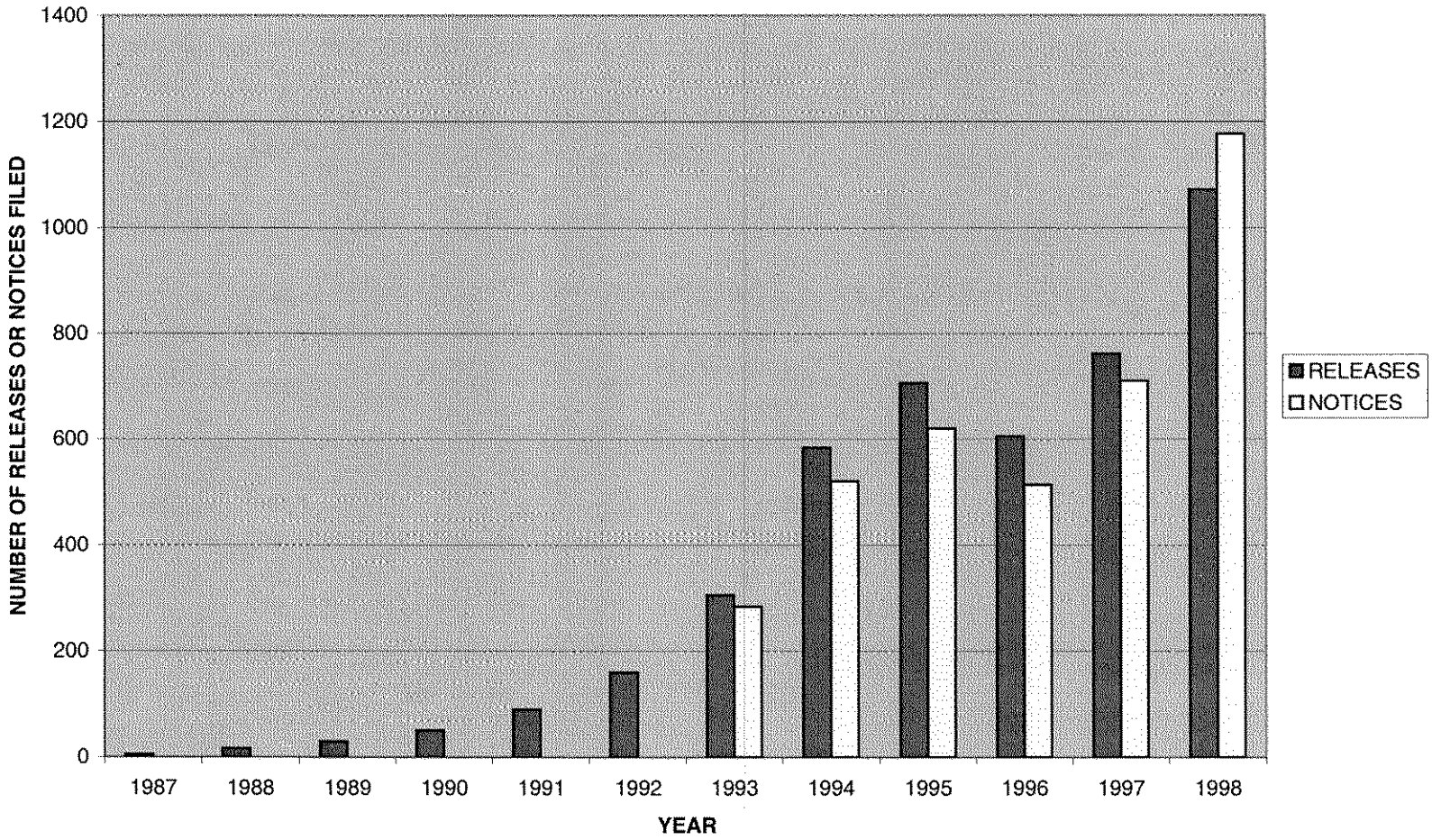


**Fig 1. Plants utility patents verses PVPCs certificates**




**(US patent class '800') granted from 1977 to 1998**
**and Plant Variety Protection Certificates (PVPCs) issued from 1981 to 1998**
**sources: US Patent and Trademark Office and USDA Plant Varitey Protection Office**

