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Biotechnology in Agriculture: Implications for Farm-Level Risk Management

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This study examines the risks associated with adoption of biotech crops and discusses their implications for risk management at the farm level. We develop an analytical risk evaluation matrix framework to illustrate changes in production and marketing risks of biotech and non-biotech crops. Price uncertainty generated by consumer concerns is the major risk facing biotech farmers, while cross-pollination with biotech crops and preservation of non-biotech status are major concerns for non-biotech farmers. Improved market infrastructure to handle biotech products and modification of the current risk management tools to accommodate new risks are essential in reducing the farm-level risks.

Key Words: biotechnology, genetically modified organisms, marketing risks, production risks, risk evaluation matrix, risk management

Agricultural biotechnology has delivered products that could significantly transform food production and consumption in the next millennium. At the same time, genetically engineered foods are attracting considerable attention and concerns among consumers and environmentalists. Although various studies have analyzed the environmental and health issues associated with the adoption of genetically modified (GM) or biotech crops (for example, Alteri, 2000; Lehrer, 1999; Paoletti and Pimentel, 1995), no comprehensive studies have investigated the risks facing farmers with the advent of biotech crop varieties.[1] The purpose of this paper is to assess the farm-level risks associated with the adoption of biotech crops, and then to provide a discussion of risk management strategies designed to reduce production and market uncertainties for both biotech and non-biotech crop producers.

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[1] Biotechnology is a collection of techniques involving biochemical manipulation of genes or DNA of living organisms. The term "biotech" in this article more narrowly refers to genetically engineered or modified crops.

Developments in transgenic crops engineered for insect resistance (e.g., Bt cotton, Bt corn), herbicide tolerance (e.g., Roundup-Ready soybeans), and value enhancement (e.g., high oleic soybeans and colored cotton) are expected to benefit producers and consumers (Traxler and Falck-Zepeda, 1999; Moschini, 1999), and have the potential to significantly change how farmers produce and market their products. Adoption of biotech crops in the U.S. has been extremely rapid, as many producers have benefited through decreased pesticide use and the consequent lower production costs, greater flexibility in the timing of planting, and the potential for higher yields and lower yield variability [U.S. Department of Agriculture/Economic Research Service (USDA/ERS), 2000]. By 1999, nearly 60% of soybean harvested acres in the U.S. was planted to herbicide-tolerant biotech soybeans, while about one-third of corn harvested acreage and about 55% of cotton harvested acreage were planted to pest-resistant biotech varieties (USDA/National Agricultural Statistics Service, 2000).

Some consumers in the United States and abroad remain wary of the new technology, despite reviews by the U.S. Food and Drug Administration (FDA) which have determined biotech foods currently in the marketplace are safe for human consumption (USDA/ERS, 2000; Lin, Chambers, and Harwood, 2000).[2] Although biotech crops have been successful in resisting selected pests, their effect on the environment and nontarget organisms remains unclear. One concern is that, in the long run, insects and weeds may develop resistance to Bt and other substances in biotech crops, leading to the development of super-pests or super-weeds (see U.S. Congress, House of Representatives, Committee on Science report, 2000). The long-term opportunities and uncertainties associated with biotechnology are the focus of continued debate.

The market is responding, albeit on a limited scale, to consumer preferences for non-biotech products. For example, a few grain handlers have begun to segregate biotech from non-biotech commodities for non-biotech niche markets, particularly for shipments to the European Union (EU) and Japan. Down the processing chain, changes have also occurred. In July 1999, both Gerber and Heinz announced their baby food processing facilities would immediately stop using biotech inputs. In January 2000, Bestfoods, Inc., decided to end its use of biotech ingredients in manufactured foods destined for the EU in order to avoid the EU's labeling requirement, and Frito-Lay, Inc., announced it would cease using biotech corn in its snack food manufacturing (Lin, Chambers, and Harwood, 2000). In October 2000, Kraft Foods recalled millions of taco shells potentially containing a genetically engineered variety of corn that produces the Cry9C protein. This protein is not

