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Economic Viability of Bt-corn in the U.S.

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ABSTRACT

Bt-corn, a genetically engineered insect resistant variety, has been adopted by almost one-quarter of all corn farmers, resulting in economic impacts on both conventional corn growers and Bt-corn growers. we estimate changes in profits for both types of farmers with different levels of seed premiums, yield increases and adoption rates. We find that Bt-corn growers will see their profits decline when the adoption rate and seed premium are high, if they are not offset by higher yields. Conventional corn growers will always experience a decline in profits because the yield increase from Bt-corn causes corn price to fall.

Key words: biotechnology, European Corn Borers, genetically engineered corn, agricultural production model, economic benefits

INTRODUCTION

In 1999 United States corn production was estimated at $19 billion and accounted for over 90 percent of the value of all feed grains in the U.S. with approximately 20 percent exported to other countries. However, an insect, the European Corn Borer (ECB), has stymied the healthy growth of corn production in the U.S. This pest, first introduced in North America in 1919, has been responsible for widespread crop damages and a loss of profits for corn farmers. For example, crop losses were estimated to range up to 33 bushels per acre in Iowa between 1991 and 1996 (Rice and Pilcher). Corn growers in other regions have been experiencing similarly significant damages to their crops.

In 1996 Bt-corn was introduced to fight ECB. It relies on a genetically engineered seed that produces a protein found in a soil bacterium (Bacillus thuringiensis) which kills ECB. Since then, the corn market has undergone a dramatic change. Bt-corn growers have experienced yield increases of 11.7, 4.2, 3.3 bushels per acre in 1997, 1998, 1999, respectively, over conventional corn yields. The seed premium for Bt-corn was $10 per acre in 1997 and 1998, and $8 in 1999. The adoption rate of Bt-corn has increased from 6% in 1997, to 18% in 1998, and 26% in 1999 (Carpenter and Gianessi).

Several studies (Alstad et al.; Andow and Hutchison; Marra, Carlson, and Hubbell; Stewart, Schaafsma, and Sears; Carpenter and Gianessi) have looked at the economic effects of adopting Bt-corn in the U.S. These studies have found that, as Bt-corn is better able to fight ECB and produce higher yields, those who grow it are likely to enjoy higher profits compared to conventional corn growers. However, since the yield loss caused by ECB varies from year to year, the benefits to Bt-corn growers also vary and depend on the adoption rate and seed premium. Alstad, et al. studied the risk of investing in Bt-corn in southern Minnesota from 1988

to 1995 and found an increase in average profits of $17.24 an acre for Bt-corn growers during this period. However, for the years when ECB infestations were low, the increased yield was only enough to cover the seed premium. Marra, Carlson, and Hubbell analyzed farm-level survey data in South Carolina which showed that a yield increase between 4 and 8 percent resulted in gains ranging from $3 to a loss of $16 per acre.

Stewart, Schaafsma, and Sears showed that the yield increase for Bt-corn ranged from 3 to 5 bushels an acre in low infestation areas, 5 to 8 bushels in moderate infestation areas, and 10 to 15 bushels in high infestation areas. Increases in Bt-corn grower's profit varied from $7.50 to $37.50 per acre depending on the infestation level. Profit increases were sometimes higher and sometimes lower than the seed premium costs of $9 to $14 an acre. Carpenter and Gianessi estimated that in 1997, when ECB infestation was high and only 4 million acres of Bt-corn were planted, Bt-corn increased total yields in the U.S. by 47 million bushes and increased the Bt-corn growers' income by $72 million. In 1998 when ECB infestation was low and 14 million acres of Bt-corn were planted, Bt-corn growers lost $26 million due to the small yield increase per acre and a significant decrease in the price of corn. The profit changes for Bt-corn growers were estimated to have an increase of $18 per acre in 1997, and a decrease of $1.81 and $1.71 per acre in 1998 and 1999, respectively.

These studies were conducted with the farm-level historical data and focused only on the profits of Bt-corn growers. But farm-level analyses necessarily ignore how changes in Bt-corn yields influence the market price for corn. When total corn output increases, due to yield gains on Bt-corn farms, the market price for corn, as well as the expected profits for all corn farmers are likely to decline. Thus, changes in yield and production costs for corn affect farmers' cropping patterns, which result in changes in market price for all crops, including that of corn.

No study has taken into consideration the price consequences and the likely impact of Bt-corn production on conventional corn growers, and ignoring them will likely overestimate the economic benefits of Bt-corn. Therefore, a comprehensive economic study of Bt-corn should take into consideration that adoption rate, yield increase, and seed premium for Bt-corn vary year to year, and that these factors combined have an influence on market price for corn. These dynamics, which are excluded in the existing studies, can affect corn growers' profits significantly.