## Fig 2. Transgenic plant releases and notices




**Filed with USDA-APHIS from 1987-98, source: USDA, Animal and Plant Health Inspection Service**

**Figure 3: Complementary assets and the vertical structure**

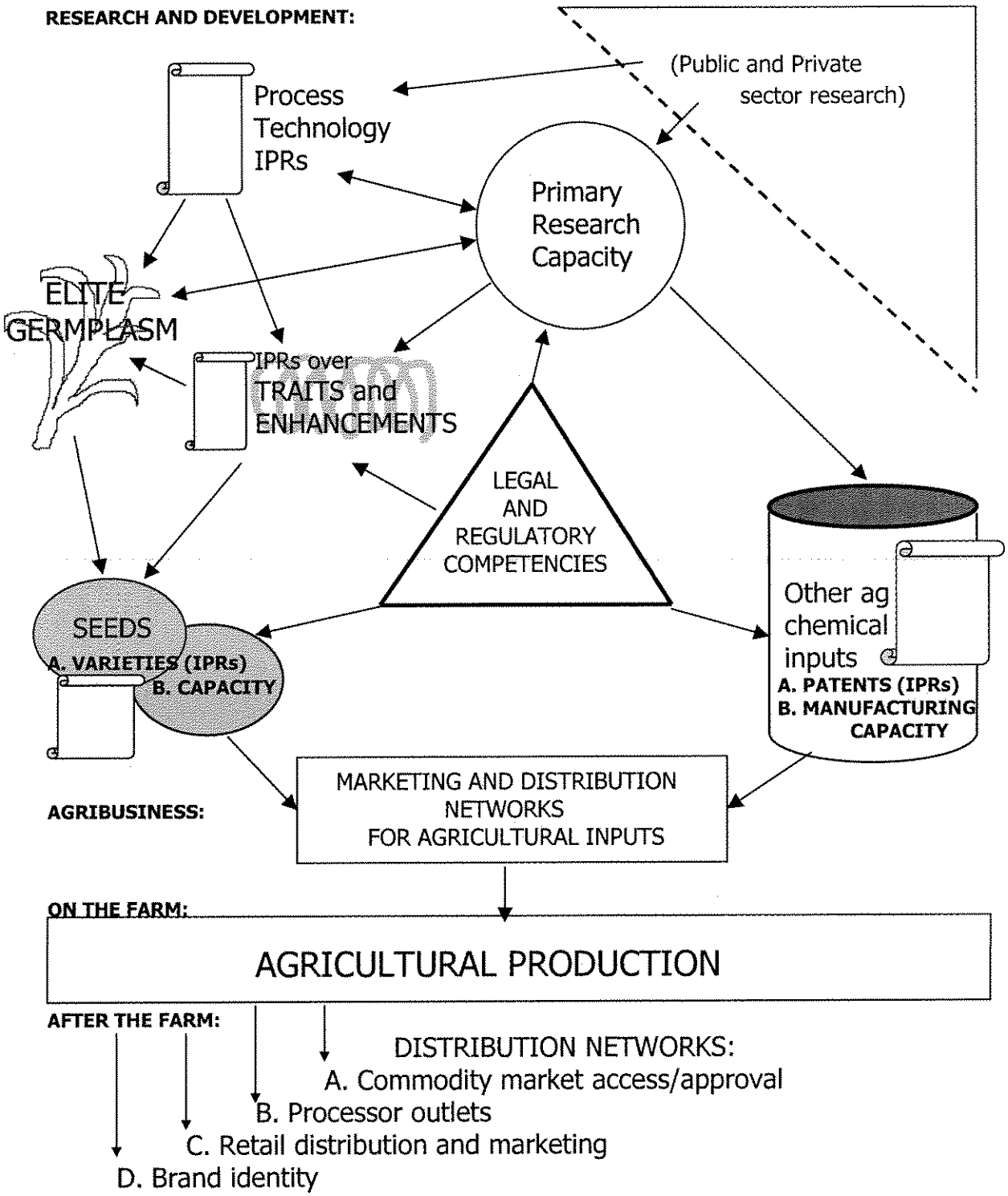
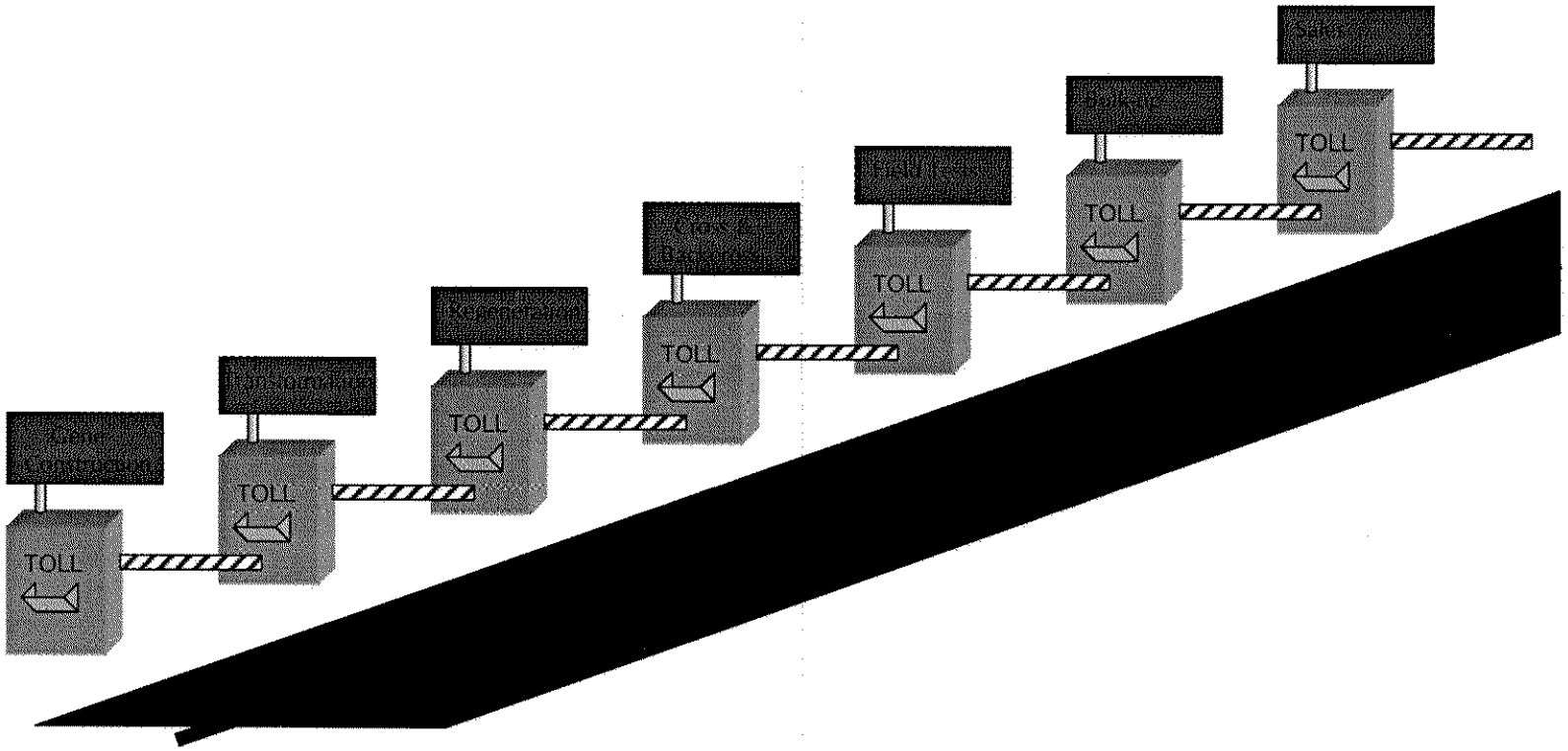


FIG 4

# The Commercial Highway (from genes to market)