[2] The U.S. government is committed to the safe development of the products of biotechnology from the laboratory, through field testing, and into the market place. In 1986, the U.S. government adopted a "Coordinated Framework" to assess the risks to agriculture, the environment, and human health. USDA regulates the development and field testing of genetically modified plants and evaluates biotech crops for agricultural and environmental safety. The Environmental Protection Agency's (EPA's) responsibility is to ensure the safety of the environment and natural resources from biotech crops. FDA assesses the food and feed safety and nutritional aspects of biotech products (McCammon, 1999).

suitable for human consumption because of concerns it might trigger allergic reactions.

These developments have created uncertainties in the production and marketing environment for both biotech and non-biotech crops. For example, events of the past years suggest farmers who adopt biotech crops may face price risks associated with diverting their crop to certain feed markets if large shifts occur in consumer preferences (USDA/ERS, 2000). In contrast, those who plant non-biotech crops may face the conventional risks of pests and diseases and, depending on the market outlet, the risks of additional costs associated with segregated production and marketing. The costs associated with segregated marketing include testing for biotech or non-biotech content along the marketing chain, and keeping non-biotech products separate during storage, shipping, and processing (USDA/ERS, 2000; Dunahay and Lin, 1999).

At issue is whether agricultural biotechnology calls for new risk management strategies on the part of producers. Does biotechnology create new production and marketing risks for biotech as well as non-biotech farmers? What tools are available to mitigate risks if farmers themselves or their neighbors adopt biotech crops? How easily will insurance providers be able to modify and/or develop contracts to accommodate the risks generated by the adoption of biotech crops? Addressing these issues calls for assessing farm-level risks and understanding specific farm-level risk management strategies to mitigate uncertainties for both biotech and non-biotech farmers.

Method of Analysis

For this investigation, we develop an analytical risk evaluation matrix (REM) framework, within which we attempt to capture the intra- and inter-year planting season risks faced by farmers.[3] REM captures, in a stylized fashion, the risks related to biotechnology through the production and marketing systems. While the adoption of biotech crops may generate a variety of risks for a host of economic agents, we concentrate in this study on producers' risks. As little or no data are available on the extent and kinds of risks associated with biotech crops, the REM approach provides a framework for capturing the channels through which biotechnology generates and transmits its effects.

Our risk evaluation matrix is designed to illustrate the direction of change in risks, relative to status quo, associated with different stages in the production and marketing of biotech and non-biotech commodities for different end uses. Table 1 summarizes the risks in the production and marketing of biotech and non-biotech products. The table illustrates the interaction between the different stages of production and

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[3] The risk evaluation matrix is similar in construction to the policy evaluation matrix (PEM), which is widely used in policy analyses (e.g., Organization of Economic Cooperation and Development, 2000) when data are scarce and/or qualitative in nature. The PEM captures, in a table form, the impact of various policy changes on production, trade, farm incomes, etc., and interactions of the policies among themselves.

Table 1. Biotech and Non-Biotech Crops: Potential Changes in Production and Marketing Risks

