The Economic Impact of StarLink Corn

Troy G. Schmitz
Morrison School of Agribusiness and Resource Management, Arizona State University, 7001 E. Williams Field Rd., Mesa, AZ 85212. E-mail:tschmitz@asu.edu

Andrew Schmitz
Food and Resource Economics Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611–0240. E-mail: ASchmitz@mail.ifas.ufl.edu

Charles B. Moss
Food and Resource Economics Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611–0240. E-mail: CBMoss@mail.ifas.ufl.edu

ABSTRACT

The discovery of StarLink corn in U.S. food products caused considerable disruption in corn markets in 2000 and 2001. Segregation costs were incurred by the U.S. grain-handling system in order to ensure that domestic and export sales of food corn and export sales of non-food corn to Japan meet stringent tolerance levels. These costs reduced the revenue that U.S. corn producers would have received in the absence of StarLink. However, the Loan Deficiency Payment Program (LDP) effectively reduced the loss in revenue attributed to StarLink. This study develops a partial equilibrium model that encompasses both segregation costs and the LDP program in order to obtain empirical estimates of the impact of StarLink on U.S. corn producers over the 2000/2001 marketing year. It is estimated that StarLink caused U.S. producers to lose between $26 and $288 million in revenue. [EconLit citations: Q18, Q17, L51.] © 2005 Wiley Periodicals, Inc.

1. INTRODUCTION

In the late 1990s, Aventis CropScience (Aventis), a multinational French-based corporation, introduced StarLink corn into the United States even though the Environmental Protection Agency had not approved StarLink corn for human consumption. On September 18, 2000, the Cry9C Starlink gene was found in a sample of Taco Bell taco shells. Kraft Foods, Inc., the producer of Taco Bell taco shells, recalled the product after further testing by the U.S. Food and Drug Administration. Many other food products were also recalled because of the presence of StarLink corn, including other corn-based taco shells, tostada shells, tortillas, tortilla chips, and chili seasonings kits. Due to the recalls, Archer Daniels Midland began testing corn deliveries at its elevators on October 12, 2000, and Japan temporarily halted U.S. corn imports on October 27 until testing procedures were firmly established.

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StarLink corn is toxic to European corn borers and certain other insect pests. In 1998, approximately 9,000 acres of StarLink corn were planted in the United States. The area planted to StarLink corn increased to 247,000 acres in 1999. By 2000, StarLink corn was grown on approximately 362,000 acres, roughly 40% of which were in Iowa (Kalaitzandonakes, Marks, &Vickner, 2004). StarLink corn became commingled with non-StarLink corn in the U.S. grain-handling system. According to Lin, Price, & Allen (2001), commingling of StarLink corn with other corn varieties was exacerbated by three factors: (1) some of the corn grown on the buffer zone was probably cross-pollinated with StarLink corn, (2) a portion of the StarLink corn (including that grown on the buffer zone) had entered the marketplace prior to the effort to contain StarLink-commingled corn, and (3) some elevators did not know they were receiving StarLink-commingled corn. The commingled corn may have come from the 1998, 1999, or 2000 Starlink corn crops but was not detected in the grain-handling system until September 2000.[1] In order for U.S. corn to be sold for food purposes both in the United States and in major importing countries, such as Japan and South Korea, it now had to be segregated and tested. Once implemented, StarLink testing became highly stringent—the tolerance level ranged from one kernel in a sample of 400 (in the United States) to as much as one kernel in three samples of 800 (in Japan).

Several class-action lawsuits directly ensued. *Fingers et al. v. Kraft Foods North America, Inc., et al.* was one such case. The plaintiffs claimed they had allergic reactions to food containing Cry9C. The Centers for Disease Control tested the 17 people who claimed StarLink had made them sick and found that none of them had antibodies consistent with allergic reactions to StarLink. Despite these results, a federal judge approved a $9 million settlement in March 2002.[2]

Mulholland et al. v. Aventis Crop Science USA Holding, Inc. was another such case. The plaintiffs, who were non-StarLink corn growers in seven Midwestern states, claimed property damage and corn loss claims. Property damage claimants were compensated for lost market value, transportation, and storage costs resulting from actual contamination of their crops, fields, equipment, and property. Corn loss claimants were compensated for the alleged reduction in the general price of corn due to the presence of StarLink corn in the U.S. corn supply. A settlement for $110 million was reached in February 2003.[3]

The latter case is important since it is applicable to ongoing debates over the acceptance and impacts of genetically modified organisms (GMOs) both within the United States and abroad. The StarLink incident illustrates the complexity of isolating crop varieties within the existing grain marketing system and preventing unwanted commingling.

The discovery of StarLink in food products caused considerable disruption in corn markets in 2000 and 2001 (Lin, Price, & Allen, 2001–2002). Segregation costs were incurred by the U.S. grain-handling system in order to ensure that domestic and export sales of food corn and export sales of non-food corn to Japan met stringent tolerance levels. These segregation costs were incurred since buyers wanted to be assured that the level of Starlink corn detected in sales destined for food markets was negligible. These costs reduced the revenue that U.S. corn producers would have received in the absence of StarLink during the 2000/2001 marketing year. However, the Loan Deficiency Payment Program

[1]The detection of StarLink corn in the U.S. grain-handling system in September 2000 is referred to as the "StarLink event" throughout this paper.

[2]See Robinson (2002) for more details regarding this settlement.

[3]See Uchtmann (2002) for a comprehensive discussion of the entire StarLink incident.

(LDP) effectively reduced the loss in revenue due to StarLink, since there were periods of time immediately following the discovery of StarLink during which the market price dropped below the loan rate for corn. This study develops a spatial price equilibrium model that encompasses both IP costs and the LDP program in order to obtain empirical estimates of the impact of StarLink on U.S. corn producers over the 2000/2001 marketing year. The results of our analysis are compared to the court settlement amount referred to earlier.

2. THEORETICAL MODEL OF CORN MARKETS

2.1 In the Absence of StarLink

Both the U.S. domestic market and foreign market are depicted in Figure 1.[4] Panel A represents the U.S. corn market and Panel B represents the export market for U.S. corn in the rest of the world. The total supply curve for U.S. corn is S_T. This supply curve is vertical because the forthcoming analysis focuses on the implications of StarLink for the 2000/2001 marketing year only. Shipments of corn containing StarLink were not terminated until October 15, 2000, at which time nearly the entire U.S. corn crop had been harvested. Producers did not have time to adjust their planting decisions; hence the supply of both food and non-food corn for the 2000/2001 marketing year was already set by the time StarLink was discovered.

