Sensitivity Analysis

Our estimated benefits from the adoption of three biotech crops in 1997 represent base scenarios that assume a set of supply and demand elasticities as well as specific farm-level effects realized by ROW producers. However, uncertainty surrounding the values of these parameters warrants sensitivity analyses to determine how the results may differ in response to changes in these parameters. In addition, we tackle uncertainty surrounding the estimated stakeholder benefits by showing the percentile distributions of the estimated surplus gains for the three crops.

Supply and Demand Elasticity Assumptions

To gauge the extent to which different supply and demand elasticities affect surplus estimates, the elasticity values in the base scenarios were adjusted for each biotech crop. In total, there were four alternate scenarios for each crop. The benefits were computed with U.S. and ROW supply elasticities that are (a) double their original values and (b) half their original values. Likewise, stakeholders' benefits were computed with U.S. domestic and net export demand elasticities, as well as a ROW demand elasticity, that are (a) double their original values and (b) half their original values.

The sensitivity analysis indicates that changes in the supply elasticities (especially for the United States) have a dramatic effect on estimated total surplus gains (figs. 10-12). For example, the increase in estimated world welfare associated with Bt cotton adoption (using the estimated ARMS effects) is 74 percent higher than in the base case when the U.S. and ROW supply elasticities are cut in half. In contrast, the estimated total benefit is 37 percent smaller when the supply elasticities are doubled (fig. 10).

The estimated benefits that accrue to U.S. farmers greatly depend on the values of the supply elasticities. For example, variations in supply elasticities produce dramatic changes in the estimated surplus for U.S. soybean producers. With smaller values, U.S. farmers would have realized an estimated surplus gain ($301.5 million) that is nearly 5 times as large as in the base case (fig. 12). In contrast, U.S. farmers would have incurred an estimated welfare loss with higher supply elasticities.

U.S. producers' share of the estimated total benefits is also affected by the magnitude of the supply elasticities, particularly for Bt cotton and herbicide-tolerant soybeans (fig. 13). Doubling the supply elasticities causes U.S. soybean producer's share to disappear. Lowering supply and demand elasticities results in higher benefit estimates for U.S. consumers and the net ROW. Because the factors (e.g., adoption rates, technology fees, and seed premiums) that determine the innovators' benefits are fixed in the model for a given crop year, their estimated welfare gains remain unchanged as the supply and demand elasticities are adjusted.

Figure 10

Sensitivity of benefit estimates to changes in supply elasticities: Bt cotton (estimated ARMS effects)