		End Uses of Biotech and Non-Biotech Products			
Potential Risks	Row Nos.	[1] Food Use	[2] Feed Use	[3] Industrial Use	[4] Exports
		! ! ! ! ! ! ! ! ! ! ! BIOTECH CROPS ! ! ! ! ! ! ! ! ! ! !			
Production Risks:	1				
Seed Cost and Availability	2	(?)	(?)	(?)	(?)
Pest and Disease Risk	3	(–)	(–)	(–)	(–)
Yield Risk	4	(–)	(–)	(–)	(–)
Cross-Pollination Risk	5	(NA)	(NA)	(NA)	(NA)
Management Risk	6	(?)	(?)	(?)	(?)
Marketing Risks:	7				
Transportation Risk	8	(0)	(0)	(0)	(0)
Storage Risk	9	(0)	(0)	(0)	(0)
Testing Risk	10	(NA)	(NA)	(NA)	(NA)
Market Outlet Risk	11	(0)	(0)	(0)	(0)
Price Risk	12	(+)	(+)	(+)	(+)
		! ! ! ! ! ! ! ! ! NON-BIOTECH CROPS ! ! ! ! ! ! ! ! !			
Production Risks:	13				
Seed Cost and Availability	14	(?)	(?)	(?)	(?)
Pest and Disease Risk	15	(0)	(0)	(0)	(0)
Yield Risk	16	(0)	(0)	(0)	(0)
Cross-Pollination Risk	17	(+)	(+)	(+)	(+)
Management Risk	18	(+)	(+)	(+)	(+)
Marketing Risks:	19				
Transportation Risk	20	(+)	(+)	(0)	(+)
Storage Risk	21	(+)	(+)	(0)	(+)
Testing Risk	22	(+)	(+)	(+)	(+)
Market Outlet Risk	23	(+)	(+)	(0)	(+)
Price Risk	24	(?)	(?)	(?)	(?)

Notes:
(+) = increased risk (relative to the existing technology)
(–) = decreased risk (relative to the existing technology
(0) = no change in risk (relative to the existing technology)
(?) = cannot tell/indeterminate
(NA) = not applicable

the risks to producers associated with sales to different end-use destinations. Each cell in table 1 contains a sign to indicate the direction of change in farm-level risk due to the advent of biotech crops in agriculture. A *plus* sign (+) in a particular cell means an increase in risk, while a *minus* sign (–) indicates a decrease in risk. Similarly, *zero* (0) indicates no change in risk, and a *question mark* (?) implies that we cannot determine the direction of change.

Our empirical analysis will focus on risks to producers associated with the production and marketing of biotech and non-biotech corn, cotton, and soybeans. We rely on two sources of information to construct the REM table. First, we use a number of previous studies that examine farm-level production and marketing issues associated with biotechnology. Second, we use data obtained from the Agricultural Resource Management Study (ARMS), an annual survey conducted jointly by the USDA's Economic Research Service and National Agricultural Statistics Service. The ARMS survey provides information on farm-level decisions and practices, costs of production, and farm income.

Potential Changes in Risks

In this section, we discuss the potential changes in risks associated with biotech and non-biotech crops and their implications for farm-level risk management. We analyze risks that can arise during different stages of production and marketing across both intra- and inter-year time spans. Each of the stages is discussed in turn below.

Production Risks

The production stage primarily involves farmers making decisions on growing biotech or non-biotech crops, which would be influenced by the availability and costs of inputs, the expected profitability of the crop, and market uncertainty associated with these products. Between planting and harvesting periods, producers face a series of risks in ensuring stable yields. Some risks are common to both biotech and non-biotech crops, while some are unique to biotech crops. There are some negative externalities in the production of biotech crops that increase the risks to non-biotech crop producers (e.g., cross-pollination for corn). In the following subsections, we discuss production-related risks associated with the adoption of biotech (or non-biotech) crops.

Seed Cost and Availability

Typically, companies charge higher seed prices (and in some cases technology fees as well) to help recoup their research investments. For example, seed companies charged a price premium of $9 to $9.50 for Bt corn per acre in 1999, about 35–40% above the amount charged for conventional varieties (Chambers, 1999; U.S. General

Accounting Office, 2000). Because seed companies are heavily engaged in developing and promoting biotech varieties, a potential risk could emerge regarding shortages of seeds for either biotech or non-biotech crops in certain areas. The severity of this risk depends on farmers' demand in the following planting season/seasons, with the associated risks most likely to be felt at the local rather than at the national level (USDA/ERS, 2000).[4]

Given the development of stacked-gene crop varieties with end-use specific traits, some experts believe tightly integrated vertical linkages between seed genetics and grain origination will begin to emerge over the long run (Riley and Hoffman, 1999). These vertically integrated systems may emerge into "value clusters" where limited competition among firms may result in input market uncertainties and cost variability to producers in the future. Non-biotech crops capturing the trend toward more refined quality standards cause producers to face similar risks associated with variability in seed cost (USDA/ERS, 2000). These potential circumstances imply that the risks associated with input supply are hard to determine for both biotech and non-biotech crops, regardless of the end-use destination, but may be more likely to increase than decrease (see table 1, row 2, all columns, and row 14, all columns).

