A Prospective Analysis of the Potential Effect of Bio-Engineered Grains On Commodity Marketing Systems

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Abstract

The goal of the analyses described in this paper is to explore market system changes that could result from adoption of bioengineered crops, if that adoption occurs. The analysis results reported are prospective in nature with the overall purpose of identifying questions and key issues, rather than predict specific outcomes.

INTRODUCTION

The overall goal of this paper is to describe and analyze the market system changes that could result from adoption of bioengineered grains and oilseeds in U.S. agriculture, if that adoption occurs. Clearly there is considerable uncertainty regarding biotechnology's role in agriculture, with the extent of consumer and societal acceptance in this country and in export markets heading the list of unknowns. Because of the highly volatile nature of today's agricultural marketplace, quantitative predictions based upon analysis of historical data are of limited applicability. Therefore, the analysis results reported in this paper are conceptual and prospective in nature. Their purpose is primarily to identify questions and key issues, rather than to project specific outcomes.

In this study, three types of analyses are employed and integrated. The dynamics of change in commodity markets are explored through application of system dynamics. Second, in-depth futuring exercises with sector decision makers solicit expert opinion regarding the evolution of alternative market channels. Third, scenario analysis is employed to investigate the managerial implications of potential adoption of bio-engineered crops and market channel change.

THE DYNAMICS FOR CHANGE

If widely accepted by consumers, agricultural biotechnology offers the potential to provide substantial benefits, but also challenges, to participants throughout the commodity production and marketing system. The existing commodity system is not designed to produce and deliver diverse sets of differentiated output. The following discussion will examine the dynamic interactions likely to result in a setting where biotechnology drives structural change in the production and marketing system.

<u>Investing in a Vision</u>

The vision that there are potential benefits from biotech commodities has driven investment into research and development initiatives. Figure 1 suggests that *Theoretical Value from Biotech* supports [*S*] the *Speculative*

Investment that in turn supports [*S*] *Biotech Development*. This tends to be a reinforcing process[R] where new developments generate more ideas for value that drives more investment. For many types of biotech value traits, this depicts where we are in the current situation—especially for value traits that provide benefits to participants further down the value chain beyond the producer. The bold dashed lines that intersect the linkage between *Speculative Investment* and *Biotech Development* denotes that there are time delays between the decision to invest and actual development of innovations.

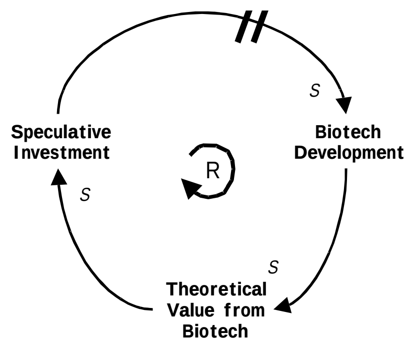

Figure 1. The potential for value drives development.

<u>Moving from Theoretical Value to Realized Value</u>

As development continues and biotech-driven quality improvements become reality, it becomes possible to move from theoretical value to realized value. Figure 2 expands our diagram to illustrate that *Transportation and Handling Infrastructure* will be needed in conjunction with the *Biotech Development* to generate *Realized Value from Biotech*. Other system components will be needed to facilitate the full adoption of biotech grains. For example, the factors below are just as important as the transportation component.

- New marketing and business arrangements that will be needed to facilitate the re-distribution of value through the value chain,
- The utilization of information technologies,
- The evolution of testing technologies, and
- Public acceptance of different kinds of products.

Figure 2 illustrates where the current structure is lacking today and most likely in the near future unless changes are made to the *Transportation and Handling Infrastructure*. That is, the amount of *Biotech Development* is continuing to advance and build *Theoretical Value from Biotech*, while (without investment) the *Transportation and Handling Infrastructure* can quickly become a limiting factor in realizing the potential value.