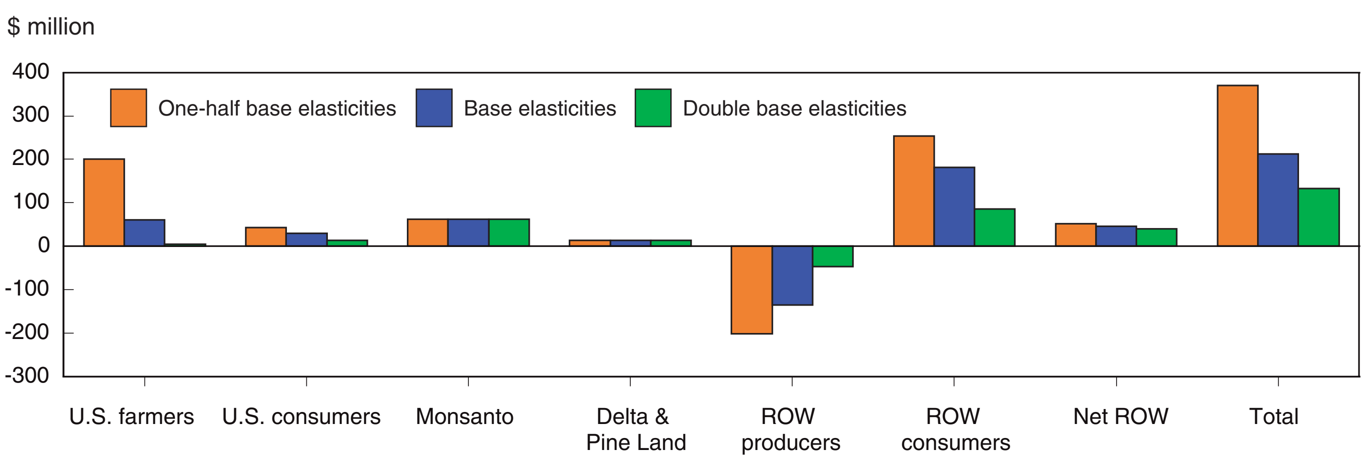


Figure 11

Sensitivity of benefit estimates to changes in supply elasticities: Herbicide-tolerant cotton

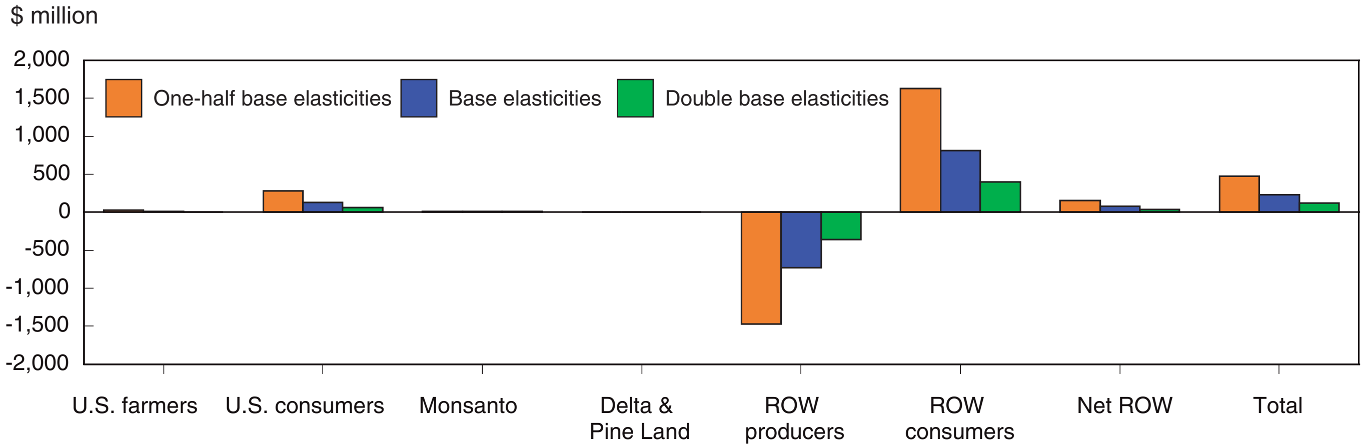


Figure 12

Sensitivity of benefit estimates to changes in supply elasticities: Herbicide-tolerant soybeans