Pest and Disease Risks

ERS-USDA researchers have found an association between increased adoption of herbicide-tolerant soybeans and significant decreases in total herbicide use in soybean production (USDA/ERS, 2000). Also, herbicide-tolerant and Bt cotton varieties are associated with decreased pesticide use (Klotz-Ingram et al., 1999). Farmers who have adopted biotech crops are able to use a broader variety of herbicides that are more effective in weed control. These are some of the reasons explaining the rapid adoption of biotech crops. As pest control becomes more effective due to the inherent characteristics of biotech crops, biotech producers are more likely to face decreased pest and disease risks for all end uses of biotech crops (table 1, row 3, all columns). In contrast, pest and disease risks remain the same for non-biotech crops regardless of end-use destinations (table 1, row 15, all columns).

Yield Risk

Many uncontrollable events—including floods, droughts, extreme temperatures, hail, insects, and diseases—affect crop yields. Biotech crops are designed to better tolerate these unfavorable growing conditions and achieve higher productivity and improve end-use quality. Biotechnology presents opportunities for higher agricultural productivity and potentially lower production costs for producers (at current technology fees) in locations where insects or diseases are a particular problem. As a result, yield risks may decline for certain crops in certain areas (Klotz-Ingram et al., 1999;

[4] The report qualifies the 1999 adoption data and provides an update as to 2000 plantings.

Traxler and Falck-Zepeda, 1999). For example, Klotz-Ingram et al. found significant increases in yields from Bt cotton. However, the results on yield levels and yield variability of biotech crops depend very much on the likelihood that the problem addressed by planting a particular crop actually applies in a given agricultural production area. In addition, farmers planting pest- and disease-resistant biotech crops benefit from flexibility in the timing of planting and insecticide applications, and thus decrease their dependence on weather conditions, which is a major source of yield risk independent of end-use destination (table 1, row 4, all columns). On the other hand, the risks for non-biotech crops remain the same for all end-use categories (table 1, row 16, all columns).

Cross-Pollination Risk

Cross-pollination of a non-biotech crop with a biotech crop in the field can result in the loss of non-biotech status, a type of production risk most relevant for corn (because it is an open pollinated crop). Controlling for cross-pollination requires producers to follow special management practices. In the case of contract production, producers are typically responsible for ensuring the integrity of their product at specified tolerance levels. Cross-pollination risk is likely to be an issue for non-biotech products, in particular to those used for food, feed, or exports (see table 1, row 17, columns 1, 2, and 4). Producers can attempt to minimize cross-pollination through the use of buffer plantings and other management techniques, such as planting non-biotech up wind of biotech fields (Hyde et al., 1998). For biotech crops, however, cross-pollination is not likely to be an issue, regardless of the end-use destination (table 1, row 5, all columns).

Management Risk

Production of biotech crops may challenge producers to become more informed and rely more on science for their decision making. Biotech crops may require farmers to follow special production practices to keep the crop pure or to prevent cross-pollination of non-biotech fields or relative species in the wild. For example, farmers are required to plant a portion of their crops with a non-biotech variety (e.g., 20–50% of total corn acreage in conventional varieties—20% for states in the North and 50% in the South). The rationale behind these "refuges" is to prevent or delay the development of tolerance by insects, as these non-Bt plants will allow a haven for insects. Another benefit from refuge planting is that it can reduce cross-pollination. However, maintaining refuge crops may involve additional costs to farmers.

