# Enhanced Output Traits and Market Coordination

## Issue

The first generation of biotechnology involves crop traits that affect crop production—for example, herbicide or pest resistance. Biotechnology's second generation involves crops with enhanced output characteristics, such as high oil content or other specialized features. As crop differentiation advances, marketing channels will likely emerge to facilitate the coordination of end-user desires and grower crop management and production. What mechanisms will likely coordinate the production, processing, and end-user phases of output-enhanced commodities? How will the value from enhanced-output traits be shared? How will market coordination change as enhanced-output traits are introduced?

## Background

Contracting and some vertical coordination have been the predominant mechanisms of coordination in the broiler industry since the 1960's, and more recently, the hog industry appears to be following a similar coordination strategy. Contracting and some vertical integration are frequently found in vegetable production but less so in grain, oilseeds, and cotton production (Barkema and Drabenstott). The availability of government support programs for producers of these crops may have lessened the need for other forms of coordination.

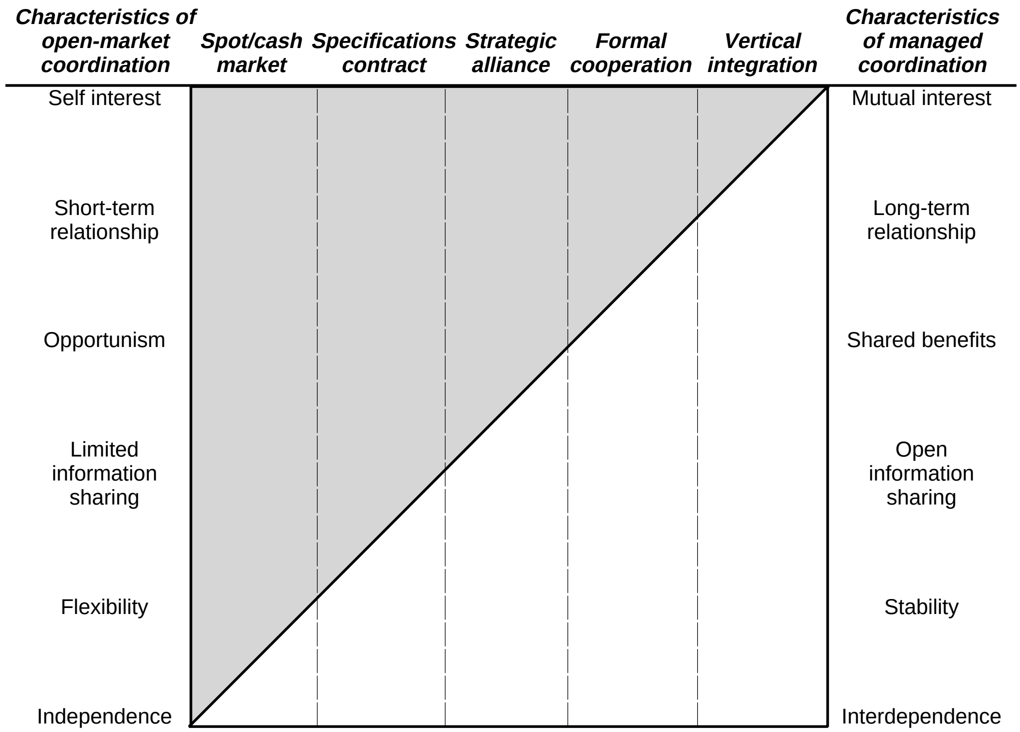
Traditionally, open-market prices have been able to provide signals for grain production and distribution that resulted in efficient commodity production. The open-market system requires minimal control and information from the buyer. A system of grades and standards provides a set of criteria that can distinguish grain by its physical characteristics. Tests are available to measure a commodity's grade level or to measure upon request non-grade-determining factors, such as moisture, oil, protein, and starch. Production (yield and quality) and price risk are the sole responsibility of the producer. Lastly, prices are discovered through the futures market, and these prices are transmitted to country cash markets incorporating spatial, time, and form characteristics. However, prices do not always transmit specifications desired by end-users. All commodities are assumed homogeneous, and extra value, unless segregated, is lost in the commingled system. Thus, the existing open-market system does not work well for some commodities with value-enhanced traits and needs to be changed, supplemented, or replaced by other coordinating arrangements.