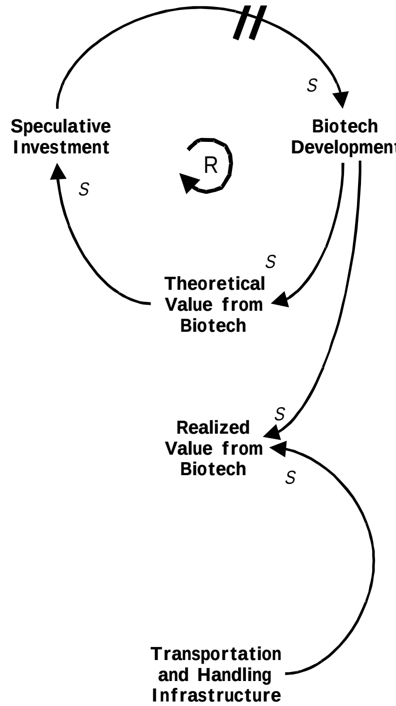

Figure 2. Physical infrastructure as a gap limiting value realization.

<u>The Incentive to Invest in Infrastructure</u>

Investment in *Transportation and Handling Infrastructure* is fundamentally different than the investment in *Biotech Development*. Investments in biotech are large and speculative, but perceptions of high long-term payoffs justify investing. This tends to attract long-term investors. On the other hand, investment in *Transportation and Handling Infrastructure* is more mundane but has a more tangible outcome. There is little question that a particular infrastructure can be built. The speculation is whether the market will provide adequate return to the *Transportation and Handling Infrastructure* to provide sufficient return to the investment—especially in a sector that has historically been characterized as highly competitive with very narrow margins. However both components are important if value is to be actually realized value from biotech commodities.

Figure 3 builds on the previous figures to include a very important linkage from the *Theoretical Value From Biotech* to *Infrastructure Development* that supports the development of the *Transportation and Handling Infrastructure.* The notion here is that it as the *Theoretical Value From Biotech* increases over time, it will reach a threshold at which time someone in the system will become convinced that it makes sense to invest in the development of infrastructure. (Of course, the perceived theoretical value can decline which would retard investment.) The two short, bold lines that intersect the linkage between Theoretical Value from Biotech and Infrastructure Development suggest that this time delay is likely to be both significant and lengthy. Over time, this will provide the infrastructure needed to realize the value from the biotech developments. The time lag between the point where the biotech product is ready for market and the time when it is actually generates market returns is critical. There is the potential for substantial lost opportunity if a biotech product is ready for market, but sits stagnant even for a couple of years while the necessary infrastructure is developed.

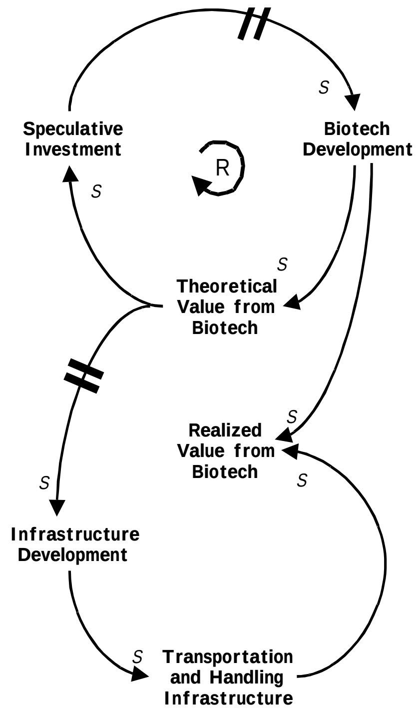

Figure 3. Infrastructure investments are needed to realize market value.

Closing the Loops

It will be important to understand the dynamics of the continued evolution of the *Transportation and Handling Infrastructure* as the system matures. Figure 4 identifies feedback loops that will provide a return to those who invested in *Biotech Development* and *Infrastructure Development*. Over time, these feedback loops will generate varying degrees of additional investment, depending on how successful (profitable) the existing products have been. Again the magnitude of any delays between the time when value begins to be actually realized (*Realized Value from Biotech*) and *Infrastructure Development* will significantly affect the pace by which returns accumulate and fuel further investment.