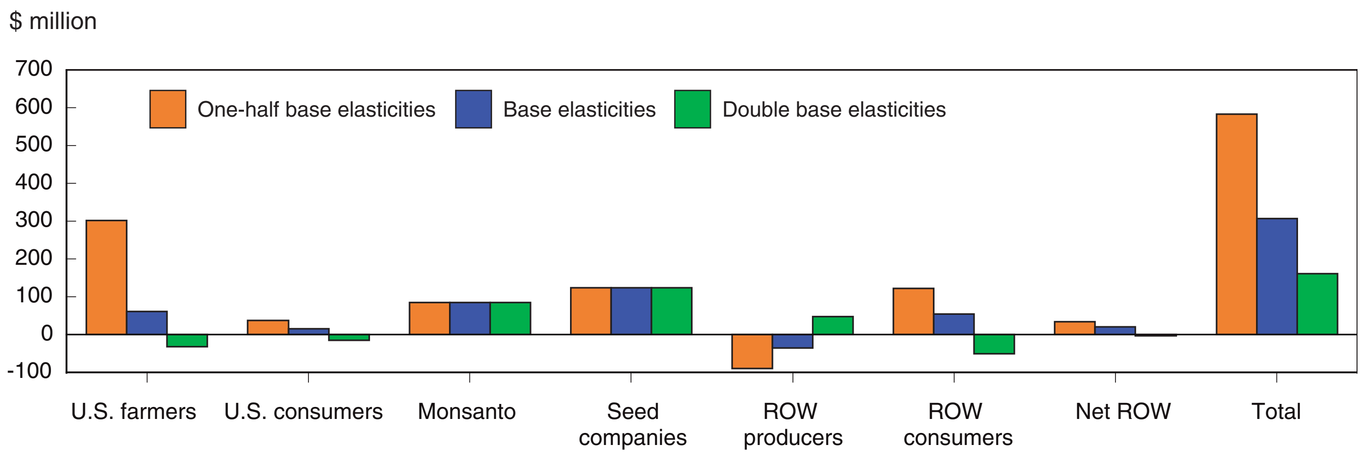
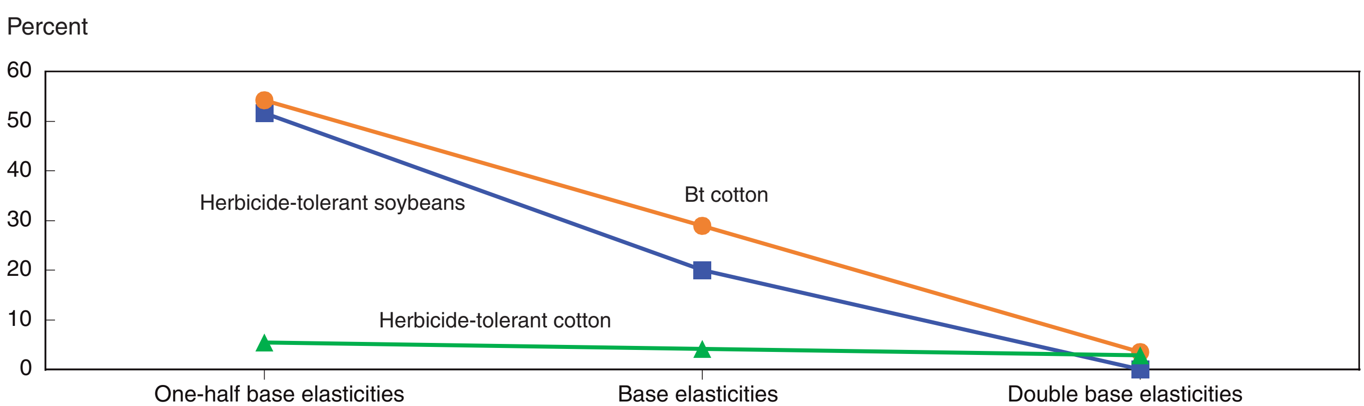


Figure 13

Sensitivity of U.S. farmers' share of estimated surplus gain to changes in U.S. and ROW supply elasticities



Altering the demand elasticities leads to more modest changes in estimated total benefits for the three crops and smaller changes in estimated producer and consumer surpluses (figs. 14-16). For example, given inelastic supply and demand, the estimated U.S. consumer surplus increases slightly and U.S. producer surplus falls slightly when the U.S. demand becomes even more inelastic. If U.S. supply becomes more inelastic, the estimated U.S. producer surplus becomes considerably larger. Sensitivity analysis of the EMD benefit estimates produces the same results.