The total domestic demand schedule for U.S. corn in the absence of StarLink is D_T in Panel A. The excess supply and excess demand schedules for all U.S. corn are ES_{US} and ED_{US} (Panel B), respectively. The equilibrium price for U.S. corn in the absence of StarLink is P^*. The total quantity of corn produced and consumed in the United States is Q^* and Q_D^*, respectively.

Total U.S. corn demand is divided into the demand for food corn (D_F) and the demand for non-food corn (D_N). The equilibrium quantity of food corn consumed in the United States in the absence of StarLink is Q_{F}^* and the quantity of non-food corn consumed is Q_{N}^*. The total equilibrium quantity of corn exported by the United States is X^*, which is comprised of U.S. food corn exports (X_{F}^*) and U.S. non-food corn exports (X_{N}^*).

2.2 In the Presence of StarLink

The discovery of StarLink in the U.S. grain-handling system introduced additional segregation costs in the U.S. corn sector. Elevators were willing to pay less for corn because the additional segregation costs had to be borne directly throughout the supply chain for all food corn sold to both domestic and foreign markets and to all non-food corn exports bound for Japan. This indirectly translated into losses to U.S. corn producers in the form of reduced realized prices.

The segregation costs induced by StarLink caused the domestic derived demand for food corn facing farmers to shift to $D_{\mathrm{F}}^{\mathrm{S}}$ (Figure 1). This resulted in a new (kinked) demand curve for all U.S. corn equal to $D_{\mathrm{T}}^{\mathrm{S}}$, which shifted the import demand schedule

[4]The economic models derived herein follow the standard welfare economic analysis used by many researchers, including Moschini, Lapan, and Sobolevsky (2000); Gardner (2000); Schmitz, Schmitz, and Dumas (1997); and Just, Hueth, and Schmitz (1982); Schmitz, Moss, and Schmitz (2004).

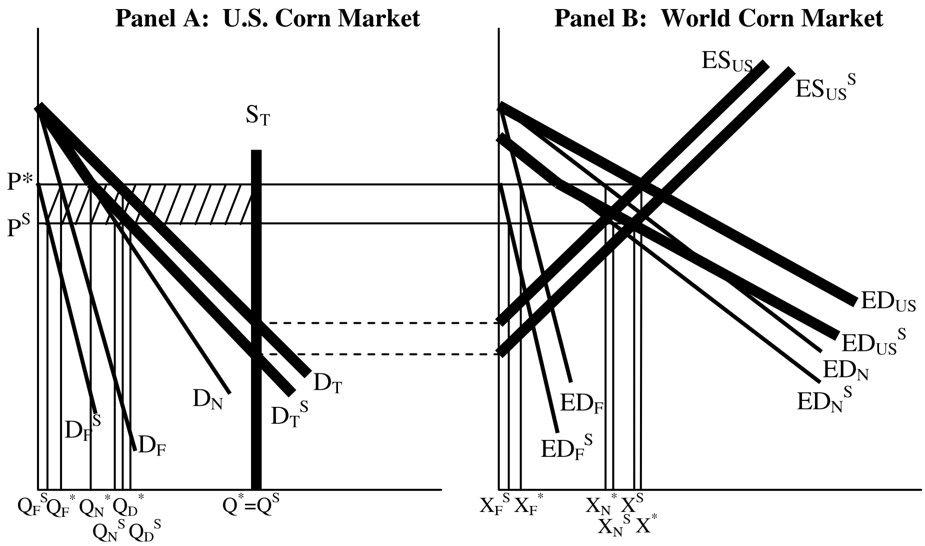

Figure 1 Economic Impact of StarLink on Domestic and International Corn Markets

for U.S. food corn from ED_F to ED_F^S. The import demand schedule for Japanese non-food-corn imports (not shown but included in the total import demand for U.S non-food corn) also shifted inward. This caused a slight reduction in the import demand schedule for all U.S. non-food corn exports from ED_N to ED_N^S. These two reductions in the demand for U.S. food and non-food exports resulted in a new (kinked) excess demand schedule ED_{US}^S for all U.S. corn.

The equilibrium price of corn induced by StarLink dropped to P^S, while Q^* did not change, because U.S. producers did not have time to adjust supply during the 2000/2001 marketing year. However, the total quantity of corn consumed in the United States increased from Q_D^* to Q_D^S. The quantity of food corn consumed in the United States was reduced from Q_F^* to Q_F^S and the quantity of non-food corn consumed in the United States increased from Q_N^* to Q_N^S.

Total U.S. corn exports were reduced from X^* to X^S as a result of StarLink. U.S. food corn exports dropped from X_F^* to X_F^S and U.S. non-food corn exports changed from $X_N^*$to X_N^S. The relative shapes of the supply and demand curves drawn in Figure 1 depict the situation in which U.S. exports of non-food corn increased from X_N to X_N^S because of StarLink. However, depending upon the relative shapes of the demand schedules, U.S. exports of non-food corn could theoretically be higher or lower after StarLink was introduced. There is a trade-off between the outward shift in the excess supply schedule, which induces an increase in U.S. non-food corn exports, and the inward shift of the excess demand schedule for non-food corn, which induces a decrease in U.S. non-food corn exports.

The economic impact of StarLink on U.S. corn producers is measured by the difference between the total revenue in the absence of StarLink and the total revenue in the presence of StarLink. Using this measure of economic loss, if it had not been for StarLink, U.S. corn producers would have received an additional amount of revenue equal to the cross-hatched area in Panel A of Figure 1 over the 2000/2001 marketing year, *ceteris paribus*.