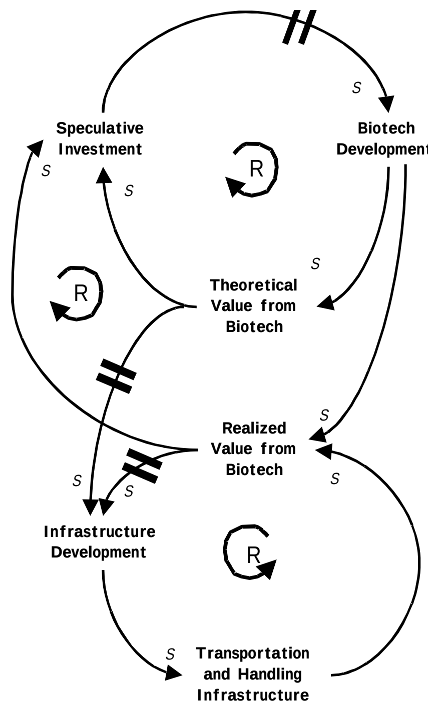

Figure 4. Returns from the market flow to investors.

The relationships and dynamics illustrated in the preceding diagrams are used as points of reference for the remainder of this analysis. The time lags noted in those diagrams are of critical importance. They identify a significant mismatch between the processes by which expectations are formed that lead to investment in biotechnology development versus investment in infrastructure. Although infrastructure is not needed until crops from biotechnology are in the marketplace, delay in the availability of that infrastructure will reduce profitability and restrain further investment in biotech development.

BIOTECHNOLOGY AND THE COMMODITY MARKETING SYSTEM

The production and marketing system for major commodity crops in the United States is designed to provide maximum value through the low cost delivery of massive amounts of homogenous grains and oilseeds.[1] Key characteristics, which result in successful operations in the current commodity setting, conflict with the needs that appear to be required for effective marketing of bio-engineered crops.

<u>Expected Challenges To The Commodity Marketing System</u>

Even though the biotechnology revolution is still in its infancy, significant transportation, handling and logistical implications can be identified that may result from the continued adoption of bio-engineered crops by producers and end-users. For two very different reasons, it now appears that crop identity will have to be maintained in production and marketing supply chains for at least some portion of the crop.

So-called first generation crops were altered to enhance agronomic performance. Because output traits were not affected, segregation of these crops was not expected to be necessary. In some international markets, however, acceptance of bio-engineered crops is a controversial issue. Labeling of bio-engineered crops currently has been mandated for some uses. Therefore, separate handling systems for bioengineered products and non-bioengineered commodities may need to be created because of the lack of immediate acceptance of genetically modified crops in those markets.

The most significant impact of biotech crops on the crop transportation, handling and logistical systems should occur with the second generation of biotechnology, where crops with quality related traits that have added value for specific end users are available. The added value of these crops is found beyond the farm level. Potential examples include high lysine corn, high oleic soybeans, or wheat with improved processing traits. These products will require segmentation to preserve their identity through the grain handling systems to the point where the value is captured. If grain with specific end use value is commingled with other grain, value is likely to be lost.

Alternative Marketing Channels Defined

The following discussion will delineate possible market structures that may develop to accommodate the production and marketing of biotech grains and oilseeds. Assessing these market structure alternatives is necessary for evaluation of possible transportation, handling and logistical implications. As a starting point, the marketing channels described as part of the U.S. Grains Council's *1998-1999 Value-Enhanced Corn Quality Report* are employed. These marketing channel definitions were developed as a way to describe the various alternative systems that can be used to produce and merchandise value-enhanced corn.

The U.S. Grains Council marketing channel definitions work well for describing most systems used for the production and merchandising of value-enhanced grains. However, a few modifications to these structures may be useful as we look at the impact of biotech enhanced grains on the crop marketing systems Table 1 identifies the channel alternatives and their differentiating characteristics and the modifications made for this study. Vertical

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[1] In reality, of course, homogenous commodities dominate the current system; however, there are a variety of value-enhanced crop products on the market as well. In general, market transactions and transportation logistics work smoothly for these niche products in small volumes and with premium pricing.

Integration was added as an alternative marketing channel and traceability was added as another differentiating characteristic. The new additions are shaded in the table.

