StarLink Contamination and Impact on Corn Prices

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Abstract

StarLink is a bio-engineered corn variety that was approved by the U.S. Environmental Protection Agency in 1998 for commercial production for animal feed but not for human consumption (i.e., a split license). However, StarLink soon became co-mingled with non-StarLink corn and this led to recalls of hundreds of food products domestically and overseas. The split license was flawed regulation and it adversely affected worldwide public acceptance of bio-engineered crops. Non-StarLink growers in the U.S. cornbelt were harmed and they brought a class action suit against Aventis, the company that developed StarLink. Through statistical analysis we measure the market effects of the StarLink event and estimate it depressed the general corn market price by about 6% and lasted for several months. We estimate that the class action settled for about 20% of total damages.

Introduction

There are various theories of why some legal disputes are settled out-of-court before going to trial and how the final settlement amount is determined (Bebchuk, 1984; Priest and Klein, 1984; Spier, 1992; Wittman, 1988). Waldfogel tests the Bebchuk and Priest and Klein models and finds support for the Bebchuk theory that out-of-court settlement is due to asymmetric information between the plaintiff and defendant. However, Clermont and Eisenberg explain that there has been insufficient empirical work on understanding the litigation process. For instance, there has been little analysis of the Bebchuk model's prediction of the settlement amount. Bebchuk's model predicts that the settlement amount will depend on the size of the total damage, the litigation costs, and the nature of the information held by the parties involved.

This paper empirically analyzes a high-profile class action case over a financial issue that arose from defective government regulation and that was settled out-of-court. The case dealt with StarLink, a bio-engineered corn. The potential damages were very high because corn is a huge volume U.S. crop. The StarLink case has important implications for the ongoing biotechnology revolution in agriculture.

We measure the reaction of the U.S. corn market to contamination of the entire corn supply by StarLink that happened sometime in 2000. This event was the subject of a class action litigation brought by non-StarLink growers that was settled out of court for $110 million (see StarLink Corn Products Liability Litigation, MDL No. 1403, Judge James B. Moran, 2003). Both the duration of the event and the impact on the market price of corn are estimated.

Event studies are used in class action litigation to assess damages in securities fraud cases (Black, 1984; Dennis, 1984; Mitchell and Netter, 1994). For instance, in class actions plaintiffs may allege that stock prices were artificially manipulated due to corporate misstatements or misleading documents (e.g., Basic Incorporated, et al., v. Max L. Levinson et al. 485 U.S. 224,1988). The event study approach is acceptable to the courts because in an efficient market the event's effects will be reflected immediately and fully in the market price (MacKinlay, 1997). Typically these studies examine a well-defined time period during which the impact of the event on the market is examined. In other words, the "event window" is known. The StarLink contamination was an economic event, but the event window has to be estimated.

Bio-engineered StarLink corn was first commercially grown in the United States in 1998. Unlike most other genetically modified corn, the U.S. government did not approve StarLink for human consumption. Instead, the Environmental Protection Agency (EPA) issued a "split" license, approving the corn as safe only for animal consumption. StarLink was not approved for human consumption because it contained

Cry9C, a protein that might cause allergic reactions in some humans. Cry9C is toxic to European corn borers and other insects, a desirable characteristic for a bio-engineered corn.

In retrospect, the U.S. grain handling system was not prepared to handle the split licensing of StarLink (Uchtmann, 2002) and as a result StarLink easily and quickly became co-mingled with non-StarLink corn and found its way into U.S. and foreign food products and bulk export cargoes. The contamination took place on-farm and in the bulk handing and transportation system. Even though companies selling StarLink claim that they instructed growers to keep it separate from other crops, a number of growers claimed they never received any such warning.[1]

Aventis, a French multinational corporation, developed StarLink and the Garst Seed Company produced the StarLink seed. The class action lawsuit was brought on behalf of thousands non-StarLink corn farmers, who claimed that StarLink damaged the value of their corn through unintended contamination and threat of contamination. The plaintiffs argued that the presence of StarLink in the system caused a price decline for non-StarLink corn and a shift in foreign demand away from U.S. corn. Prior to the lawsuit, Aventis reimbursed StarLink growers and other handlers for out-of-pocket losses related to StarLink, and there was a buy back program for corn seed suspected

[1] In the fall of 2000, the Iowa Attorney General launched an investigation of a mailing of letters by Aventis to StarLink growers. The letters were reportedly mailed after the contamination became public knowledge and enclosed with the letters were copies of agreements the growers were asked to sign and return to Aventis. The letters were backdated to April 2000. The New York Times reported that many StarLink farmers had not signed such agreements and were unaware of restrictions on use of StarLink (*New York Times*, "1999 Survey on Gene-Altered Corn Disclosed Some Improper Uses" Section C, p.2, September 4, 2001.)

of contamination with StarLink. However, Aventis did not compensate non-StarLink growers for any price erosion.