Efficiency of Technology Transfer

In this sensitivity analysis, the base assumption for efficiency of technology transfer is varied to encompass "low" and "high" farm-level impacts in the ROW. Specifically, ROW producers are hypothesized to have realized either 10 percent (the low-efficiency case) or 100 percent (the high-efficiency case) of the technologies' impacts on crop yields and pest control costs, as compared with 50 percent in the base scenario. The efficiency assumption was not considered for herbicide-tolerant cotton since that variety was not commercially available to ROW producers in 1997. About 30 percent of Bt cotton was grown outside of the United States in 1997—mostly in Australia and South Africa (James). For soybeans, about 23 percent of the herbicide-tolerant variety was produced in the ROW, primarily in Argentina.

The estimated total world surplus would increase as a result of a more efficient transfer of technology, with

Figure 14

Sensitivity of benefit estimates to changes in demand elasticities: Bt cotton (estimated ARMS effects)

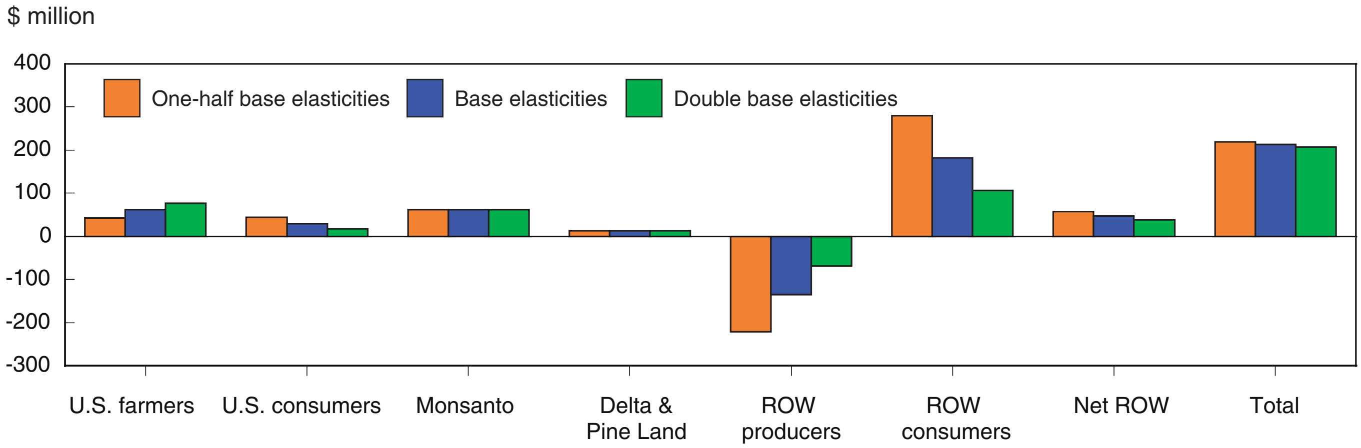


Figure 15

Sensitivity of benefit estimates to changes in demand elasticities: Herbicide-tolerant cotton