Corn growers adopt Bt-corn as insurance against ECB damage, but, prior to planting, farmers do not know if and/ or to what extent their corn crop will be infested with ECB and hence they cannot predict yield reliably. Furthermore, at the start of a planting season, farmers do not know to what extent Bt-corn will be adopted and hence influence yields. A reliable knowledge of the yield increase and the adoption rate would allow corn growers to form expectations concerning corn price and profitability, ultimately deciding whether to grow Bt or conventional corn. The fact that the market price for corn will decrease as corn production increases means corn growers must look at not only the expected yield changes, but also at the adoption rates, and the seed premiums. This study estimates the potential economic effects of Bt-corn adoption on Bt-corn and conventional corn growers under different corn yield, seed premium, and adoption rate levels. The analyses are conducted with a mathematical programming model of the U.S. crop sector (the United States Agriculture and Resource Model - USARM). The results will give corn growers and agricultural policy makers an insight into as to the viability of Bt-corn in the U.S.

METHODOLOGY

A market equilibrium model for crop production is needed to measure the impact of the changes in adoption rate of Bt-corn, corn yield, and seed premium, on the market price for corn and ultimately farmer's profits. Measuring the impact on corn price is crucial in capturing the net economic effect of Bt-corn on its adopters as well as conventional corn growers.

USARM is a non-linear mathematical program model that accounts for endogenous price effects, cropping patterns, acreage, and the substitution of inputs in response to changes in prices and production costs (see Howitt; Konyar and Howitt for a detailed description of USARM). This model is based on the assumption that farmers maximize their profits by selecting the crop mix, acreage, and input levels. As market conditions change due to changes in policy and resource use, this model allows farmers to determine the total level of production, to adjust production among crops, and to substitute their production input mix in such a way to maximize their profits (Murphy et al.). The model represents the full range of substitution available to U.S. crop producers. Failure to address such adjustments by farmers would results in overestimation of economic costs of policy shocks.

USARM combines the 48 contiguous states into twelve regions. Each region is treated as a farming unit using seven inputs to produce nine field crops (barley, corn, cotton, hay, oats, rice, sorghum, soybeans, and wheat) grown under dry or irrigated cultivation. These crops accounted for 94% of all harvested crop acreage in the U.S. in 1990. Cropping activities are modeled with a constant elasticity of substitution (CES) production function and farmers are assumed to maximize profits. For a given external shock, the model predicts acres allocated to specific crops in each region (with or without irrigation), the amount of inputs used, and the impact on crop prices, consumer surplus, and farm net income.

A two-step procedure is used in estimating per acre profit changes for Bt-corn and conventional corn growers. First, USARM simulates a medium (2-3 years) equilibrium market price and regional acre for corn based on farmer's profit maximization as yield change, adoption rate, and seed premium vary. Then, per acre profits for Bt-corn and conventional corn growers are calculated based on the resulting corn price. Since the benefits for growing Bt-corn are an increase in yield rather than a reduction in pesticide costs, the benefits of growing Bt-corn are calculated as the economic value of increased yield minus the seed premium for Bt-corn. Changes in net profit for Bt-corn growers per acre are:

1) $\Delta\pi_{Bt} = (\Delta P_{corn} \times Y_{acre}) + (P_{corn} \times \Delta Y_{acre}) - PRM_{seed}$

where,

$\Delta\pi_{Bt}$: change in profits per acre for Bt-corn growers

P_{corn} : market price for corn per bushel (Market price for corn is assumed at $2.289 per bushel.)

ΔP_{corn} : change in market price for corn due to change in yield per acre

Y_{acre} : average yield in bushels per acre (Average yield per acre is assumed at 130 bushels.)

ΔY_{acre} : yield increase in bushels per acre

PRM_{seed} : seed premium per acre

Net profit changes for non Bt-corn growers per acre would be:

2) $\Delta\pi_{nonBt} = (\Delta P_{corn} \times Y_{acre})$

where,

$\Delta\pi_{nonBt}$: change in profits for non Bt-corn growers per acre

The total of 64 combination of yield increases, adoption rates, and seed premiums were considered and USARM estimates new equilibrium market prices for corn for each of the 64 combinations. Per acre profits for Bt-corn and conventional corn growers were then calculated based on equations 1 and 2. The following are the different levels of the variables used in the 64 combinations:

1) yield increases of 2%, 5%, 10%, or 15%.
2) adoption rates of 10%, 35%, 70%, or 95%.
3) seed premiums of $10, $8, $5, or $2.