The U.S. Corn Market and the StarLink Incident

> "Literally hundreds of barges and thousands of trucks and rail cars have been redirected as a result of containing extremely low levels of Cry9C-containing (i.e., StarLink) corn." (Gadsby, p.5)

The United States is the world's largest producer and exporter of corn, accounting for about 40 percent of global output and 65 percent of world corn exports. U.S. corn growers produce about 9.5 billion bushels per year (240 million metric tons–mmt), worth more than $17 billion.

Currently, about one-third of the U.S. corn is planted to bio-engineered (i.e., genetically modified–GM) varieties, none of which are StarLink (James, 2001). The large-scale production of GM corn in the United States is a relatively recent phenomenon and its rapid adoption in the U.S. has generated international controversy. Part of the controversy was generated by the StarLink contamination incident, which some view as a major setback to the global biotechnology revolution in agriculture. For instance, the European Union points to the StarLink incident as evidence that GM crops cannot be properly segregated from non-GM crops.

In most years about 60 percent of the annual U.S. corn harvest is fed domestically to cattle, hogs, chickens and other animals and StarLink was judged by the EPA to be suitable for this segment of the market. An additional 15 percent of the annual supply is used domestically for food products and 20 percent is exported. About one-third of annual U.S. corn exports are destined for Japan, a market that was dramatically affected by the StarLink issue.

In 1998 StarLink was grown on approximately 10,000 acres in the United States and produced about 1.5 million bushels of grain. In 1999 there were 250,000 acres planted to StarLink, yielding some 37.5 million bushels. In 2000, StarLink was planted on 350,000 acres, which produced about 52.5 million bushels. This amounted to less than 1 percent of the total U.S. corn acreage in 2000.

On September 18, 2000 *The Washington Post* reported that traces of StarLink were detected in taco shells in the United States. In all likelihood this corn was from the 1999 crop. This lead to immediate food recalls of approximately 300 food products (Lin, Price, and Allen, 2001). However, in July 2000, the EPA had received reports alleging adverse events linked to corn food products (U.S. Food and Drug Administration, 2001). As early as January 2000, Aventis sent the results of a farmer survey to the EPA, which showed that some StarLink corn was sold into channels where it should not have gone.[2]

Corn production in the United States is concentrated in the nine neighboring midwestern states comprising the "corn belt." U.S. corn prices are "discovered" at the Chicago Board of Trade (CBT) futures market, in conjunction with major cash markets in Chicago, Kansas City, the Gulf, and other domestic and international locations.

There seems to be no question that traders in the corn futures and cash markets viewed the StarLink incident in 2000 as a significant news event (Bridge Commodity Research Bureau, 2001). At the time of the contamination, StarLink was not approved in Japan, the largest single customer of U.S. corn. However, the problems connected to the discovery of StarLink soon spread to Japan as on October 26, 2001, StarLink corn

[2] *New York Times*, “1999 Survey on Gene-Altered Corn Disclosed Some Improper Uses” Section C, p.2, September 4, 2001.

was publicly reported to have been discovered in snack foods and animal feed in Japan (Taylor and Tick, 2001). Similar discoveries were reported in South Korea.

The StarLink problem also spilt into other markets. For instance, traces of StarLink were found in the Canadian corn supply, jeopardizing Canadian corn exports to Japan. The EU expressed concern that some food products imported from the U.S. might contain StarLink. In addition, questions were raised about the United States' future ability to adequately segregate approved versus non-approved food products.

The U.S. market share of the world corn trade may have been eroded for a time period following the StarLink incident. In Figure 1, we show the volume of corn export sales to Japan from April 2000 through March 2001, and we see a dramatic drop in sales in July 2000. Some commodity market analysts have attributed part of the erosion of export sales to the StarLink incident. For instance, Prudential Securities (2001) stated that the StarLink contamination "shifted demand to other countries not due to price but due to concerns that food products made from U.S. supplies could be contaminated with StarLink with an eventual need to be recalled from the market." Lin, Price and Allen (2001) found an apparent negative impact on the volume of U.S. corn exports to Asia. According to U.S. Embassy staff in Tokyo, "Due to the StarLink issue, imports of US corn fell about 1.3 million metric tons in CY2001, a drop of 8 percent" (USDA, Foreign Agricultural Service, GAIN Report #JA2001).