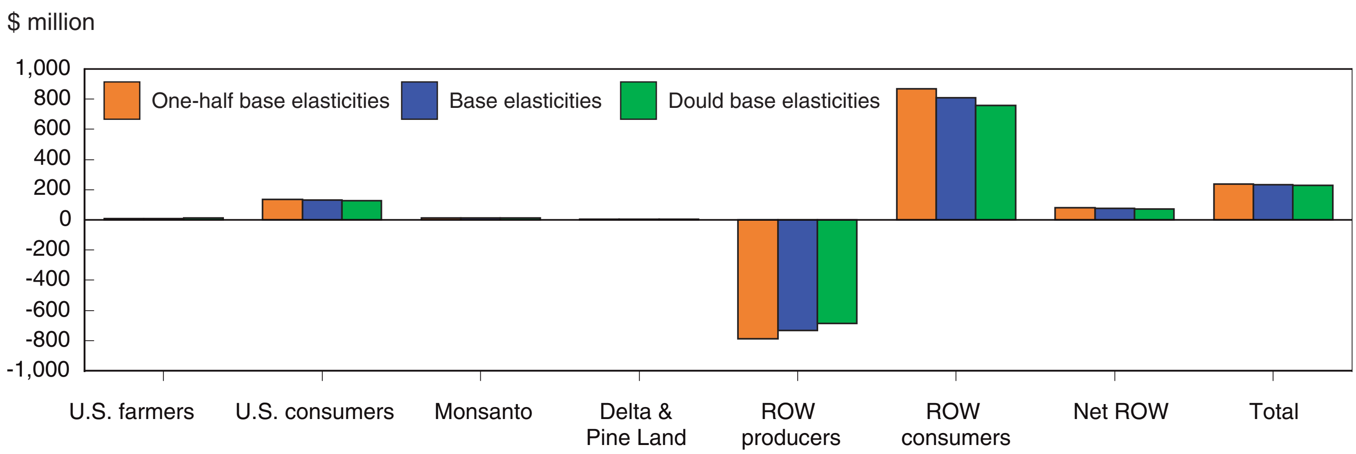
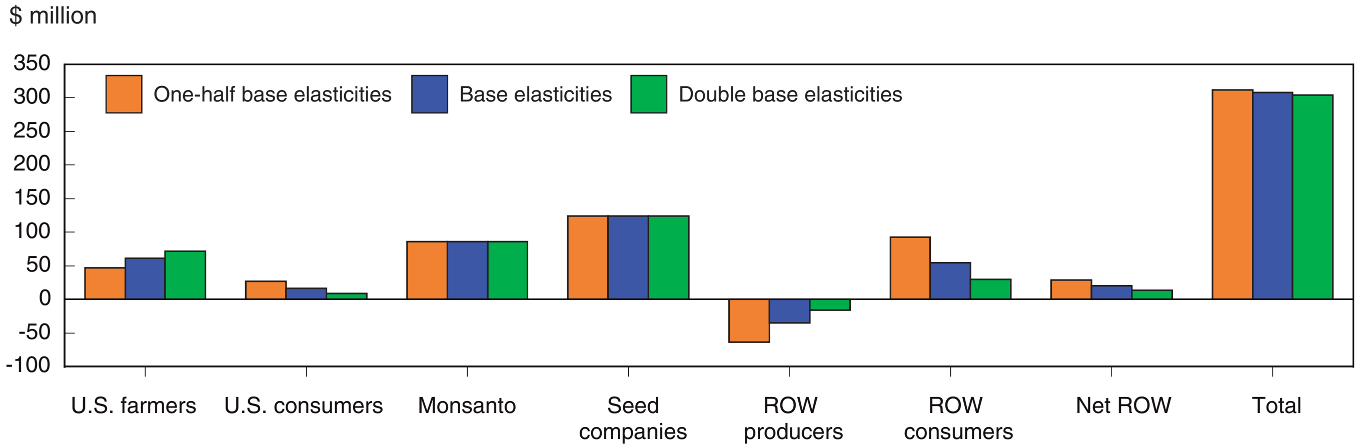


Figure 16

Sensitivity of benefit estimates to changes in demand elasticities: Herbicide-tolerant soybeans



the gains almost entirely in the ROW (figs. 17-18). While ROW producers would still incur a welfare loss, their higher yields and greater savings in pest control costs would mitigate some of the loss caused by greater supply and a lower world price. As a consequence of the downward pressure on cotton prices, U.S. farmers would experience a slightly lower estimated welfare gain. In contrast, U.S. and ROW consumers would benefit from lower prices.

Range of Estimated Surplus Gains or Losses

Variability in parameter values for certain key variables leads to estimated stakeholder benefits that are dispersed around the estimated mean values. The degree of variability for these parameters is incorporated in the @Risk simulations through assumed probability distributions.

The estimated total benefit resulting from the adoption of Bt cotton varies widely, especially when the EMD are used (fig. 19). With that data source, there is a 50-percent probability that the estimates of the total welfare change will fall between a loss of $217 million ($25^{th}$ percentile) and a gain of $817 million ($75^{th}$ percentile). This large dispersion is due primarily to variation in the estimated benefits that accrue to U.S. farmers and the net ROW. The ranges of the benefit estimates are smaller for all stakeholders (except the innovators) when the estimated ARMS effects are employed (fig. 20).