It has been predicted that the next wave of biotechnology products on the market will be crops modified to target the needs of the end-user or consumer, such as foods with altered nutritional qualities, crops with improved processing characteristics, or plants that produce specialty chemicals or pharmaceuticals. Producing and marketing commodities with these enhanced-output traits—possessing greater value than regular commodities—may require greater control and more formal information exchange than the existing open-market system. Information beyond price and grade must be transmitted between the producer and buyer. Genetics, production practices, harvesting, handling, storage, and processing may need to be more closely coordinated in order to preserve the desired traits for the end-user. Product certification or testing may be required to validate product content. Producers of value-enhanced commodities may need to know their price before they produce because of increased complexity and costs. As coordination increases, both risk and additional value will be shared among the market participants, but the distribution of this risk and value is yet to be determined.

## Alternatives

The array of coordinating mechanisms presently ranges from an open market to complete vertical integration, with contracts, strategic alliances, and formal cooperation falling between the two extremes (fig. 3). The open market allows market participants to follow

Figure 3
**Strategic options for vertical coordination**




Note: The diagonal line represents the mix of open-market and managed coordination characteristics found in each of the five alternative strategies for vertical coordination. The area above the diagonal indicates the relative level of invisible-hand characteristics, and the area below the diagonal indicates the relative level of managed characteristics.
Source: Peterson and Wysocki.

their self-interests and engage in exchange relationships that are short term, opportunistic, limited as to information sharing, and flexible, and that preserve the participants' independence. At the other extreme, managed coordination is built upon mutual interests of the exchange participants who pursue relationships that are long term, that encourage benefit sharing, and that are open as to information flow, stable, and supportive of interdependence. Control increases as we move from left to right in figure 3. The factors that are controlled are price, quantity, quality, and terms of exchange.

Can increased information flow and testing permit the open-market system to handle output-enhanced commodities? Or will the developers of the value-enhanced crop try to capture most of the value in tightly controlled market channels? Advances in testing may enable grain to be graded on numerous criteria, ranging from milling characteristics to the content of various oils and amino acids (Barkema and Drabenstott). Such a system could handle some of the output-enhanced commodities, but their developer would have to allow them to enter the open market. For example, the estimated value of these traits will guide the direction of coordination. As value increases, coordination increases, the genetic technology developer would want to control the commodity from seed to final consumer, and the open market would be completely bypassed. However, if the value is low and fluctuates more with the market of competing commodities, then the developer may release the rights to this seed and simply charge a technology fee, requiring a licensing agreement between the technology developer and seed company.

Contracts are another means to coordinate a market of enhanced output traits. Partial or full vertical coordination can be obtained with contracts. Contracts are used for limited duration, and the number of actions and decisions involved are fewer than under full vertical integration. If a market is coordinated by contracts, there is usually a desire to minimize capital outlays. Firms under contract also maintain their separate identities. One disadvantage to producers is the loss of independence.

## Genetically Engineered Products

### Transgenic Agricultural Products Approved for Unregulated Release as of May 1999

| *Product* | *Number* | *Agronomic traits* | *Value-enhanced traits* |
|---|---|---|---|
| Crop: | | | |
| Beet | 2 | Herbicide tolerance | |
| Carnation | 3 | | Altered flower color |
| Chicory | 1 | Herbicide tolerance | |
| Corn | 13 | Herbicide tolerance, insect resistance (Bt) | |
| Cotton | 5 | Herbicide tolerance, insect resistance (Bt) | |
| Flax | 1 | Herbicide tolerance | |
| Papaya | 1 | Virus resistance | |
| Potato | 4 | Insect resistance (Bt) | |
| Rapeseed | 4 | Herbicide tolerance | High-lauric-acid oil |
| Rice | 1 | Herbicide tolerance | |
| Soybean | 5 | Herbicide tolerance | High-oleic-acid oil |
| Squash | 2 | Virus resistance | |
| Tomato | 11 | Delayed ripening | |
| Noncrop: | | | |
| Chymosin | | Enzyme used in cheese production; produced in bacteria | |
| RBST | | Bovine growth hormone; produced in bacteria | |

Contracts allow for a higher level of control and information exchange beyond what the open-market system offers. Requirements can be specified and will be upheld in courts of law. The buyer must specify desired price and grade information, product attributes, shipment procedures, production methods, varieties, testing requirements, quality requirements, and quality control measures. If special tests are to be performed, the buyer must specify them—for example, tests for a specific trait for the presence or absence of genetic modification of the crop. Contracts can reduce the level of risk by clearly stating the responsibility of the producer and the contractor.

