

Summary

The adoption of biotech crops, particularly herbicide-tolerant soybeans and cotton, has been rapid since their commercial introduction in 1996. For example, herbicide-tolerant soybeans accounted for 81 percent of U.S. soybean acreage in 2003, leaping from 7 percent in 1996. Biotech crops can offer producers distinct advantages over conventional varieties, such as potentially higher yields and lower pest control costs.

But producers are not the only ones to gain from the adoption of agricultural biotechnology. Biotechnology developers and seed companies gain by charging technology fees and seed premiums to adopters who plant biotech varieties. Ultimately, U.S. and foreign consumers benefit from biotech crops through lower commodity prices, which result from increased supplies.

This study seeks to estimate the size and distribution of benefits from adopting the three most prevalent biotech crops—*Bacillus thuringiensis* (Bt) cotton, herbicide-tolerant cotton, and herbicide-tolerant soybeans—in 1997. The stakeholders considered in this study are U.S. farmers, U.S. consumers, biotechnology developers, germplasm suppliers, and producers and consumers in the rest of the world (ROW). We focus on specific and readily quantifiable market benefits accruing to stakeholders. As such, this analysis does not consider ease of pest management, a major factor in the rapid adoption of herbicide-tolerant soybeans. Similarly, nonmarket effects, including the environmental and health impacts of biotech crop adoption, are not considered in this study. Nor do we address the effects of adopting biotech crops on groups of consumers with different preferences toward biotech foods.

The estimated total benefit for each of the three biotech crops is measured in change to total welfare in both the seed input and commodity output markets. The theoretical framework accounts for monopoly profits in the input market. Because of intellectual property rights protection, the innovator prices the technology above marginal cost, allowing the firm to realize monopoly profit. The model also measures welfare changes for producers and consumers in a competitive output market, since some of the benefits generated by the innovation are passed on to them in the form of higher production efficiency and lower commodity prices.

In this study, the estimated total market benefit from adopting each of the biotech crops depends on the extent to which the commodity supply curve shifts outward after the introduction of the technology. In each case, the shift in supply reflects potential yield increases and savings in pest control costs. The estimated market benefit also depends on the interaction of the supply and demand curves before and after the introduction of the new technology. In this study, an empirical model is developed to calculate the pre- and post-innovation prices and quantities in an international market setting using information on adoption rates, crop yields, pest control costs, technology fees, and seed premiums. The framework takes into account the adoption of biotechnology outside of the United States, with assumptions regarding the efficiency of technology transfer to foreign countries.

For each of the three biotech crops in 1997, the estimated market benefits ranged from \$213 million to \$308 million. Our estimates of benefits from agricultural biotechnology are based on two data sources: data estimated from the 1997 Agricultural Resource Management Survey (ARMS) and a private database for Bt cotton. Both data sources isolate the effects of biotechnology on crop yields and pest control cost savings. Gains ranging from \$212.5 million (ARMS) to \$300.7 million

(private data source) were estimated from the planting of Bt cotton in 1997—3.6 percent to 5.1 percent of the value of upland cotton production. Herbicide-tolerant cotton improved total welfare by an estimated \$231.8 million (3.9 percent of the value of upland cotton production), while the adoption of herbicide-tolerant soybeans yielded \$307.5 million in total benefits (1.7 percent of the value of soybean production). These estimates are generally higher than those of previous studies in the case of Bt cotton, but lower for herbicide-tolerant soybeans.

The distribution of estimated benefits varied significantly across the three biotech crops. U.S. farmers received about a third of the estimated total benefit from adopting Bt cotton. (Previous studies estimated the share at around 50 percent.) In contrast, U.S. farmers captured just 20 percent of the estimated total benefit from adopting herbicide-tolerant soybeans—a share at the lower end of the benefit range reported in previous studies. With herbicide-tolerant cotton, a small U.S. farmers' share (4 percent) of the estimated total benefit was attributed to greater seed costs over conventional varieties and lower world prices (which offset the benefit of higher yields). Innovators captured 30 percent and 68 percent of the estimated total benefits from the adoption of Bt cotton and herbicide-tolerant soybeans. For herbicide-tolerant cotton, U.S. consumers and foreign producers and consumers received the bulk of the estimated benefits in 1997.

Estimates of biotech benefits are sensitive to a number of factors, including the analytical framework and supply elasticity assumptions. Sensitivity analysis indicates that changes in the U.S. and ROW supply elasticity assumptions have a more pronounced effect on the total benefit estimate than do changes in the U.S. and ROW demand elasticity assumptions. Supply elasticity assumptions affect the estimated benefits overall and those accruing to U.S. farmers more than for U.S. consumers. For example, doubling the supply elasticities reduces the estimated total benefit by about half in the case of herbicide-tolerant soybeans and causes U.S. soybean producers' share of the estimated total benefit to disappear.

Estimates of stakeholder benefits depend on the extent to which market benefits are captured in the analysis. Although not included in this study's benefit estimates, some important aspects of market benefits, such as the ease of pest management associated with herbicide-tolerant crops and the insurance value of insect-resistant crops, can affect the results. In addition, potential nonmarket benefits, including effects on the environment and human health, could influence the benefit estimates. As part of the environmental effects, biotechnology can potentially lead to lower pesticide use. Pesticide applications (measured in pounds of active ingredients) in 1997 were lower for Bt cotton in the Southeast, herbicide-tolerant cotton nationwide, and herbicide-tolerant soybeans in some major production regions. Other environmental and health benefits associated with the adoption of biotechnology, such as pesticide toxicity levels and the length of persistence in the environment, would factor into the total (nonmarket) benefits but are not part of this assessment.

Year-specific variables, including pest infestation levels, affect the size and distribution of benefits. For insect-resistant crops, such as Bt cotton, infestation levels of target pests can fluctuate over time. With low infestation, farmers are likely to derive fewer benefits from biotech crops. Weather conditions can also vary across growing seasons, which may affect potential yield enhancements associated with planting biotech crops. Hence, multiyear analyses are desirable to obtain more reliable estimates of the market benefits from agricultural biotechnology adoption.