In the case of herbicide-tolerant cotton, there is little variation in the estimated benefits that accrue to U.S. farmers and consumers, due largely to the use of point estimates for regional savings in pest control costs (fig. 21). The dispersion in the estimated total benefits ($169 million to $294 million) mirrors the variability in estimated welfare gains realized by the ROW (on a net basis). Relative to herbicide-tolerant cotton, the estimated surplus gains from herbicide-tolerant soybean adoption are more variable for U.S. farmers and the rest of the world (fig. 22). The innovators' estimated surplus gains are not constant for herbicide-tolerant cotton and soybeans because the estimates use variables that have probability distributions assigned to them.

Figure 17

Sensitivity of benefit estimates to changes in the efficiency of technology transfer: Bt cotton (estimated ARMS effects)

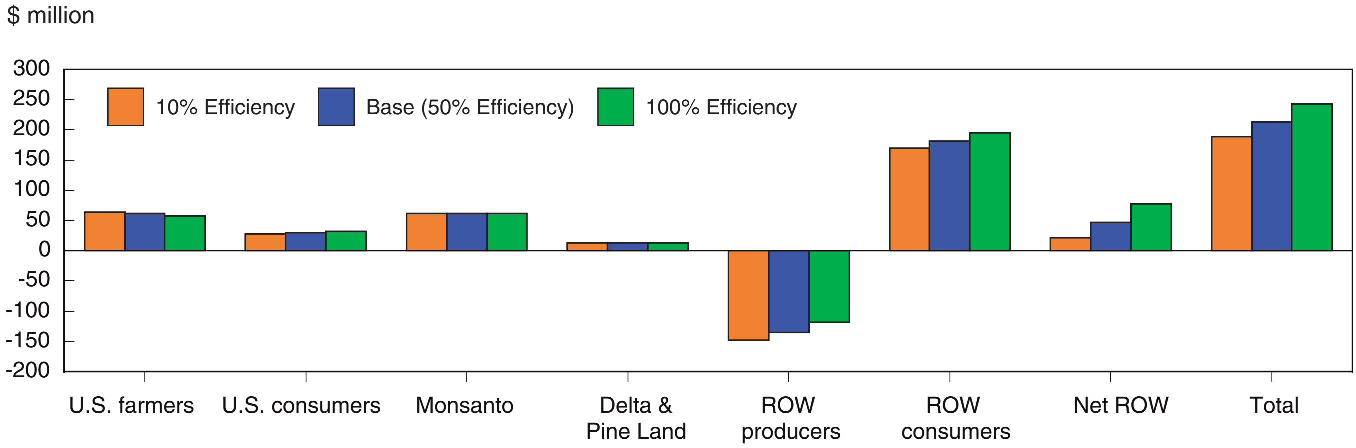


Figure 18

Sensitivity of benefit estimates to changes in the efficiency of technology transfer: Herbicide-tolerant soybeans