3. THE COSTS OF SEGREGATION

When grain is delivered to an elevator, it is dumped into a pit, then transferred via a lift to a chain that distributes the grain to various storage bins in the elevator. In order to keep corn separate, the grain path between StarLink and StarLink-free deliveries must be kept clean by the farmers, and separate facilities must be established and maintained throughout the grain-handling system—from the local elevator all the way to the delivery port. Smyth and Phillips (2003; 2004) argue that "segregation differs from Identity Preserved Production and Marketing in that the focus of the system is not on capturing premiums but rather on ensuring that potentially hazardous crops are prevented from entering supply chains that have products destined for human consumption." Under this definition, the costs incurred by the U.S. grain-handling system due to the StarLink event fall under the "segregation cost" classification and not the "IP cost" classification.[5]

The results of six studies used to approximate the segregation costs incurred by the U.S. grain-handling system because of the StarLink event are summarized in Table 1. Bender, Hill, Wenzel, & Hornbaker (1999) conducted a survey of 200 U.S. firms marketing specialty grains. Maltsbarger and Kalaitzandonakes (2000a) determined the cost of separating high oil (HO) and standard corn. Their results were based on a process simulator that modeled the operation of grain elevators. Lin, Chambers, & Harwood (2000) presented the costs of separating both non-GMO soybeans and non-GMO corn. Bullock, Desquilbet, & Nitsi (2000) estimated the cost of separating both non-GMO corn and soybeans at both the elevator and farm level. A European Union Report (EU Directorate-General for Agriculture) separated IP costs into the increased cost to the farm, the cost incurred in the marketing channel, and increased processing costs based on United States Department of Agriculture, Economic Research Service results. These costs were similar to those developed by Bullock, Desquilbet, & Nitsi (2000), but are somewhat more comprehensive. For soybeans in the United States, the EU study determined that the incremental IP trait costs, at the farm level, was 16.2 cents per bushel to 18.2 cents per bushel. The EU study also estimated the IP costs at the elevator to be 41.8 cents per bushel for soybeans and 18.3 cents per bushel for GMO corn.

There are several ways to define the increased cost of grain segregation, given the range of incremental costs reported in the literature. The Lin, Chambers, & Harwood (2000) estimated segregation cost of 22 cents per bushel is closest to official USDA estimates. However, Lin, Chambers, & Harwood included four cents per bushel for testing, which should not apply in the StarLink case because Aventis paid for all testing costs associated with both domestic and international corn deliveries. Therefore, the Lin Chambers, & Harwood (2000) estimates are adjusted downwards. Deducting the cost of testing from the USDA results yields an estimated cost of 18 cents per bushel, which appears to be more consistent with the other results for corn provided in Table 1. For the purposes of obtaining empirical results in this study, we approximate the segregation costs associated with StarLink by averaging the mid-point of the Maltsbarger and Kalaitzandonakes (2000b) results with the results for Lin Chambers, & Harwood (2000), adjusted by the testing cost, the EU estimate, and the estimate from Bender, Hill, Wenzel, & Hornbaker (1999).

[5]In this paper, we refer to "segregation costs" when discussing our theoretical model and empirical estimates. However, manuscripts that were written before Smyth and Phillips (2003) used the words "IP cost" and "segregation costs" interchangeably. That is why the term "IP cost" is used when describing the results from certain previous studies.

TABLE 1. Cost of Identity Preservation for Corn and Soybeans

Study	Additional Cost (cents/bushel)	Crop/Characteristic
Bender et al. (1999)	17	Specialty Corn
	48	Specialty Soybean
Maltsbarger and Kalaitzandonakes (2000a)	16–27	High Oil Corn
	16.4	High Oil Corn
	16–15	High Oil Corn
Maltsbarger and Kalaitzandonakes (2000b)	16.4–36.6	High Oil Corn
Lin, Chambers, and Harwood (2000)	22	non-GMO Corn
	45	non-GMO Soybeans
Bullock, Desquilbet, and Nitsi (2000)	30	non-GMO Soybeans
European Union	18.4	non-GMO Corn

This procedure gives an average segregation cost of 19.75 cents per bushel, which we use in our analysis.

An implicit assumption in the cost estimates obtained from earlier studies described above is that tolerance levels are not highly stringent. However, once implemented, StarLink testing became highly stringent—the tolerance level ranged from one kernel in a sample of 400 (in the United States) to as much as one kernel in three samples of 800 (in Japan). For example, if StarLink were present in concentrations of 0.2%, there would be a 99% probability that a shipment of corn would be rejected using a 2,400-kernel sample size. For very low thresholds, segregation costs may be much larger than those obtained from past studies. For instance, Kalaitzandonakes, Maltsbarer, & Barnes (2001) argue that segregation costs increase in a non-linear fashion as tolerance levels become closer to zero and that they become extravagant near zero thresholds. Similarly, Lence and Hayes (2003) demonstrate how such non-linearities can impact producer and consumer welfare. In their analysis, Lence and Hayes used various scenarios, with IP costs for genetically modified grain equal to between 10% and 20% of the price. This translates into IP costs of 20–40 cents per bushel assuming an approximate corn price of two dollars per bushel. In order to account for the possibility of higher segregation costs, we perform a sensitivity analysis using segregation costs of 29 cents per bushel. For completeness, we also provide results for segregation costs of only 10 cents per bushel.

4. THE IMPACT OF STARLINK IN THE ABSENCE OF THE LDP PROGRAM

In this section, we obtain estimates of the impact of segregation costs caused by the Starlink event in marketing year 2000/2001. We then compare these estimates to a time period during which Starlink corn was not detected in the grain-handling system. Average marketing conditions for the three-year period from 1997/1998 through 1999/2000 are used as a basis for this comparison.

The USDA/ERS separates corn into feed and “Food, Seed, and Industrial Use” (FSI). The FSI category contains high-fructose corn syrup (HFCS), dextrose, starch, fuel, beverages, products, and seed. The data on FSI reported for the USDA from 1980/1981 through 1999/2000 are provided in Table 2. StarLink corn is acceptable for use in creating etha-

TABLE 2. Supply and Use of Corn in the United States (1980/1981–1999/2000)[a] in Millions of Bushels