In contrast, pest-resistant biotech crop varieties, such as Bt corn and Bt cotton, have the potential to reduce the cost of pesticide application, and can reduce the efforts required to monitor and control pests. In sum, the net effect of management risk for biotech crop producers is difficult to determine for all end-use destinations (table 1, row 6, all columns), although intra-year management variability seems more likely to be reduced. On the other hand, management risks for non-biotech crops may well increase due to the need to maintain non-biotech status, regardless of the end-use destination (table 1, row 18, all columns).

Marketing Risks

Marketing of commodities for certain end-use destinations will involve identity-preserved or segregated transportation, storage, testing for genetic status, processing, and final sales, particularly as stacked-gene crops are developed with end-use specific traits, or if certain market segments continue to prefer non-biotech crops. Differentiated marketing of biotech and non-biotech crop products may require greater control and greater technical knowledge to preserve the trait-specific status of the crop (Ebbert, 1998; Kalaitzandonakes and Bjornson, 1997; Renkoski, 1997). In addition, major buyers in the EU, Japan, and Korea have cut their purchases of U.S. biotech corn and soybeans. All these changes can have a major impact on market and price stability in the U.S.

Transportation

The advent of biotech crops may involve higher farm-level transport costs because segregation at elevators may force farmers to transport their non-biotech crops farther distances to first handlers. Another issue is associated with timing, particularly if elevators accept biotech crops on certain days and non-biotech crops on other days (National Grain and Feed Association, 2000). This type of timing issue can result in delays for producers and the potential need for additional on-farm storage. In general, it may result in increased risks to producers (table 1, row 20), especially if the commodity is for food, feed, or exports (columns 1, 2, and 4). Careful cleaning of harvesting equipment, trucks, and other unloading and loading equipment is important to maintain the genetic status for non-biotech crops. Farmers also face the risk of commingling biotech with non-biotech products during transport. Consequently, risk generated by transport requirements and specifications is most likely to increase for non-biotech crops (table 1, row 20, columns 1, 2, and 4). Regarding biotech crops, transportation risks for all end uses may remain the same (table 1, row 8, all columns).

Storage

The risks associated with the availability and cost of storage space for non-biotech crops may well increase if either segregation or identity preservation, from the field through harvest and subsequent shipment to the final destination, is required (Riley and Hoffman, 1999). Producers have the potential to depend more on on-farm storage, as well as pay more for storage at elevators (due to additional, segregated bin space), resulting in increased risk for non-biotech products. Farmers are likely to absorb at least a portion of the additional costs associated with identity preservation because effective segregation begins at the farm level (Lin, Chambers, and Harwood, 2000).

Furthermore, producers must weigh the cost of storage with the price premium they expect to receive for their non-biotech crops. Storage space and methods are sources of increased risk for non-biotech crops. Although producers receive high price premiums for non-biotech crops, like food-grade soybeans in Japan, a large variance is typically associated with those premiums (USDA/ERS, 2000). We conclude that risks are likely to increase for non-biotech crops if the end use is destined for food, feed, or exports (table 1, row 21, columns 1, 2, and 4), while risks are likely to remain the same if the destination is industrial use (table 1, row 21, column 3). Storage risks are likely to remain the same for biotech crops for all end-use destinations (table 1, row 9, all columns).

Testing

Identity-preserved marketing of commodities involves containerization or complete segregation of the product by crop variety from harvest through final disposal (Dunahay, 1999; Dunahay and Lin, 1999). With segregation, however, the product is often tested at each stage of marketing, transportation, storage, and processing, as the case may be, and testing is quite critical throughout the grain handling and distribution system. This, in turn, points to the need for ensuring a well-functioning market coordination system with accurate, quick, and economical testing procedures to detect for the presence of biotech traits. There are various methods and procedures available for detecting biotech traits, but each varies in the level of precision and the risk to the farmer of a false positive result. Consequently, testing would likely be associated with increased risks, particularly for non-biotech crops destined for food use, feed use, and exports (table 1, row 22, all columns); for crops destined for industrial uses, testing would pose less potential risks. Since testing is not applied to biotech crops, risks associated with testing are not relevant for biotech crops for all end-use destinations (table 1, row 10, all columns).