There are many different types of contracts, however, and as some production or price risk may be reduced, other types of risk may be increased. Some contracts specify a price before planting, while others identify only a premium before harvest. For example, producers need to be aware of quantity and quality obligations, time of ownership transfer, and contract termination risk.

There are several different categories of contracts (Grinder):

- ***Marketing Contracts.*** Producer provides a quantity of commodities with specified physical or chemical traits or that has been produced using a specified set of practices. Pricing may be set before production, or it may be established from a commodity market (futures or local cash) with a premium.

- ***Production Contracts.*** Title to the growing and harvested crop remains with the contractor. The producer in this case is a temporary holder of the genetically modified seed. The producer usually agrees to repurchase the grain or oilseeds produced from the contractor's seed. However, the producer does not own the crop and, therefore, may not qualify for crop insurance or government program benefits.

- ***Fee for Service Contract.*** Contractor usually provides most of the nonland production inputs and sometimes more of the management decisionmaking. These fee contracts provide compensation to the producer for use of land, labor, and tillage machinery. Because the contractor has title and control of the crop produced, the producer may be viewed as a bailee.

## Genetically Engineered Products

### Examples of Transgenic Products "in the Pipeline"

#### Input traits:

- Introduction of herbicide tolerance into sugar beet, wheat, alfalfa, sugarcane, potatoes, forestry products, specialty fruits and vegetables.
- Introduction of insect resistance into tomato, sugarcane, soybeans, rapeseed, peanuts, eggplants, poplar; includes using other Bt toxins with different specificities and developing other toxins that could alleviate the problems associated with development of resistance to Bt.
- Introduction of disease resistance (to viruses, fungi, and bacteria) in corn, potatoes, and a variety of fruits and vegetables.
- Introduction of genes for other agronomic traits, including drought tolerance, frost tolerance, enhanced photosynthesis, more efficient use of nitrogen, increased yield.
- Increasing use of "stacked" traits (herbicide tolerance and Bt resistance in one plant, for example).

#### Output traits

Feed quality, food quality, value-added traits, specialty chemical production

- Traits affecting quality of animal feed:
  - Low-phytate corn.
  - Soybeans and corn with altered protein or oil levels (nutritionally dense).
- Traits affecting food quality for human nutrition (nutraceuticals):
  - Canola and soybeans producing oils high in stearate or low in saturated fats.
  - Canola with high beta-carotene (antioxidant) content.
  - Tomatoes with elevated lycopene levels (anti-cancer agent).
  - Grains with optimized amino acid content.
  - Rice with elevated iron levels.
  - Increased vitamin content.
  - Production of "low-calorie sugar" (indigestible fructans) in sugar beets.
  - Increased sugar levels in corn, strawberries, for enhanced flavor.
- Traits that affect processing:
  - Colored cotton.
  - Cotton with improved fiber properties.
  - High-solids tomatoes and potatoes.
  - Delayed-ripening fruits and vegetables, such as melon, strawberries, raspberries.
  - Altered gluten levels in wheat to alter baking quality.
  - Naturally decaffeinated coffee.
- Production of specialty chemicals (plants as bioreactors):
  - Production of pharmaceuticals, antibodies, vaccines, industrial chemicals in transgenic plants; examples include diarrhea vaccines in bananas, blood proteins in potatoes, rabies vaccine in corn, monoclonal antibodies in corn.
- Transgenic livestock:
  - Pharmaceuticals produced in milk in cows, pigs, or sheep; examples include antithrombin III (a blood anticoagulant, currently in phase III clinical trials), alpha-1-antitrypsin (used to treat cystic fibrosis), alpha lactalbumin (a human milk protein to use as a nutritional supplement).
  - Livestock with more rapid growth, less fat, disease resistance; more long term.

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Sources: Information Systems for Biotechnology website at Virginia Polytechnic Institute and State University (www.isb.vt.edu); APHIS Agricultural Biotechnology website (http://www.aphis.usda.gov/biotech/); Biotechnology Industry Organization website (www.bio.org); Monsanto website (www.monsanto.com); OECD BioTrack Online website (www.oecd.org//ehs/Service.htm).

- ***Pool Contract With a Closed Cooperative.*** A member of a cooperative delivers a commodity to a closed cooperative facility jointly owned and operated by a group of producers whose goal is to add value to the raw product they produce. Usually the cooperative requires the producer to purchase an equity instrument in direct proportion to the producer's rights and commitment to deliver under the contract. These contracts are generally sales contracts. However, because the member producers are contracting with an organization they own and control, these contracts may be treated differently than a sales contract under warehouse regulations, grain dealers' laws, farm programs, and other governmental institutions.