Table 1: Modified Marketing Channels for Grains and Oilseeds

Differentiating Characteristics	Level 0 Vertical Integration	Level I Identity Preserved	Level II Specialty	Level III Super Commodity	Level IV Standard Grade
Relative Value/Premium	Any (high to low)	High	Medium	Low	None
Buyer Control	Complete Multi-year	Variety Production Practices Certification Other	Min/Max Attributes	Attribute Preferences	Grades Only
Attribute Testing	Integrator's Discretion	Buyer's Discretion	Cost/Value-Driven	Efficient/Consistent	Grade-Driven
Types of Producer Contracts	NA	Acreage Production Bushels	Production Bushels Normal/Open	Normal/Open	Normal/Open
Producer Linkages	Complete	High	Moderate	None	None
Minimum Segregation	Any desired	Farm	1st Point of Sale	Merchandiser-Determined	MerchandiserDetermined
Product Volumes	Any desired	Low	Moderate	High	Very High
Information Carriers/ Traceability	High	High	Moderate	Low	None

Vertical Integration, as an alternative marketing channel, recognizes that some end users may require total control over the production and handling of inputs. The original channels assume a basically traditional ownership structure with independent control of production, handling, and processing functions. The original channels do account for the use of production contracts to secure production but not for the complete integration of the system. Vertical Integration provides buyers with an even higher level of control than the Identity Preserved (IP) channel. A significant advantage of Vertical Integration is that the system could be immediately responsive to the integrator's needs[2]. The integrator would not have to spend time and resources encouraging producers to raise the types of traits they needed. The integrator's entire production could be directed to any trait that they wanted each year.

Vertical Integration would most likely be used for high value products where the integrator wanted complete control over the production and handling practices to preserve the product's quality and identity. Vertical Integration may be used as a system to keep the integrator's production out of the commodity channels in cases where the specialty product may have undesirable effects if used in the wrong application. For example, in the production of corn with pharmaceutical traits it may be very important to keep the pharmaceutical corn out of the commodity corn channel. Usually the segregation challenge with specialty crops is to keep other types out of the specialty channel. Here the problem is the reverse. Vertical Integration could give the integrator greater control over the production and handling of the grain to limit the potential for the specialized grain to "leak out" into the commodity stream.

The ability for grain to "carry" information about its past and be "traceable" to its origin was added as another differentiating characteristic of marketing channels. The increased number of end use traits, food safety concerns, and consumer demand for information about the food they buy are all driving the need for better grain product traceability. In the future it will become increasingly important to be able to trace the input source of an end use product back through processing, handling, and production.

When looking across the marketing channels, it is clear that the ability for grain to carry information about its past varies over the channels. In the Vertical Integration channel the potential for information transfer and traceability is high. Integrators could maintain information about given grain lots through their system. IP systems are set up to maintain information about the identity of the grain. This is in sharp contrast to the Standard Grades or the commodity channel where there is usually no descriptive information transferred with the grain. All the buyer of commodity corn usually knows about the grain is that it is number 2 yellow corn. Nothing is known about the origin or production practices of that grain.

Currently the ability to track information about grain history along with the product flow is constrained primarily by the level of segregation performed. Segregation that is maintained all the way from the farm level can enable detailed information to be carried with the grain about its history. An example would be an IP system

[2] As a form of business organization, vertical integration has disadvantages including the challenge of managing business processes at differing levels of the supply chain. Most of these are not unique to the issue of biotechnology and will not be addressed here.

designed to deliver organically grown grain. Here the producer, production practices, and variety can be determined. Conversely, a system used to originate low stress crack corn by segregating the corn as it is dumped at the elevator would provide little information about the production history. The only factor known is that stress cracks are low.

Advances in biotech may assist in product traceability. Biotech and gene markers may enable grain with specific traits to be marked with a visible indicator or even labeled by the producer. These advances may be a few years away but would dramatically change the system's ability to trace grain products back to their origin. Traceability would no longer have to be linked to segregation. Mixed lots could still be traced back to their origin.

DECISION MAKERS ASSESS FUTURE STRUCTURES

Market and technological forces in the US grain and oilseeds sectors suggest that there is considerable potential for significant market structure change (Sonka, et. al., 2000b; Boehlje, Hofing and Schroeder, 1999). Due to rapid changes in technology, policy, and consumer preferences, decision makers throughout the sector are forced to adapt to the best of their ability using the information that is available. The ability to predict the future becomes more difficult because of the complex interrelationships among demand, supply, technology, regulatory environments and policy.

In the face of a dynamic market structure, there is very little past information or data to analyze for quantitative predictions of the future. The "normal" approach to research in agricultural economics has been to quantitatively analyze historical relationships to assess implications for the future. However, in times of dynamism, volatility, instability, and significant structural change, an *ex post* analysis approach using historical data sets is not effective in *ex ante* assessments (Boehlje, 1999). Therefore in this analysis qualitative tools are used.