RESULTS

Both Bt-corn and conventional corn growers experience significant changes in profits due to the change in the price of corn brought on by the increased supply of Bt-corn. While the adoption rate and the increased yield of Bt-corn have a strong influence on the price, the seed premium plays only a minor role. Figure 1 shows that the price of corn varies little with a 10% adoption rate. But when the adoption rate is 95% (shown in the rightmost portion of Figure 1), the price of corn falls to below $2.00 per bushel as yield increase of 15% per acre. Figure 1 also shows that the changes in the seed premiums have little effect on the price of corn compared to the adoption rate and yield. In fact, corn prices at different seed premiums vary, at most, by 3 cents per bushel. Therefore, only when high adoption rates are coupled with high yields, do corn prices change significantly.

Table 1 shows the changes in profit per acre for Bt-corn and conventional corn growers as the adoption rate increases from 10% to 95% with expected yield increases between 2% to 15% per acre, and seed premiums of $2, $5, $8 and $10 per acre. For example, the profits

increase by $7.28 for Bt-corn growers and decline by $5.33 per acre for conventional corn growers, when the adoption rate is 35%, the yield increase is 5%, and the seed premium is $2 per acre. Notice that while Bt-corn growers' profit changes range from positive to negative, conventional corn growers always see a decline in their profits.

Although conventional corn growers do not pay the Bt-corn seed premium, they are still affected by it because the higher the seed premium, the more Bt-corn growers will shift to other crops. And by devoting less land to corn, the price of corn will not fall as much. Therefore, conventional corn growers are benefited by an increase in the Bt-corn seed premium. Again, using an adoption rate of 35% and a yield increase of 5%, conventional growers see a decline in profits of $5.33 per acre when the seed premium is $2, but this lessens to $2.86 per acre when Bt-corn growers pay a $10 seed premium. Bt-corn growers also experience a reduction in their profits as the adoption rate increases. In fact, at the 95% level of adoption, Bt-corn grower benefits are always negative.

When ECB infestation levels are low, resulting in a small yield increase, and seed premium is high, both Bt-corn growers and conventional corn growers experience a decrease in profits. Table 1 shows that when the seed the premium is $10 and the yield increase is 2%, the profit change per acre for Bt-corn growers ranges from -$4.05 (10% adoption rate) to -$4.58 (95% adoption rate), while it ranges from and from $0 to -$0.52 for conventional corn grower. As the adoption rate increases, the decline in profits for both groups becomes larger. Only when the seed premium is low ($5 or $2) and the adoption rate is also low (10%), do Bt-corn growers enjoy a small profit gain at a 2% yield increase. In this case, it is better for corn growers not to adopt Bt-corn, except when both the seed premium and the adoption rates are low.

If the yield change per acre is moderate at 5%, corn growers have more chances to see profit gains by growing Bt-corn than when the yield increase per acre is low at 2%. The per acre profit gain for the Bt-corn grower was estimated at $3.92 per acre when the yield increase is 5%, the adoption rate is 10%, and the seed premium is $10, while they experience a profit loss of $4.05 per acre when yield increase is 2%. Conventional corn growers are likely to suffer more due to the large decrease in the price for corn that results from a larger increase in corn production. But even Bt-corn growers will experience a profit loss if the adoption rate is high enough to induce a large price decrease.

When the seed premium is high, $8 or $10, Bt-corn growers will experience a decrease in profits at all adoption rates unless the yield increase is high enough to offset high seed premiums. When the seed premium is low, $5 or $2, Bt-corn growers will enjoy increased profits even at a 70% adoption rate only if the yield increase if 5% or greater. On the other hand, Bt-corn growers will experience a greater decline in profits than the conventional corn growers if there are high seed premiums and low yields. But if the yield increase is expected to be 5% per acre, corn growers are likely to choose Bt-corn in order to have a profit gain or at least minimize their loss relative to conventional corn.

With a yield increase of 10% or 15% per acre, corn growers will enjoy larger profit gains by adopting Bt-corn. An increase in profits for Bt-corn grower was estimated at $37.25 per acre when the yield increases by 15% with an adoption rate of 10% and a seed premium of $2. Their profit per acre, however, declines as the adoption rate increases resulting in a large decrease in the price for corn. Even with the high increased yield per acre, Bt-corn growers suffer a decline in profits as they increase their adoption rate of Bt-corn to 95%. Conventional corn growers also experience a greater decline in profits when there is a higher yield increase for Bt-corn growers.