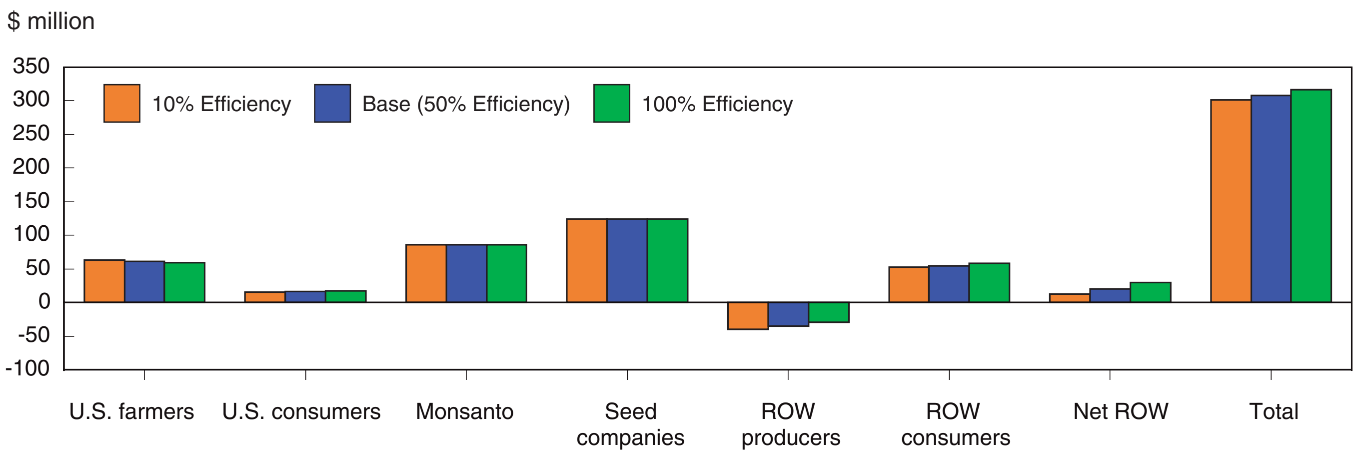


Figure 19

Dispersion of benefit estimates: Bt cotton (EMD)

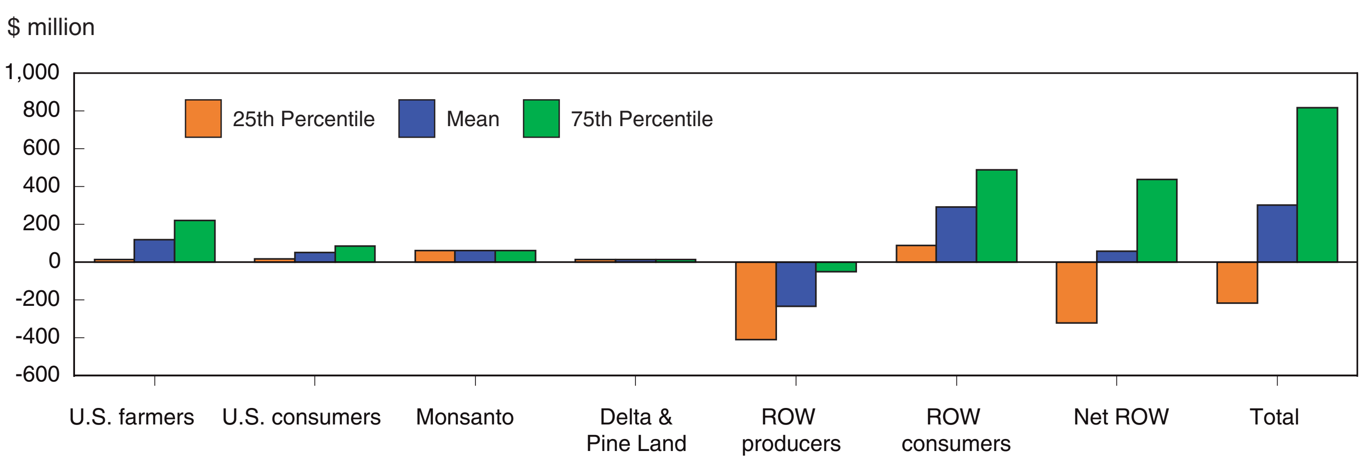


Figure 20

Dispersion of benefit estimates: Bt cotton (estimated ARMS effects)