### Strategic Alliances

A strategic alliance is a business venture involving two or more entities striving to achieve a mutually identified objective. Strategic alliances allow two or more entities to join each of their strengths. A contract may be involved as part of the alliance. The alliance is simultaneously a single organizational arrangement and a product of sovereign organizations. For example, an alliance could be an acquisition, license agreement, or research and development partnership. Alliances provide firms with a unique opportunity to leverage their strengths with the help of another organization.

Asset specificity encourages additional coordination (strategic alliances) and explains recent arrangements between Optimal Quality Grain and Continental Grain. Continental's grain storage, handling, and transportation assets are used to market Optimum Quality Grain's high-oil corn to export destinations. Also, Monsanto and Cargill have entered into a similar alliance.

A strategic alliance is an exchange relationship in which firms share risks and benefits from mutually identified objectives. For an exchange relationship to be a strategic alliance, it must exhibit the following three characteristics: mutuality in objective identification, mutuality in controlling decisionmaking processes, and mutuality in sharing risks and benefits. Thus, coordination in a strategic alliance arises from mutual control. Coordination control arises from mutual interests, but both parties retain their separate external identity. The control level is higher than for contracts or the open market. The focus of control becomes the relationship between the parties, with the immediate transaction being only one element of the relationship.

### Formal Cooperation

Organizational forms included are joint ventures, partial ownership relationships, clans, agricultural cooperatives, and other organizational forms that involve some equity commitment. The distinguishing feature between this portion of the continuum and strategic alliances is the presence of a formal organization that has an identity distinct from the exchange actors and that is designed to be their joint agent in the conduct of a coordination transaction. This organizational structure represents the center of control.

An agricultural cooperative could be used to source specific types of enhanced-output crops. They could contract with member producers for supply and merchandise or process the crop. Several U.S. cooperatives are planning to participate in such activities.

### Vertical Integration

Vertical integration is the creation of one organization that has control over the coordination transaction. This can result from a merger of two parties, the acquisition of one party by the other, or one party internally committing resources to replace the market function of the other party. In any event, coordination control is exercised within the policies and procedures of a single organization.

Vertical integration occurs when successive stages of marketing or of production and marketing are not linked through prices through direct ownership or contracting. One reason for vertical integration is to assure a flow of product with certain specifications and delivery terms. Such integration may reduce marketing costs, and these savings may or may not be passed on to consumers, depending on the firm's market power. Horizontal expansion must often be used as well if the vertical expansion is to accomplish its purpose.

Vertically integrated systems usually produce high-value but low-volume segregated crops. Such systems allow technology developers to capture innovator profits and maintain rigid quality controls (Kalaitzandonakes and Maltsbarger).

What coordinating mechanisms are likely to be used in the future? The type will depend on the product's value, volume, and competitive market characteristics, and on the firm's desired control, capital resources, costs, and asset specificity. An array of coordinating mechanisms appears likely to be used depending on the situation.

## Genetically Engineered Fruits, Vegetables, and Livestock

### Fruits and Vegetables

The development of transgenic fruits and vegetables has lagged behind the work on commodity crops, such as corn and soybeans, due to the high cost of development and regulatory approval of foods from genetically engineered (GE) crops and because of smaller markets for fruits and vegetables. Much of the work, thus far, to develop transgenic produce has been done with public funds at such institutions as Cornell and the University of California at Davis. However, a number of biotech and seed companies are now entering the field, and a significant number of genetically modified fruit and vegetable products will likely enter the market within the next few years.

The first GE food on the market was the FlavrSavr tomato, which was engineered to remain on the vine longer and ripen to full flavor before harvest. (This product was eventually pulled from the market primarily due to problems with harvesting and marketing.) As with GE commodity crops, the bulk of the first new GE fruits and vegetables will be modified for improved agronomic properties, such as resistance to fungal or viral infection, tolerance to herbicides, or delayed ripening. Thus far, virus-resistant papaya and squash have been approved for release, in addition to a number of types of delayed-ripening tomatoes.

The second wave of GE fruits and vegetables will target characteristics that appeal to the consumer directly—for example, apples that do not brown when cut, strawberries with enhanced sugar levels for improved taste, or "greener" green beans. Many companies are also using genetic engineering to develop "functional foods," products with additives that enhance the nutritional value or health benefits, such as lycopene-rich tomatoes or foods producing extra vitamins or anti-oxidants.