The working hypotheses of the analysis reported here is that industry leaders and experts have useful insights as to how the aforementioned factors will affect the future of agricultural market structure. Past management decisions have helped to build a set of tacit information that is useful to think about the future[3]. Use of scenario analysis and semi-structured personal interviews enables the researcher to extract that tacit knowledge. Scenario analysis allows the study participants to "project themselves" into alternative futures and to describe how

[3] Explicit knowledge is formal, repeatable knowledge; that which can be written down. Tacit knowledge refers to the informal, experience based insights, judgment and experience that decision makers employ (Nonaka and Takeuchi, 1995)

individuals in managerial roles would respond to those futures. The objective of this section is report on the insights discovered as to likely impacts of biotechnology on the market system.

Research Design

Qualitative research, the process of analyzing words and thoughts, is employed in this portion of the analysis. This type of analysis is routinely employed in strategic and market research (Wolcott (1992); Miles and Hubermann (1994); Creswell (1998)). After consideration of the options available for conducting qualitative research, the method of research chosen for this project was face-to-face interviewing. More than thirty decision makers with extensive experience and who represent interests from throughout the production and marketing sector participated. Because the questions designed require knowledge about the topic, outside sources were consulted to gain perspective on what individuals would have this knowledge. Academics, experts and experienced researchers were consulted to build a list of possible contacts with positions from throughout the supply chain to be interviewed.

To ensure participation of the informants, strict confidentiality was promised. The sectors represented include (with the number of participants in parentheses):

Input supply (6)

Production (5)

Handler (4)

Processor (2)

Service/ Finance Providers (6)

Research & Consulting (9)

Academic/ Extension (6)

Interviews ranged in length from 45 to 60 minutes, took place during the late winter and early spring of the year 2000, and occurred in the respondent's office (or a location of their choosing). More detailed information on the design process and the study participants is available in Cunningham (2000). The interview consisted of six main questions, three for each of the two time periods in question. The three questions for each time period were the same, for the purpose of comparison. Four follow-up questions were administered to get richer, more in-depth answers; to explore newly discovered avenues; and to test and modify emerging themes (Rubin and Rubin, 1995).

Near Term non-GMO Segregation

Two market structures were examined in the research. The first focused three to four years into the future and centered on the notion that a 20-30% market share exists by that time for non-GMO corn and soybeans. The respondents were told that a premium is paid for segregation. Of the 30 respondents, 43% of the respondents said the structure was realistic; 47% thought it was not realistic; and 10% said this was the current market structure. The main reasons given for not thinking that the scenario was realistic were that they didn't see the premium occurring; they couldn't see the premium sustaining the market; and they couldn't see consumers paying more for what was once a generic product.

The main issues identified for a market structure such as this to occur were:

1) There would have to be a continued increase in consumer concern surrounding GMO's.
2) Similarly, there would have to be an increase in consumer demand for non-GMO products.
3) There must be a decrease in the level of risk associated with providing a pure and segregated product at all levels of the supply chain.
4) Issues with segregation and identity preservation must be resolved.
5) There would have to be increased concern regarding international trade losses with the EU and Japan.
6) Governmental regulations and requirements will need to be better understood to certify the products.
7) Market structure would need to change to accommodate differentiated products and premiums.

Respondents were asked how their decisions and behaviors would change in response to a market structure where 20-30% of corn and soybeans were marketed as non-GMO. Of the 30 respondents, 60% said that their behaviors and decisions would change; 40% said that they would not change; and 30% said that they were already prepared or preparing for this scenario[4]. The major behavior and decision changes that were discussed were as follows:

1) Respondents said that in this sort of structure, there would be a need to establish better infrastructure throughout the supply chain.

[4] Note that those who said that they were prepared or already preparing are included in the number of respondents who said that their behaviors and decisions would not change.

2) As there would be an opportunity for new markets, management decisions would change to facilitate these opportunities.

3) To provide segregation, new services, or new products necessary to serve this market, respondents said that they would need to increase investments in some aspect of their business.

Longer Term Responses to Enhanced Output Attributes

The second market structure focused eight to twelve years in the future and concentrated on a market structure where 40-50% of the market is sold as differentiated output traits. The respondents were told that the premium now lies in the value added nature of the product. Of the 30 respondents, 80% thought that the scenario realistic; 20% thought that the scenario not realistic.