The decline in profits for conventional corn grower ranges from $4.68 to $39.52 per acre when the yield increases 15%, the seed premium is $2, and the adoption rate varies from 10% to 95%.

Figure 2, which holds the seed premium constant at $8, shows how the adoption rates have a dramatic influence on the change in profits for both types of corn growers, and that this effect is magnified by the increases in yield. The left set of bars (showing a 10% adoption rate at different yields) illustrate the dramatic increase in profits for Bt-corn growers and the slight reduction in profits for conventional corn growers as the yield increases. Bt-corn growers see a negligible increase in profits per acre when the yield increase is 2%, but if the yield of Bt-corn is 15% higher than conventional corn, there is a remarkable increase of $31.70 in per acre profits for the Bt-corn growers. The dramatic increase in profits for the Bt-corn growers and the small decline in profits for the conventional growers occur because the adoption rate remains at 10%. When the adoption rate increases to 95%, profits for both Bt-corn and conventional corn growers remain negative at all yield levels. The negative effects are most pronounced for conventional corn growers who see declines in their profits up to $39.52 per acre when the yield increase for Bt-corn is 15%.

CONCLUSION

This study has analyzed the potential economic effects of the adoption of Bt-corn on U.S. corn growers when corn yield, seed premium, and adoption rate vary. Changes in corn growers' production decisions and market conditions were simulated through the use of USARM to estimate changes in Bt-corn and conventional corn growers profits associated with the Bt-corn adoption.

The simulation results show that Bt-corn growers benefit as corn yield increases (relative to conventional corn growers) if the seed premium and the adoption rate remain low. On the other hand, Bt-corn growers can suffer declines in profits when the adoption rates and the seed premiums are high. At lower adoption rates, higher yields partially shield Bt-corn growers' profits. Higher yields, however, fail to prevent Bt-corn growers from suffering profit losses when adoption rates reach 95%. Conventional corn growers experience a fall in profits when corn yields for Bt-corn increase and the market price for corn decreases. Moreover, as yield increase per acre rises, conventional corn growers experience a greater decline in profits due to the larger price decrease for corn. Therefore the changes in profits of Bt-corn growers range from negative to positive. It is always negative for conventional corn growers, assuming the market for Bt-corn is not segregated from conventional corn.

Changes in profits, for both Bt-corn and conventional farmers, depend largely on the adoption rate, which in turn depend on the farmer's risk tolerance. If infestation levels are expected to be low and seed premiums are high, only risk-averse farmers will plant Bt-corn as insurance against an ECB outbreak. On the other hand, if infestation levels are expected to be high and seed premiums are low, rational corn growers will adopt Bt-corn only when they expect the yield increase is large enough to offset the price decrease. The availability and the adoption of Bt-corn is not necessarily a welcome event for all; the higher yields from Bt-corn farms are likely to depress the market price of corn and cause depressed or negative economic profits for conventional corn farmers. The solution to the plight of the non-adopters might not lie in for them adopting Bt-corn. A wholesale adoption of Bt-corn could result in profit losses for all corn farmers.

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Table 1. Changes in Profits ($ per Acre)

Adoption Rate	Yield Change	Bt-corn Growers				Conventional Corn Growers			
		Seed Premium for Bt-corn				Seed Premium for Bt-corn[a]			
		$2	$5	$8	$10	$2	$5	$8	$10
10%	2%	3.42	0.69	-2.18	-4.05	-0.52	-0.26	-0.13	-0.00
10%	5%	11.38	8.51	5.79	3.92	-1.43	-1.30	-1.04	-0.91
10%	10%	24.47	21.61	18.75	16.90	-2.99	-2.86	-2.73	-2.60
10%	15%	37.25	34.55	31.70	29.10	-4.68	-4.42	-4.29	-4.81
35%	2%	1.17	-1.67	-2.58	-4.18	-4.03	-2.73	-0.52	-0.13
35%	5%	7.28	4.96	2.65	2.28	-5.33	-4.68	-4.03	-2.47
35%	10%	16.17	13.89	11.46	10.89	-10.53	-9.88	-9.36	-8.06
35%	15%	24.25	21.99	19.59	18.04	-15.99	-15.34	-14.82	-14.43
70%	2%	0.24	-1.44	-3.24	-4.31	-3.64	-2.34	-1.17	-0.26
70%	5%	2.23	0.46	-1.18	-2.36	-10.14	-8.97	-7.67	-6.89
70%	10%	5.16	3.45	1.74	0.59	-20.54	-19.37	-18.20	-17.42
70%	15%	7.65	6.00	2.85	3.24	-30.42	-29.25	-29.38	-27.30
95%	2%	-1.09	-2.36	-3.64	-4.58	-4.94	-3.25	-1.56	-0.52
95%	5%	-1.59	-2.82	-4.18	-5.09	-13.78	-12.09	-10.53	-9.49
95%	10%	-2.42	-3.56	-6.13	-5.70	-27.43	-25.74	-25.35	-23.13
95%	15%	-2.81	-3.87	-7.91	-6.93	-39.52	-37.83	-38.74	-36.14

[a] Conventional corn growers do not pay the seed premium, but since it influences the planting decisions of Bt-corn growers, conventional corn growers' profits are affected by its level.