Year	Production	Exports	Feed	FSI	Domestic Use	Food[b]	Non-Food[d]
1980/81	6,639	2,391	4,232	659	4,248	542	3,707
1981/82	8,119	1,997	4,245	733	6,122	556	5,566
1982/83	8,235	1,821	4,573	854	6,414	607	5,807
1983/84	4,174	1,886	3,876	930	2,288	638	1,651
1984/85	7,672	1,850	4,115	1,067	5,822	680	5,142
1985/86	8,875	1,227	4,114	1,152	7,648	718	6,931
1986/87	8,226	1,492	4,660	1,233	6,734	774	5,960
1987/88	7,131	1,716	4,789	1,252	5,415	794	4,621
1988/89	4,929	2,028	3,934	1,298	2,901	831	2,070
1989/90	7,532	2,367	4,383	1,370	5,165	865	4,300
1990/91	7,934	1,727	4,609	1,425	6,207	887	5,321
1991/92	7,475	1,584	4,798	1,534	5,891	940	4,951
1992/93	9,477	1,663	5,252	1,556	7,814	923	6,891
1993/94	6,338	1,328	4,680	1,609	5,010	929	4,081
1994/95	10,051	2,177	5,460	1,705	7,874	940	6,934
1995/96	7,400	2,228	4,693	1,612	5,172	975	4,197
1996/97	9,233	1,797	5,277	1,692	7,436	1,011	6,425
1997/98	9,207	1,504	5,482	1,782	7,703	1,035	6,668
1998/99	9,759	1,981	5,472	1,860	7,778	1,038	6,740
1999/00	9,431	1,937	5,664	1,913	7,494	1,078	6,416
1997–99[c]	9,465	1,807	5,539	1,852	7,658	1,050	6,608

Source: Feed Situation and Outlook Yearbook, Market and Trade Economics Division, ERS-USDA, Various Issues.
[a]The crop year begins September 1 and ends on August 31.
[b]For the purposes of this study, food corn is defined as Food, Seed, and Industrial use (FSI), minus the amount used as fuel, minus $\frac{1}{2}$ of the amount used for High Fructose Corn Syrup (HFCS).
[c]Three-year unweighted average of 1997/98 through 1999/00 crop years.
[d]The USDA breaks down domestic use in terms of Feed and FSI. For the purposes of this study, domestic use is separated into Food (see Table 2) and Non-Food Use.
Domestic Use is computed as the difference between U.S. production and exports.

nol fuel. In addition, some companies did not restrict the use of StarLink corn for HFCS (mostly used in making soft drinks), while other companies (such as Pepsi) did. Due to the lack of information regarding how much HFCS was processed from corn that contained StarLink, we assume that one-half of the HFCS was certified StarLink-free. Therefore, for the purposes of this study, food corn is defined as that contained in the FSI category, minus the amount used for fuel, minus one-half of the amount used for HFCS.

USDA/ERS data on the supply and use of corn in the United States are also provided in Table 2. The amount of corn produced by the United States is given in column 1. This supply is either sold as exports (column 2), feed consumption in the United States (column 3), or FSI consumption in the United States (column 4). Total domestic use of U.S. corn (column 5) is equal to the sum of feed and FSI from the prior two columns. For the purpose of this study, food corn (column 6) is subtracted from domestic use in order to compute the amount of non-food corn consumed in the United States (column 7).

The three-year average values used as the basis for comparison in this study are provided in the bottom row of Table 2. Average total U.S. corn production from 1997 to 1999 was 9.46 billion bushels, of which 1.8 billion bushels were sold as combined exports, 1.05 billion bushels were sold as U.S. food corn, and 6.6 billion bushels were sold as U.S. non-food corn. Hence, 13.7% of all corn consumed in the United States is considered food corn and the remaining 86.3% is considered non-food corn. In the absence of better information, it is assumed that U.S. food and non-food corn are exported at the same ratio as in the domestic U.S. market. Hence, 1,807 million bushels (bottom of column 2 in Table 2) of the total U.S. corn exports are divided into 248 million bushels of food corn exports and 1,559 million bushels of non-food corn exports.

Segregation costs associated with StarLink induce the following: (1) a downward shift in the intercept of the demand schedule for U.S. food corn; (2) a downward shift in the intercept of the excess demand schedule for U.S. food corn exports; and (3) a slight downward shift in the intercept of the excess demand schedule for U.S. non-food corn that is caused by the fact that segregation costs must also be incurred for non-food shipments to Japan. In order to obtain empirical estimates of the losses accruing to producers because of StarLink, we must first determine the degree to which the intercepts of these curves shifts. Each of these is discussed in turn.

The three-year average price of corn received by U.S. producers, as reported by the National Agricultural Statistical Service (USDA/NASS, 2004) from September 1997 through August 2000, was \$2.06 cents per bushel. Hence, segregation costs of 19.75 cents per bushel represent a downward shift of 9.6% in the intercept of the demand schedule for U.S. food corn. This translates into an effective shift in the entire demand schedule for all U.S. corn by 1.3%, because food represents only 13.7% of the entire demand schedule for U.S. corn.

The excess demand for U.S. food corn exports also shifts downward by 1.3%, because segregation costs must be incurred on all food corn exported from the United States and because it is assumed that the ratio of food to non-food corn exports is the same as the ratio of food to non-food corn consumed in the United States.

Total average exports of U.S. corn to Japan were 587 million bushels over the 1997/1998 through 1999/2000 marketing year, according to the USDA/ERS data in Table 2. Out of that amount, it is assumed that 80 million bushels (13.7%) are used for food purposes and the remaining 493 million bushels used for non-food purposes. U.S. non-food corn exports over that same time period were 1,559 million bushels. U.S. non-food corn exports to Japan comprised 31.6% of all U.S. non-food corn exports. Hence the downward shift of 9.6% induced by segregation costs must be applied to 31.6% of all U.S. non-food exports. This translates into an effective shift in the excess demand for U.S. non-food corn by 3%. Combining this result with the shift in the excess demand for U.S. food corn yields an effective shift of 4% in the total excess demand schedule for U.S. corn.

In order to estimate actual monetary values using the model described above, the U.S. supply and demand curves (S_T and D_T in Panel A of Figure 1) and the excess demand curve facing U.S. corn producers in international markets (ED_{US} in Panel B of Figure 1) are assumed to be linear.[6] Estimates of the intercept and the slope of the demand schedules (D_F, D_N, and D_T in Panel A of Figure 1) and the excess demand schedules facing the United States (ED_F, ED_N, and ED_{US} in Panel B of Figure 1) are obtained by specifying

[6]In reality, these curves are most likely not linear. However, since we are dealing with small changes relative to the size of these markets, a linear curve represents a first-order mathematical and statistical approximation and has been used in a large number of studies that estimated the economic impact of shocks to market equilibrium.

the elasticities and using the actual prices and quantities that existed over the 1997/1998–1999/2000 period. Following the modeling work of the USDA-ERS, the price elasticity of U.S. corn demand was estimated to be between −0.3 and −0.5. In addition, Adams (1996) estimated a demand elasticity of −0.673. For this analysis, we use a value of −0.5, which is near the middle of the range. The shapes of the U.S. food and non-food corn demand schedules are readily obtained by disaggregating the total demand schedule for U.S. corn into a demand schedule for food corn and a demand schedule for non-food corn.