The responses about what would have to occur for the scenario to take place were similar to those given in the first scenario. They are as follows:

1) For the market to be heavily concentrated with differentiated output traits, there must be consumer demand for the products. Additionally, the consumer must realize some value in the product and have few or more expensive substitutes. Many respondents thought that the traits would be niche markets driven by lifestyle or preference changes.

2) There must be an available supply of technology to grow the differentiated output traits. Biotechnology developers must have the incentive to supply products that are worthwhile and useful for a long period of time.

3) There will be a continued trend of market structure change. Respondents talked about consolidation, which has led to a high level of alliance both horizontally and vertically along the supply chain.

4) There must be a method of "insurance" against loss to the environment, misproduction, or commingling of high-value differentiated output products.

5) Issues of difficulty of segregation and purity must be resolved.

6) International trade concerns surrounding biotechnology and "American science" must be resolved.

Respondents were asked how their decisions and behaviors would change in response to a market structure where 40-50% of corn and soybeans were marketed with differentiated output traits. Of the 30 respondents, 67% (2/3) said that their behaviors and decisions would change; 33% (1/3) said that they would not change; and 20% said that they were already prepared or preparing for this scenario[5]. The behavior and decisions changes were once again much like those that were discussed in the first scenario. The major behavior and decision changes that were discussed were as follows:

1) Respondents said that this market would force them to form new relationships with other members of the supply chain. Many saw their firm consolidating or forming alliances with other firms.
2) In response to the potential for new markets, management would need to facilitate these opportunities.
3) To provide segregation, new services, new products or other functions necessary to this market, respondents said that they would need to increase investment in some aspect of their business.
4) Respondents said that in this sort of structure, there would be a need to establish a better infrastructure throughout the supply chain.

Scenario Analysis

There are many factors pushing the grain and oilseeds markets toward specific trait products but there are many obstacles as well. Although the grain system will likely change in the future, predicting exactly how those changes will occur is nearly impossible. Instead it is useful to look at some potential scenarios of the future. The scenarios presented are not meant to be predictions of the future but rather illustrations to help stimulate thinking about the future of the grain industry and the implications of biotech.

For each scenario, the expected market structure is described for those timeframes as though they had actually occurred. Two future scenarios are explored:

Scenario 1—Dramatic Shift Caused by Biotech Traits and Demand for Traceability

Scenario 2—Gradual Change over Time Through Traditional Traits

These scenarios fall into the “all versus nothing” approach to looking at the future of biotech. If biotech is accepted, it will be accepted broadly and biotech traits will be used in many applications. If biotech is not accepted, public and regulatory pressure as well as concerns about segmentation will restrict it from nearly all applications. (As is typical in scenario analysis, this extreme specification is useful to frame the discussion. This does not mean that a “mixed” future is not possible.) Scenario 1 assumes biotech enhanced crops will be widely accepted. If they are accepted, a

[5] Note that those who said that they were prepared or already preparing are included in the number of respondents who said that their behaviors and decisions would not change.

rapid segmentation of the crop market into specific use traits is likely to occur. Scenario 2 assumes that biotech traits are not accepted. Under Scenario 2, gradual segmentation of the market continues with traditional trait development as it has in the past. Table 2 highlights the major background characteristics of the scenarios.

Table 2: Future Scenario Background Summary

Characteristic	Scenario 1 Dramatic Shift through Biotech	Scenario 2 Gradual Change without Biotech
Biotechnology enhanced traits	The number of traits explodes.	Developments cease.
Biotechnology acceptance	Broadly accepted, niches of resistance remain.	Not accepted
Demand for traceability	High, grows quickly	Moderate, grows slowly
Cost of segregation	Low	Moderate
Producer alignment with end users	High	Moderate
Relative value of specialty traits over commodity	High	Moderate

In Scenario 1, (Figure 5) the benefits of biotech and the demands of the public will be the primary drivers pushing the handling and transportation infrastructure to change rapidly. Assuming that the specialty and IP channels are further subdivided, this scenario will require radical change to the handling and transportation system.