Figure 1. Corn price

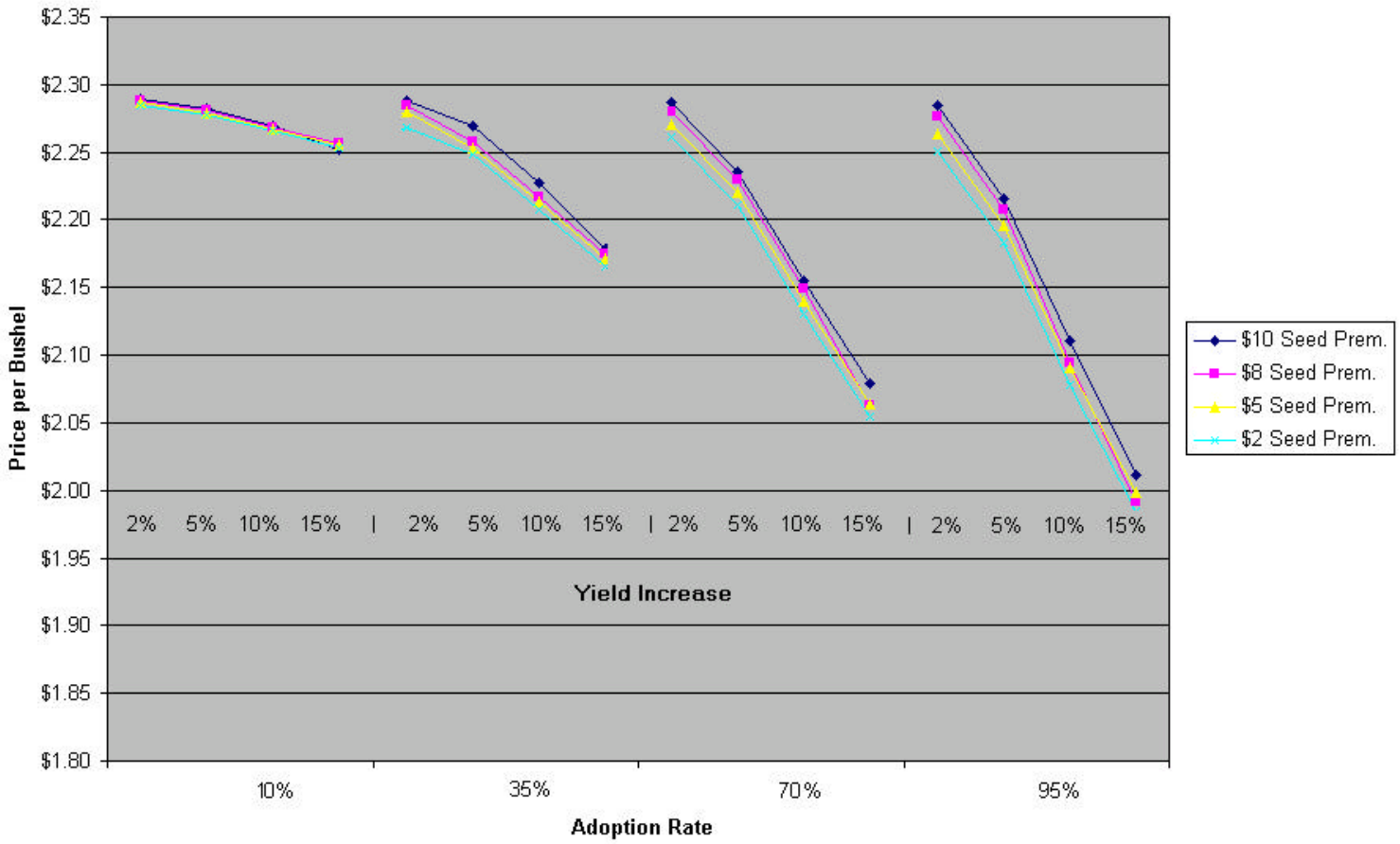

Figure 2. $8 Seed premium