The final required parameter is the elasticity of the excess demand for U.S. corn in international markets. While this number has not been estimated specifically, it is generally accepted that the excess demand elasticity for feed grains does not fall below −1.0. Some have suggested that it may be as high as −20 (Schmitz & Gray, 2000). The reason the excess demand elasticity for U.S. corn exports is much higher than the domestic demand elasticity is that if the price of U.S. corn increases, countries can substitute away from U.S. corn imports to imports from other countries and/or (in the case of feed corn) can substitute away to alternative sources such as barley and soybeans. We use an estimate of the excess demand elasticity for U.S. corn exports of −2.0.

Estimates of the changes in U.S. corn markets, resulting from incurred segregation costs for sales of food corn and for sales of non-food corn to Japan, are provided in Table 3. The most likely outcome shown in Table 3 is associated with a segregation cost of 19.75 cents per bushel, an elasticity of the domestic demand for all U.S. corn of −0.5, and an elasticity of the excess demand for all U.S. corn exports equal to −2.0. Without StarLink, during a typical marketing year (represented by three-year average, 1997/1998–1999/2000) U.S. corn producers would have received an additional 10.18 cents per bushel, all else remaining equal. This translates into additional revenue of $964 million dollars. Domestic food sales would have been 125 million bushels higher and residual food sales would have been 47 million bushels higher.

No matter what happens to market prices, U.S. producers sell all the corn they produce. Because of this, in equilibrium, the significant reduction in food corn sales must be exactly countered by an increase in non-food corn sales. In the absence of StarLink, domestic

TABLE 3. Impact of StarLink (Not Adjusted for LDP Payments)

	19.75		10.00		29
IP Cost (cents/bu)	Most[a] Likely	High[b] Sensitivity	Most[a] Likely	High[b] Sensitivity	Most[a] Likely
Corn Price (cents/bu)	−10.18	−6.22	−5.16	−3.15	−14.95
Revenue (mil $)	−964	−589	−488	−298	−1,495
Domestic Food Sales (mil bu)	−125	−238	−63	−121	−183
Residual Food Sales (mil bu)	−47	−105	−24	−53	−69
Domestic Non-Food Sales	163	399	83	202	239
Residual Non-Food Sales	8	−56	4	−28	12
Total Sales (mil bu)	0	0	0	0	0

Source: Calculated by Authors

[a]Refers to an elasticity of demand for U.S. corn equal to −0.5 and an elasticity of excess demand for U.S. corn exports of −2.0.

[b]Refers to an elasticity of demand for U.S. corn equal to −2.0 and an elasticity of excess demand for U.S. corn exports of −5.0.

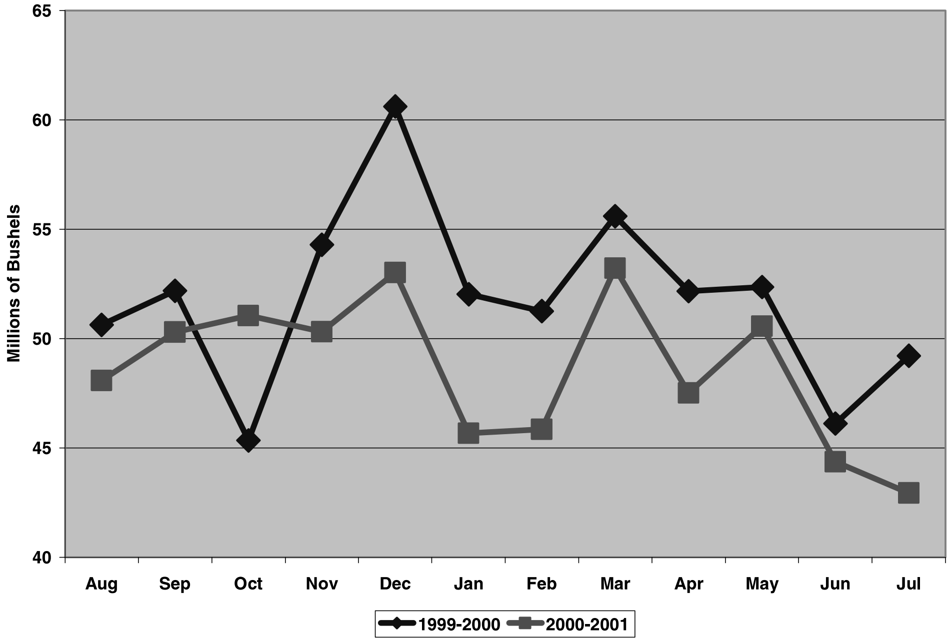

Figure 2 Monthly US Corn Exports to Japan over the Last Two Years (August 1999 through July 2001)
Source: World Trade Atlas, "Trade Information System", Japanese Edition, compiled from Japanese Customs Data, 1993–2001 Global Trade Information Services, Inc.

non-food sales would have been 163 million bushels lower and residual non-food sales 8 million bushels lower. This is because the segregation costs affect food markets much more significantly than they affect non-food markets. Even though non-food sales to Japan are lower due to StarLink, non-food sales to all other countries are much higher, because the 10.18 cents per bushel drop in the price of corn makes it less expensive for countries that do not differentiate between StarLink and non-StarLink to buy more non-food corn.

As a point of reference, we show what actually happened to U.S. corn exports to Japan once StarLink was introduced (Figure 2). The first time series shows monthly U.S. corn exports to Japan from August 1999 through July 2000. The second time series shows monthly U.S. corn exports to Japan from August 2000 through July 2001. Notice that starting in November, monthly exports in 1999/2000 were much higher than monthly exports in 2000/2001. Despite the reduction in Japanese corn imports from the United States, total Japanese corn imports did not decrease during the 2000/2001 marketing year. Japan substantially increased its imports of corn from South Africa, China, Argentina, and Brazil (not shown) which made up for the decrease in imports from the United States.