Market Outlet Risk

Marketing of non-biotech food grains requires more tightly coordinated arrangements for preserving the desired traits for the end user. Some grain elevators have asked producers to sign contracts which stipulate that in the event of shipment rejection caused by a false positive for biotech content, growers would be liable for any financial losses (USDA/ERS, 2000). Companies producing and marketing biotech seeds have also developed “growers’ agreements” stating that farmers are responsible for finding domestic market outlets for their crops if export markets are closed. With these risks being passed on to producers, it appears market outlet risks for non-biotech producers could increase, particularly for food, feed, and export outlets (table 1, row 23, columns 1, 2, and 4). For biotech producers, market outlet risks would not likely change (table 1, row 11, all columns).

Price Risk

In some ways, price represents the cumulative effects of all risks past the farm gate. As consumers' preferences change for biotech versus non-biotech products, producers are facing market uncertainties as well as price risks generated by intra- and inter-year price variability. Although the domestic market for biotech crops is more important than foreign markets, particularly for corn and soybeans, it is difficult to gauge and predict current U.S. consumers' attitudes toward biotech commodities (USDA/ERS, 2000; Dohlman, Hall, and Somwaru, 2000), implying price risk is a relevant concern.

If foreign markets restrict biotech products which extend to processed livestock and poultry feed and require non-biotech commodities to include strict regulations on processed food labeling, then price risks to U.S. producers could be substantial. In other words, shifts in foreign demand could affect domestic market and domestic price variability (USDA/ERS, 2000) and trigger increases in price risks for biotech crop producers. Likewise, if sales to export markets were limited for biotech products and farmers were not able to divert their crops to domestic feedlots, producers would also face increased price risks. If storage costs due to segregation and inadequate storage facilities become an issue, producers might face price variability and increased price risks, especially in the short run. In sum, biotech producers may face greater market uncertainties and price risks, as the demand for biotech products is most likely to be affected by changes in consumer preferences (table 1, row 12, all columns).

Producers of non-biotech crops are compensated with price premia, which vary, however, by commodity and end-use destination. As handlers and processors rely on farmers to establish the non-biotech content of the product, and some elevators develop contracts stating that farmers are liable in the event any non-biotech shipment is rejected, non-biotech producers could face increased market uncertainties for ensuring their product identity. Increased market uncertainties, in turn, increase price variability and cause increased price risks for non-biotech producers. If contracting prevails and the open market becomes less responsive in capturing the underlying market forces, non-biotech producers might be less able to estimate fair market prices and gauge the direction of the market. The net effect of these combined factors on non-biotech commodity prices is not clear at this time (table 1, row 24, all columns).

What Do These Risk Factors Mean for Farmers?

Biotechnology has created a new set of production and marketing risks not experienced previously by farmers. These new risks require new strategies to mitigate farm-level risks associated with production and marketing of both biotech and non-biotech crops. Farmers adopt a combination of strategies to reduce yield and price risks. The prominent strategies include crop yield and revenue insurance contracts, and marketing and futures contracts, as well as improving market capacity to handle biotech and non-biotech commodities separately. In the discussion below, we examine several strategies or approaches that could reduce the risk and uncertainty in production and marketing of both biotech and non-biotech products. For ease of exposition, we first discuss the strategies farmers can adopt to mitigate production and marketing risks, followed by strategies to improve market capacity and to reduce price uncertainties.

Effective Risk Management Strategies at the Farm Gate

Crop Yield and Revenue Insurance Contracts

Crop yield and revenue (i.e., crop revenue, income protection, revenue assurance) insurance contracts are designed to protect farmers against yield and price risks. As noted in earlier sections, the advent of biotech crops has brought changes in the risks associated with production and marketing of both biotech and non-biotech crops. At issue is the effectiveness of existing yield and revenue insurance products in mitigating changes in risk of biotech and non-biotech crops and adopting proper modifications required for making the products more useful to both biotech and non-biotech farmers.