The cost of development and obtaining regulatory approval for biotech food products is quite high, and it can take 8 years or more to bring a product to market. To recapture their investments, seed developers can be expected to charge higher prices for the seed; the producers will in turn charge a premium for the new product (for output traits) or recoup these costs in savings on pesticides or labor (for input traits). Officials in the fruit and vegetable seed industry do not foresee a need for restructuring the supply chain for their commodities, as the many varieties of fresh fruits and vegetables are not bulked and stored but often transported in small lots to markets. Thus, it should be relatively simple to incorporate GE varieties with value-added traits into the current marketing system.

### Livestock

The first transgenic livestock—sheep and goats—were produced in 1985, using techniques similar to those used to produce transgenic mice in 1981. Genetic transformation of animals has become fairly routine, although it remains a time-consuming and expensive process. To introduce foreign DNA, newly fertilized eggs are flushed from an animal's reproductive tract and the cells are individually injected with DNA. The eggs are implanted into a surrogate mother, and the offspring are tested for the presence of the new gene. Fewer than 1 in 10 babies are transgenic, and the overall efficiency of the process is actually lower, as most of the fertilized embryos do not develop following implantation.

Because the development of transgenic animals is slow, inefficient, and expensive, much of the research to date has been performed at USDA's Agricultural Research Service or at private companies that have identified potential products with high payoffs. The three major types of research involve (1) genetic modifications that promote animal growth or health, including introduction of growth hormone genes or disease-resistance genes; (2) modifications that allow the use of animals as human disease models or as human organ donors (for example, expression of human proteins in a pig heart to lessen the risk of rejection in cross-species organ donations); and (3) use of animals as bioreactors to produce pharmaceuticals in milk.

Research and development in the last category is progressing rapidly, with several products currently in clinical trials. The first product to be approved will likely be antithrombin III, an anticoagulant used during heart bypass operations. Other promising products are alpha-glucosidase, used to treat patients with the muscle disorder Pompe's disease, and alpha-1-antitrypsin, a protease inhibitor used to treat cystic fibrosis. The potential for use of transgenic animals will probably increase as the technology improves for cloning animals. In contrast to production of a transgenic, cloning allows the exact genetic reproduction of an adult animal. This technique would allow the inexpensive reproduction of a transgenic animal to produce identical herds with certain desirable characteristics.

***Policy Issues.*** The use of animals as bioreactors and as sources for human organs could raise ethical issues as well as concern about animal welfare. There should be little effect on the markets for beef and pork for consumption, as GE meat, if leaner and tastier, would likely be sold as a specialty product. The production of pharmaceuticals in milk would not likely have any effect on the dairy industry, as the numbers of animals used in a production facility would be small and the animals would be well isolated. However, this technology could significantly reduce the cost of production for many pharmaceuticals, which could have a major impact on the current drug industry.

Open markets, licensing agreements, contracts, strategic alliances, cooperatives, and full vertical integration are all likely candidates in conjunction with a segregated or identity-preserved handling system.

Increased value will tend to lead to further coordination within the market. The technology provider creates the original value of this crop and will likely want to control this value and share it according to each market participant's bargaining position, assumed risk, or additional costs relative to the traditional commodity system.

According to some industry sources, as the biotechnology industry commercializes more value-enhanced traits, market channels may become more coordinated and involve fewer participants. Specifically, the vertical value chain will be shorter and more coordinated (Renkoski). It has been suggested that value-added commodities will need contract production in conjunction with segregated or identity-preserved handling systems (Hayenga). Others suggest that future merchandising systems for value-enhanced crops may parallel a diminished traditional commodity system but possess added value (expand market, create new markets, increase product differentiation, and improve management of both logistics and supply) (Kalaitzandonakes and Maltsbarger). A modified open market could continue to provide a way to coordinate output-enhanced commodities with minor additional value, especially considering the introduction of new testing procedures for selected end-use traits.

## Policy Issues

Marketing arrangements, like contracting and various forms of vertical integration, have emerged as important coordination mechanisms for moving products from producers to processors to consumers. Some important questions for policymakers to consider are: When are contractual arrangements detrimental to farmers? When are they beneficial? And what role, if any, should government play in regulating contracts? Cooperatives represent opportunities for farmers to gain more leverage in the marketplace. While cooperatives have existed for a long time, their importance has grown as a form of countervailing power to gain bargaining clout in both input and output markets. Cooperative arrangements also need to be explored, particularly the potential for their further development and government's role in promoting and strengthening them.

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