As more evidence of the reduction in U.S. corn exports to Japan caused by the StarLink event, FASonline (2003) reports that actual U.S. corn exports to Japan from September 1, 2000 through August 31, 2001 were 573 million bushels. That same publication also reports that U.S. corn exports to Japan from September 1, 1999 through August 31, 2001 were 623 million bushels. This translates into a 9.2% reduction in actual U.S. corn exports to Japan from the year prior to the introduction of StarLink. This number is very close to the 9.6% shift in the export demand schedule induced by the 19.75 cents per bushel segregation costs for U.S. exports of food and non-food corn to Japan, estimated in the above analysis.

The results of sensitivity analyses are also reported in Table 3. The second column associated with segregation costs of 19.75 cents per bushel represents the empirical results where the elasticity of domestic demand for U.S. corn equals −2.0 and the elasticity of excess demand for U.S. corn exports is −5.0. Under these elasticities, the average price of corn received by all U.S. producers over a typical marketing year immediately following the discovery of StarLink would have been 6.22 cents per bushel higher had StarLink not been discovered in the grain-handling system. This translates into a loss of $589 million in aggregate revenue realized by all U.S. corn producers. Corresponding estimates were also obtained in the case in which segregation costs are reduced to 10 cents per bushel. Under these scenarios, the average reduction in price induced by StarLink drops between 3.15 and 5.16 cents per bushel, which translates into estimated damages of $298 to $488 million for a typical marketing year immediately following the discovery of StarLink.

5. THE IMPACT OF STARLINK ADJUSTED FOR THE LOAN DEFICIENCY PAYMENT PROGRAM

The estimates we obtained regarding the impact of StarLink in Section 4 (Table 3) may seem somewhat high. Part of the reason is that the above empirical results apply only in a typical marketing year during which no loan deficiency payment (LDP) is paid by the government to U.S. corn producers. However, for the marketing year from September 1, 2000 through August 31, 2001 corn prices at times fell below the U.S. loan rate. Hence, the estimates from Section 4 must be adjusted to account for the dampening effect of the LDP.

When the posted county price (PCP) in a certain county falls below the loan rate for that county, U.S. corn producers are able to take an LDP payment for as much of their crop as they desire at that time. The county loan rate is computed using a formula, based on the national loan rate, set yearly by the U.S. Secretary of Agriculture. The loan rate for corn has remained at $1.89 per bushel since 1995. U.S. corn producers are essentially guaranteed that the market price will not drop below $1.89 per bushel. If the PCP drops below $1.89 per bushel (with an adjustment based mostly on the distance of the county to the closest major market), farmers can opt to take the loan deficiency payment on as much of their harvested crop as they desire.

The average quarterly corn market prices for the United States as compiled by the USDA are provided in Figure 3. The loan rate upon which loan deficiency payment rates are based is also shown in Figure 3. Notice there are times in which StarLink disrupted the marketing system (i.e., October 15, 2000–August 31, 2001) when the average market price was lower than the loan rate. For example, from September 1 through November 31, 2001, the average market price was $1.76 per bushel. This is obviously lower than the national loan rate of $1.89 per bushel. Therefore it is important to realize that because the government supports the price of corn during periods of extremely low market prices, the economic impact of any disruption in the market price will not be fully passed along to U.S. corn producers.

This exercise of accounting for LDPs is made difficult by the fact that while the USDA tracks total LDPs made on a monthly basis throughout the year, the USDA's payments are

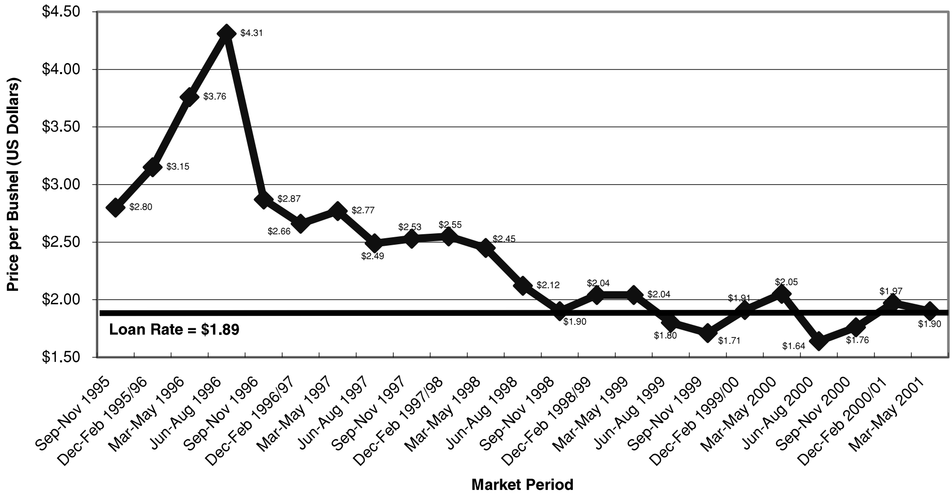

Figure 3 Average Quarterly Corn Market Price in the United States (September 1995 through May 2001)

typically lagged by one to three months. Also, accurate data for shorter time periods are unavailable. The methodology employed is to divide the marketing year into 24 time periods so that each month represents two time periods. The first period of each month is defined as marketing days (Monday to Friday) falling between the first and the fifteenth of the month, while the second period for each month is defined by the days remaining after the fifteenth of the month.

The county loan rate and the posted county price can differ across all counties, in all states, and on a daily basis due to the minor adjustment factor the USDA uses to compute LDP rates. Because it is not feasible to examine every corn-producing county in the United States, representative counties are used for the analysis. Using NASS Crop County Data Files for production in the year 2000, the largest corn-producing county in each of the top ten corn-producing states is identified and used as a proxy for the average daily LDP rate in the respective state. We acquired the daily LDP rates for September 2000 through August 31, 2001 in each of these 10 largest producing counties.[7] The daily data were averaged across each of the 24 periods using equal weights for each day.

Results of these computations are provided in Table 4. The first column provides the period of time. For example, “Sep 1” represents September 1, 2000 through September 15, 2000 and “Sep 2” represents September 16, 2001 through September 30, 2001. Column 2 reveals the estimated bimonthly use. This number is derived from quarterly data on Grain Stocks provided by the National Agricultural Statistics Service in various issues by subtracting beginning corn stocks in the current quarter by beginning corn stocks in the previous quarter, dividing that number by six (since there are six bimonthly periods that make up a quarter), and distributing the use evenly across the three months.