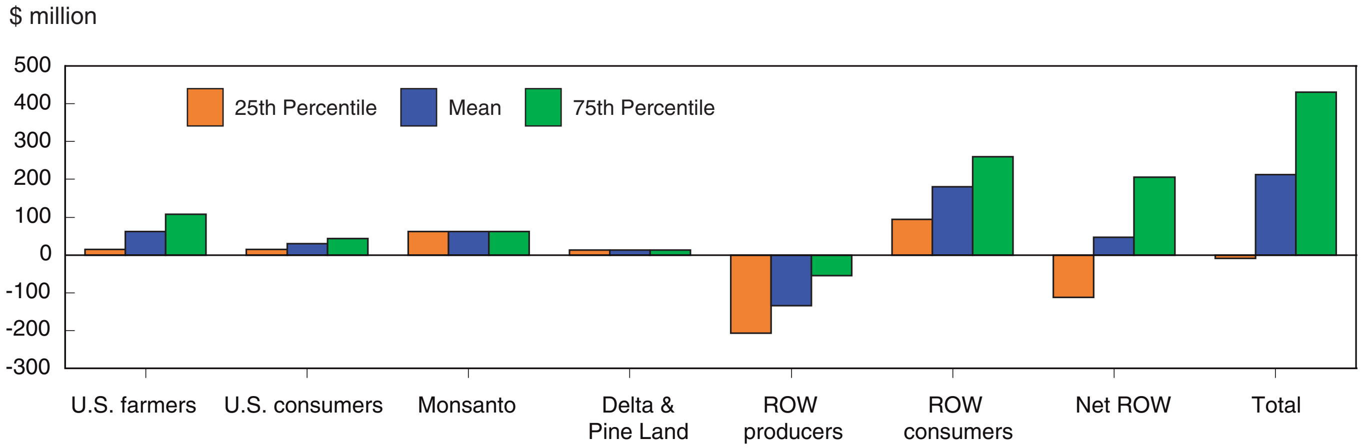


Figure 21

Dispersion of benefit estimates: Herbicide-tolerant cotton

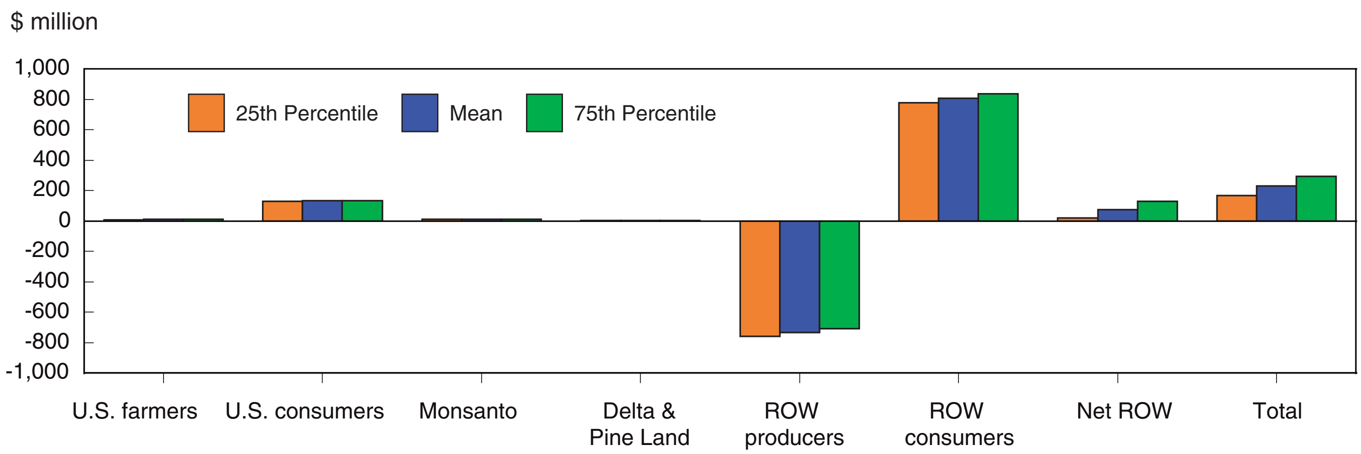


Figure 22

Dispersion of benefit estimates: Herbicide-tolerant soybeans