Certain biotech crops are associated with higher expected mean yields, through improved resistance to pests and diseases or greater tolerance to environmental stress, and therefore lower variance of yield (table 1, row 4). Conceptually, this implies biotech crops may reduce yield risks to farmers and reduce the problems associated with input usage, which can increase yield dispersion of crop yields. In addition, non-biotech producers, particularly those attempting to capture the price premium associated with their crop, might more likely focus on actions and increase their efforts to ensure the best outcomes for their crop, thus reducing yield variability problems. However, if crops increasingly require specialized in-field production practices, it may become difficult for insurers to monitor producers and ensure their commitment to the highest possible yields (table 1, rows 5, 6, 17, and 18).

Producers of non-biotech crops would benefit if existing insurance contracts were expanded to cover possible decreases in market values due to cross-pollination or accidental commingling during the marketing of the product (see table 1, rows 5, 8, 9, 17, 20, and 21, all columns). In the future, production of both GM and non-GM crops may also face problems associated with cross-pollination and commingling. The major challenge to the crop insurance industry is to recognize these additional risks facing farmers and provide adequate protection.

Insurance programs rely on the farmer's average historical yield on a given parcel of land (called the actual production history or APH yield) and a projected price (either based on an average of futures prices or USDA's projected season average price) to determine premium rates and indemnity payments (in case of yield loss).[5] Producers who switch to biotech crops may experience increased yield differentials causing their expected yield to exceed their past average yields (Klotz-Ingram et al., 1999). However, such farmers would be offered yield contracts which guarantee payments for yield levels based on previous non-biotech variety yields. In this case, farmers may find the expected value of such a contract to be lower than their willingness to pay for the contract, and therefore may be less inclined to purchase crop insurance contracts. Furthermore, the increased yield differentials can alter farms' risk classification, which increases the cost of insurance to biotech crop producers. Thus, adjusting farmers' yield history to accurately account for shifts in yield levels and yield risks is critical.

Non-biotech producers may prefer yield insurance contracts if they receive price premiums or have production and marketing contracts. Farmers would benefit if the existing yield insurance contracts are made to cover possible decreases in market values due to contamination or false tests.

Production and Marketing Contracts

For commodities with certain value-enhanced traits, including the absence of biotech content, a more coordinated production and marketing system will likely emerge, specifying non-biotech status and associated prices and grades. The major purpose of such a system would be to ensure the flow of product with specific traits and delivery terms. Contractual arrangements may well emerge requiring greater control, product certification, testing, and an adequate information system between producers and users, similar to the production contracts currently used in the specialty crops and poultry industries.[6] Production and marketing contracts set a fixed price and/or outlet for a crop before harvest. Such contracts could reduce marketing and price risks to farmers and others involved in the marketing chain.

Futures Contracts

A more refined futures contract that distinguishes biotech and non-biotech products may very well provide farmers with a method for reducing price risks. At present, futures contracts do not reflect price differentials between biotech and non-biotech commodities, although new types of contracts may well emerge.

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[5] Under current programs, premium rates are driven by a producer's average yield, where producers with higher APH yields are assessed lower premium rates and vice versa on the assumption that expected losses decrease as the expected yields increase (Makki and Somwaru, 2001).

[6] Production contracts in the broiler industry were found to reduce risk by more than 95% relative to an independent grower case (Knoeber and Thurman, 1995). Martin (1997) reports similar findings in the case of hog contracting.

Mitigating Price Risks Beyond the Farm Gate

The traditional competitive marketing system, which is based on price signals through futures markets, can be characterized as an efficient production and marketing system linking producers and consumers. While marketing mechanisms vary from open market to vertical coordination, existing marketing channels used for marketing bulk grains might require adjustment for accommodating the needs of marketing both biotech and non-biotech crops. The marketing system accounting for advances in coordination, testing, and formal information exchange among producers and buyers can provide the information needed via the price signals to both biotech and non-biotech producers.