Columns 4 through 13 provide the bimonthly average LDP rates for each of the top corn-producing counties in each state (labeled at the top of each column). Numbers along the bottom row provide the total amount of corn produced in 2000/2001 in each state.

[7]Available online at http://www.grainline.com.

TABLE 4. Corn LDP Rates for the Top 10 Counties in the Top 10 Corn Producing States Bimonthly (September 1, 2000–August 31, 2001)

Date (county)	Estimated Use	Average LDP	Iowa Kossuth	Illinois McLean	Nebraska York	Minnesota Renville	Indiana Jasper	Ohio Darke	S. Dakota Brown	Kansas Haskell	Missouri Saline	Wisconsin Dane
Sep 1[a]	604	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sep 2[b]	604	.33	.42	.42	.38	.42	.42	.33	.31	.43	.40	.20
Oct 1	604	.24	.32	.29	.27	.29	.30	.27	.24	.31	.29	.14
Oct 2	604	.17	.22	.22	.19	.22	.21	.19	.18	.25	.21	.09
Nov 1	604	.10	.12	.11	.10	.14	.12	.08	.19	.13	.10	.06
Nov 2	604	.07	.09	.10	.07	.11	.10	.08	.13	.11	.07	.00
Dec 1	325	.04	.05	.08	.03	.05	.07	.03	.03	.09	.04	.00
Dec 2	325	.00	.00	.00	.00	.00	.01	.00	.00	.01	.00	.05
Jan 1	325	.01	.00	.00	.02	.01	.00	.04	.12	.00	.01	.07
Jan 2	325	.06	.07	.06	.08	.09	.06	.07	.15	.04	.08	.05
Feb 1	325	.05	.05	.06	.04	.05	.07	.04	.11	.07	.04	.01
Feb 2	325	.04	.04	.04	.04	.03	.05	.03	.07	.03	.03	.10
Mar 1	228	.02	.01	.02	.02	.04	.00	.04	.10	.01	.03	.09
Mar 2	228	.08	.07	.11	.07	.11	.11	.10	.11	.12	.08	.06
Apr 1	228	.07	.08	.08	.08	.10	.08	.06	.10	.10	.07	.04
Apr 2	228	.12	.13	.14	.15	.17	.14	.14	.17	.17	.15	.19
May 1	228	.14	.17	.16	.17	.19	.18	.16	.19	.21	.17	.17
May 2	228	.18	.20	.22	.20	.23	.22	.20	.23	.25	.20	.21
Jun 1	504	.17	.20	.22	.20	.22	.19	.20	.22	.22	.20	.18
Jun 2	504	.21	.24	.27	.24	.27	.26	.23	.27	.30	.24	.25
July 1	504	.09	.11	.10	.11	.12	.10	.10	.12	.13	.11	.10
July 2	504	.04	.04	.05	.04	.07	.05	.02	.07	.04	.04	.04
Aug 1	504	.03	.04	.03	.04	.05	.04	.02	.05	.03	.04	.03
Aug 2	504	.01	.02	.00	.02	.04	.01	.00	.04	.03	.02	.00
TOTAL SUPPLY	9,968		1,740	1,669	1,014	957	816	485	431	416	396	363

Source: LDP rates are derived from daily county data [http://www.grainline.com].

Supply data are from NASS Crop Country Data Files, Year 2000 [http://www.usda.gov/nass/graphics/county00/indexdata.htm]

Estimated use is derived from Grain Stocks, National Agricultural Statistics Service (NASS), Agricultural Statistics Board, USDA, Various Issues.

Note. Average LDP rates are computed for the first part of the month (1–15) and the second part of the month and are weighted by state supply levels. Use and Supply are given in millions of bushels.

[a]LDP data for the first two weeks of September are not readily available. However, the average LDP rate was higher than 33 cents/bushel during this period.

[b]Average LDP rates for the end of September do not include the earliest days, because the data are not readily available.

This number is taken from state-level data provided by NASS. States are ordered from the largest corn-producing state (Iowa) to the tenth largest corn-producing state (Wisconsin). The number in column 3 in each period is equal to the average bimonthly LDP payment in each of the ten counties, weighted by the quantity produced in each state (shown in bold in the very last row).

The estimated changes in corn markets due to the segregation costs induced by the introduction of StarLink (Table 3) are divided into 24 bimonthly periods. Each period is weighted by the corresponding value for total use (Table 4, column 2). Each outcome in Table 3 is adjusted for the LDP and then aggregated over the entire marketing year in order to generate Table 5.

As a first example, consider the most likely outcome associated with segregation costs of 19.75 cents per bushel (Table 3, column 1). This indicates a price drop of 10.18 cents per bushel for the 2000/2001 marketing year. However, column 3 of Table 4 indicates that the average LDP rate was 17 cents per bushel for U.S. corn producers during the second period of October. Because this is higher than the losses attributed to StarLink in the absence of the LDP program, 604 million bushels of the total corn crop for the 2000/2001 marketing year (Table 4, column 2) are estimated to have no effect on the actual price or revenue accruing to U.S. corn producers during that two-week period.

As a second example, Table 4 indicates that in the second period of January 2001, the average LDP rate was 6 cents per bushel. The average price effect attributed to StarLink for the entire marketing year is 10.18 cents per bushel (from Table 3). Hence, the economic loss accruing to U.S. corn producers in the second period of January is equal to (10.18–6.00) or 4.18 cents per bushel. If this is multiplied by the approximate use of 325 million bushels (Table 4, column 2), the economic loss to U.S. corn producers resulting from StarLink from January 16 through January 31, 2001 equals $19.5 million.