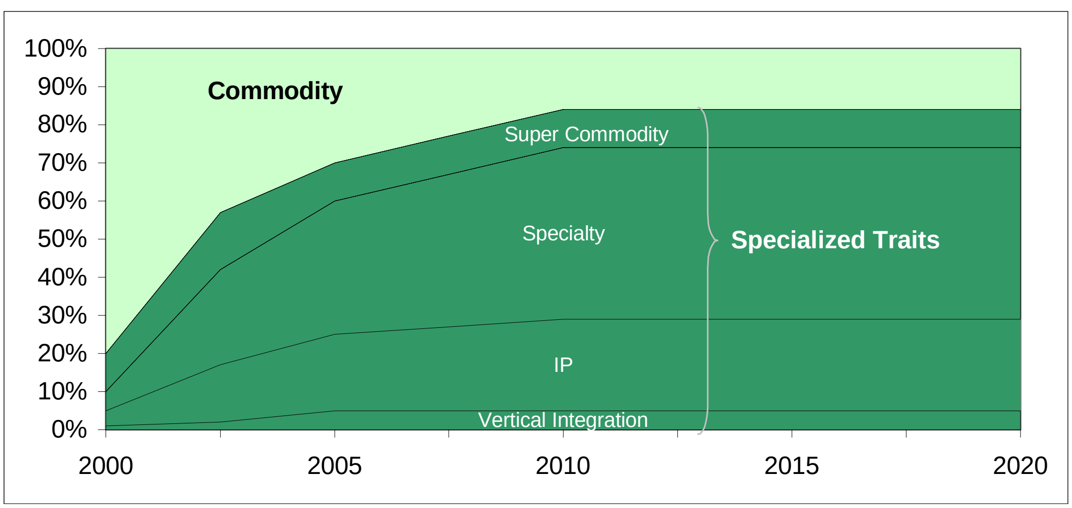

Figure 5. Scenario 1—Dramatic Shift Caused by Biotech Traits and Demand for Traceability.

If this scenario occurred, the transportation and handling system would have to be changed dramatically from what it is today. Nearly every channel would push towards the utilization of small to medium grain flow configurations. Taken collectively, this suggests:

- No storage at terminal elevators
- High utilization of on-farm storage
- No barge utilization
- High utilization of trucks
- High utilization of testing
- Pressure to produce specialty grains near the respective end user

Thus, if market pressures (e.g. the value from biotech grains is sufficiently high) drive the industry in this direction, the handling and transportation infrastructure will need to change in the following ways:

- Terminal elevators will need to be able to segregate into at least a few different channels.
- On-farm storage will need to increase.
- Barge transportation must adopt to handle multiple channels, either through coordination (each barge hold has a separate product), or through the use of some type of containerization.
- Trucking capacity must increase.
- Testing methods must be developed that are accurate, fast, economical, and have the confidence of all parties involved.
- End users must strategically locate in areas where they can secure adequate amounts of the specialty grain that they need while having access to outbound transportation for their output.

Scenario 2 (Figure 6) ends up in the same position as does Scenario 1, in terms of the share of the market held by each channel. However, the pace at which the commodity channel is supplanted is considerably slower than in Scenario 1. Therefore at the end of the period, one could expect similar implications with on-farm storage and truck transport increasing at the expense of large-scale high volume commodity-oriented mechanisms.