Market Information

A marketing system designed to provide information regarding price premiums and discounts, potential legal liabilities, testing and certification standards, and market outlets is critical for reducing price risks for non-biotech producers. For biotech commodities, in contrast, information regarding prices, delivery locations, and export demand may help farmers in making timely decisions.

Testing and Certification

As the demand for non-biotech products increases, rapid, reliable, inexpensive testing methods may be needed to verify the biotech status and facilitate segregated marketing (table 1, rows 10 and 22, all columns). Development of tests acceptable to all stakeholders may be difficult but not impossible. Such tests will improve marketing efficiency and will benefit both consumers and producers.

Labeling of Biotech Products

Several countries, including the EU, Japan, and Australia, favor labeling biotech products to let consumers make informed choices. Labeling would provide information to consumers, allow them a choice between biotech and non-biotech content, and help them avoid exposure to potential allergens. Labeling with full disclosure would be a step toward more informed decision making and would provide a way to increase consumers' acceptance of this new technology. Because labeling would reduce the market uncertainty for biotech foods, it may help reduce risks to biotech crop producers. However, labeling may involve additional costs in setting standards for testing, certification, and enforcement. Also, labeling might not be the best tool to address externalities (such as cross-pollination, accidental commingling, etc.) associated with biotech crops (Golan, Kuchler, and Mitchell, 2000).

Global Agreement on Health and Biosafety Standards

Even though the evidence on environmental and health risks associated with biotech products/crops at this time is not clear, we cannot ignore the potential future marketing risks (such as risks associated with allergens or the transfer of genes to nontarget plants through pollen) of biotech crops. A major part of the controversy has been fueled by attitudes among regulators and manufacturers who dismiss unanswered questions about biotech foods (Lefferts, 1999). If a science-based global approach is established to assess the risks to agriculture, the environment, and health, and to develop acceptable standards, then consumers' reluctance toward biotech products might be reduced. Development of sound safety regulations and establishment of standards acceptable to the global community are important for the efficient marketing of biotech products and perhaps full realization of biotechnology's potential.

Summary and Conclusions

This study has examined the risks to farmers associated with the production and marketing of biotech and non-biotech crops, and strategies were presented for minimizing these risks at the farm level. For purposes of this investigation, an analytical framework was developed to illustrate in a consistent manner the risks generated by the adoption of biotech crops.

Using a risk evaluation matrix, we were able to capture production and marketing system risks, by end-use categories, for both biotech and non-biotech crop producers. Although biotech crops were initially adopted because of the benefits they offered farmers, such as potential increased yields and decreased input costs, the driving force behind the market uncertainties for biotech products has been consumers' preferences, primarily originating in the export markets.

These uncertainties, in part, bring new challenges to managing production and marketing risks in agriculture. Yield and revenue insurance contracts, as well as futures contracts, may adjust accordingly to account for new production practices in mitigating producers' risks. At the same time, producers may consider increased diversification of their production practices in response to changing consumers' preferences. In addition, production and marketing contracts may be used increasingly in the crops sector to address the risks associated with the production and marketing of both biotech and non-biotech crops. A more sophisticated market infrastructure to handle biotech and non-biotech products separately and the ability to provide efficient testing and certification would benefit all stakeholders in agriculture.

The globalization of U.S. agriculture, resulting from falling trade barriers and increased demand, has provided opportunities for expanding sales of U.S. agricultural products. At the same time, foreign markets' preferences via price mechanisms have the potential to affect U.S. producers. If a science-based global assessment of the risks associated with the production and marketing of biotech crops occurs and a harmonization mechanism is established, then the global market system would likely adjust more effectively. In the meantime, the net effect of changing risks discussed here is difficult to determine, and over time will likely vary by crop and specific end-use market.

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