The aggregate results for the entire 2000/2001 marketing year were obtained once the 24 time periods were adjusted for the LDP (Table 5). Notice that sales are not affected by the LDP adjustment; the bottom five rows of Table 5 are identical to the bottom five rows of Table 3. Hence, the equilibrium price impact facing everybody except U.S. corn

TABLE 5. Impact of StarLink in 2000/2001 (Adjusted for LDP Payments)

	19.75		10.00	
IP Cost (cents/bushel)	Most Likely[a]	Sensitivity Analysis[b]	Most Likely[a]	Sensitivity Analysis[b]
Corn Price (cents/bu)	−3.04	−1.19	−0.82	−0.27
Revenue (mil $)	−288	−112	−78	−26
Domestic Food Sales (mil bu)	−125	−238	−63	−121
Residual Food Sales (mil bu)	−47	−105	−24	−53
Domestic Non-Food Sales	163	399	83	202
Residual Non-Food Sales	8	−56	4	−28
Total Sales (mil bu)	0	0	0	0

[a]Refers to an elasticity of demand for U.S. corn equal to −0.5 and an elasticity of excess demand for U.S. corn exports of −2.0.
[b]Refers to an elasticity of demand for U.S. corn equal to −2.0 and an elasticity of excess demand for U.S. corn exports of −5.0.
Source: Calculated by Authors

producers is the same regardless of the LDP adjustment. The only difference is that the U.S. government makes up some of the loss in market price induced by StarLink by paying corn producers extra money through LDP payments. This results in increased revenue and an increase in the average price that U.S. corn producers actually receive over what they would have received if there were no LDP program.

When adjusting for LDP payments, the most likely outcome (column 1 in Table 5), is an average drop in the price farmers actually received for corn (including the price they receive from the market plus LDP payments) of 3.04 cents per bushel. This results in an economic loss of $288 million dollars accruing to all U.S. corn producers as a result of the introduction of StarLink corn from September 1, 2000 through August 31, 2001. The LDP adjustments made for each of the other outcomes are also provided in Table 5. The impact ranges from 0.27 cents per bushel to 3.04 cents per bushel, which translates into losses of between $26 million and $288 million. The difference between the revenue loss unadjusted for the LDP and the revenue loss adjusted for the LDP is borne by the federal government through agricultural policy. Such numbers are much lower than those generated from the model that did not take the LDP program into consideration (Table 3).

6. CONCLUSIONS

The discovery of StarLink corn in the U.S. grain-handling system became a serious problem for U.S. corn producers during the 2000/2001 marketing year because of added segregation costs incurred by the U.S. grain-handling sector. Segregation costs were applied to corn used as food in the United States, to U.S. corn exported as food to other countries, and to U.S. non-food corn exported to Japan. U.S. corn producers received lower revenue through lower average market prices because of these segregation costs. Without taking LDP payments into account, StarLink would have reduced producer prices by anywhere from 3.15 to 10.18 cents per bushel and the resulting revenue losses would have ranged from $298 to $964 million over the 2000/2001 crop year.

The above estimates represent the total welfare loss to U.S. society on account of StarLink. However, in order to calculate the impact of the StarLink event on producers, LDP payments provided over the course of the 2000/2001 marketing year must be accounted for, since part of the cost of StarLink was picked up by the federal government as added LDP payments. The LDP payment program dampened the effect of StarLink on producers, resulting in lost producer revenues ranging from $26 million and $288 million. After adjusting for LDP payments, the realized producer price dropped by only 0.27 to 3.04 cents per bushel. Government programs played a significant role in reducing the economic impact that StarLink had on U.S. producers.

The $110 million settlement reached in February 2003 falls within the range of our empirical estimates, even with the property damage claims of $10 million and legal fees estimated at approximately $44 million. Considering that the size of the U.S. corn crop is nearly 10 billion bushels per year, a $100 million drop in revenue represents only about a one cent per bushel reduction in the realized producer price over the 2000/2001 marketing year. This is the exact amount corn loss claimants—those compensated for the alleged reduction in the general price of corn caused by StarLink—received under the settlement.

More undesired genetically modified organisms are likely to enter the U.S. food handling system in future years. In retrospect, StarLink corn would have been a much bigger problem for U.S. producers if the percentage of all corn used as food had been higher or if StarLink seed were planted over a wider geographical area. Moreover, if corn prices had remained higher than the loan rate throughout the entire 2000/2001 marketing year, government programs would not have reduced the burden on U.S. producers.

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Troy G. Schmitz *received his B.Sc. (high honors) in Mathematics and B.Sc. (honors) in Computer Science from the University of Saskatchewan in 1990. He received his M.Sc. from the University of California, Berkeley in 1991. He received his Ph.D. in Agricultural and Resource Economics from the University of California, Berkeley in 1995. Dr. Schmitz is currently Associate Professor in the Morrison School of Agribusiness and Resource Management at Arizona State University. His research interests include WTO trade disputes, the economics of biotechnology regulation, E-commerce in agribusiness, import demand systems, golf economics, and international grain, sugar, and cotton policy. Dr. Schmitz has published research articles in twelve different peer-reviewed domestic and international journals.*

Andrew Schmitz *is the Ben Hill Griffin, Jr., Eminent Scholar and Professor of Food and Resource Economics at the University of Florida; Research Professor, University of California, Berkeley; and Adjunct Professor, University of Saskatchewan. His publications have won six major research awards and four research of enduring quality awards from the American Agricultural Economics Association (AAEA), and in 2003, he won the Lifetime Achievement Award from the Southern Agricultural Economics Association (SAEA). He has been a consultant to hundreds of private and public organizations, the Canadian and U.S. Departments of Justice, Agriculture and Agri-Food Canada, U.S. Department of Agriculture, and the World Bank. Some of his recent books include Government Policy and Farmland Markets: The Maintenance of Farmer Wealth, Iowa State Press; The Welfare Economics of Public Policy, Elgar Publishing; Agricultural Policy, Agribusiness, and Rent-Seeking Behaviour, University of Toronto Press; and Sugar and Related Sweetener Markets: International Perspectives, CABI Publishing.*

Charles B. Moss *is a professor in the Food and Resource Economics department at the University of Florida. He also had the privilege to serve as a McKethan-Matherly fellow in the Economics Department at the University of Florida from 1989 to 1994 while working with the late Professor Henri Theil and is currently an affiliate member of the Center for Applied Optimization at the University of Florida. The prevalent focus of his research has been in the areas of financial risk and stress in the farm sector. In addition to work in finance, he has applied his expertise in quantitative analysis to problems which include water resource management, timber resources, citrus crop decisions, coffee marketing in Mexico, trade issues in sugar, analysis of technology adoption including precision agriculture, and agricultural productivity measures. In addition to his own research and publication activities, Chuck has served as Co-editor of the Journal of Agricultural and Applied Economics and on the editorial boards of the Journal of Agricultural and Resource Economics and the Journal of Agricultural and Applied Economics.*