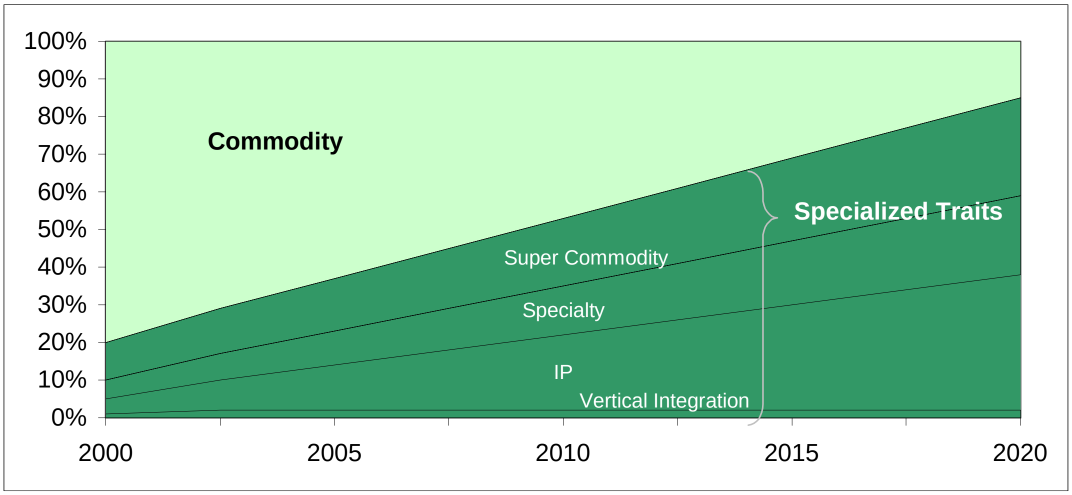

Figure 6. Scenario 2—Gradual Change over Time Through Traditional Traits.

Although transportation, handling and logistical infrastructures will need to adjust, the speed of change can occur at a moderate pace. As the normal replacement of infrastructure occurs, in combination with advances in technology, systems that can accommodate the more precise requirements of IP, Specialty and Super Commodity grains will evolve. Regionalized production will emerge around the locales where systems capabilities exist. In contrast with Scenario 1 where infrastructure retarded the pace of change, in Scenario 2 infrastructure investment will at times act to lead the evolution in channels.

SUMMARY

In this study, three types of analyses are employed and integrated. The dynamics of change in commodity markets are explored through application of system dynamics. Second, in-depth futuring exercises with sector decision makers solicit expert opinion regarding the evolution of alternative market channels. Third, scenario analysis is employed to investigate the managerial implications of potential adoption of bio-engineered crops and market channel change.

Results of these analyses can be summarized into three general findings. First, to effectively produce and deliver grains and oils with differentiated traits to customers, alternative market channel mechanisms and infrastructure will be needed to extend the capabilities of today's commodity system. A typology of alternative market channels is specified in this report. These alternatives bracket the plausible range of expected needs. The alternative channels are categorized in terms of eight distinguishing characteristics deemed important to industry participants. Each of the alternatives is plausible today, although expected advances in measurement technology and scale efficiencies will reduce future costs. Therefore, mechanisms do exist (or could be expected to rapidly emerge) by which a whole range of differentiated output could be marketed. Further, because of differing requirements and value opportunities, bioengineered grains and oilseeds may be marketed in each of the alternative channels. And some output types may be marketed in more than one channel.

Second, there is a fundamental mismatch in the decision expectations between investing in biotechnology and investing in transportation, handling, and logistical infrastructure. Yet if grains and oils with differentiated output traits through biotechnology are to be effectively provided in the marketplace, investment in transportation, handling, and logistical infrastructure also is essential.

Scenario analysis was employed to explore these investment dynamics. Results of two scenarios are of particular interest. In the scenario where widespread consumer acceptance in the future is assumed, advances in biotechnology drive relatively rapid and substantial change. Existing market system infrastructure, which is economically viable but not well suited to differentiated output traits, acts to slow the rate of change. One expected result of this conflict would be considerable pressure for biotechnology stakeholders to establish dedicated, vertically coordinated systems outside the existing organizational structures. To optimize these new structures, production of the products with differentiated output is likely to be regionally localized. Advances in measurement technology are not a significant impediment to change as organizational structures partially substitute for the need for measurement capabilities.

In the scenario where biotechnology is assumed to have limited acceptance, the pace of change is relatively slow as biotechnology does not act as a driving force. The slower pace of change in this scenario allows marketing system infrastructure to evolve at a rate that is more consistent with the normal investment patterns. Indeed investment in system infrastructure in a particular region may be a force that leads differentiated trait production in that region. The rate at which measurement technology advances will be a larger determinant of the rate of change in this setting, as it will facilitate low cost transactions in less tightly controlled vertical systems.

The third general implication of the research is that relationships along the agricultural supply chain will need to change substantially.   An intensive qualitative analysis of decision maker responses to biotechnology in agriculture identified several different types of relationship change. The most visible of these changes is horizontal and vertical consolidation, as well as alliances, among agricultural firms. Several respondents discussed farmer-input supplier and farmer-grain handler relationships changing because of the Internet and the options available in contracting and specialization. Intriguingly, new forms and types of relationships with final consumers also are expected. All respondents discussed the fundamental and crucial role of the consumer at some point during their interview.

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