In November 2000, the International Grains Council in London reported that "a recent slowdown in the pace of US sales to Japan and S. Korea, linked to buyer concerns about the presence of traces of the GM variety StarLink in some export cargoes, continued to have a negative effect on prices. The introduction of agreed testing procedures for maize shipments destined for food use in Japan considerably allayed concerns, but reports that both Japan and S. Korea has purchased limited quantities of maize from China, combined with reports that Australia was offering weather-damaged wheat, continued to unsettle futures markets. There was evidence of a two-tiered market developing, with shipments of certified non-StarLink corn commanding premiums of up to $5 per ton."

Because of zero tolerance for StarLink in Japan and in the U.S. food system, the contamination jeopardized the entire supply of U.S. corn for the purposes of serving these markets and others. According to Aventis (Gadsby) about 70 percent of the inbound corn samples tested by Japan between September and December 2000 tested positive for Cry9C. Table 1 reports results from the Japanese testing of inbound U.S. corn and the level of commingling was 67% of the lots tested from April to September 2000. Thus it appears that StarLink had contaminated the corn supply a few months before the announcement in the Washington Post and this may have been known in the grain trade. This is consistent with the drop in export sales in July 2000 that is shown in Figure 1. In Table 1 it is reported that the measurable level of commingling declined to 47% from October 2000 to March 2001, and then to 15% from April to September 2001. So it was not the case that contaminated corn was quickly and easily isolated.

Our hypothesis is that the disruptions in these Asian markets were translated into lower corn prices on the CBT, as corn futures contracts could be filled with StarLink corn before and after September 18, 2000. As a result, CBT corn futures prices were depressed because of the risk of contamination in any shipment originating in the United States. In turn, these lower futures prices would result in lower cash price quotes within the United States and reduced prices paid at local elevators to growers in the U.S. corn belt.

The reported declines in U.S. corn sales to Japan due to the StarLink incident led to new testing protocol introduced by the U.S. Department of Agriculture (USDA). The new testing procedure was developed by the USDA to assure Japan that any further corn imported from the United States would not contain detectable StarLink material. According to the *Wall Street Journal*, the U.S.-Japan agreement lifted corn prices. In the Commodities column, the Wall Street Journal[3] reported that "March corn futures at Chicago Board of Trade rose five cents to $2.2325 a bushel on news that US and Japan have reached agreement on export inspections for genetically modified StarLink corn."

The StarLink contamination was particularly disruptive because a relatively large share of the market had zero tolerance for its use, and zero tolerance is impossible to attain (Lin, Price and Allen, p. 15). Zero tolerance for StarLink applies to food use of corn in the U.S., Japan and South Korea. In addition, Japan has zero tolerance for animal feed use of StarLink, which meant that any StarLink presence is prohibited in Japan. So, in total, zero tolerance markets accounted for approximately 20 to 25 percent of the demand for U.S. corn.

The USDA's Grain Inspection, Packers and Stockyards Administration (GIPSA) issued a directive on sampling and testing for StarLink corn. GIPSA calculated statistical confidence levels for approved StarLink testing procedures. Figure 2 displays the essential GIPSA results. The horizontal axis in Figure 2 shows the hypothetical

[3] *Wall Street Journal*, Section C; Page 15, Column 1, December 19, 2000.

percentage of StarLink in a single cargo of corn. The vertical axis shows the corresponding “false positive” probability of accepting a cargo as non-StarLink.

Suppose a cargo of corn is destined for Japan and the actual level of contamination is 1/10th of 1% (i.e., 0.10%), shown by point X in Figure 2. GIPSA found there is more than a 9% chance that the cargo in question would be falsely determined to be StarLink free through accepted testing procedures. With a contamination level of 0.10%, there could be millions of kernels of StarLink tainted corn in this cargo, which would later possibly show up in food products. This example illustrates why Lin, Price and Allen (2002) say it is impossible to meet a 0% tolerance level and why StarLink contamination was such a serious market disturbance.

Cointegration Between Corn and Sorghum

To estimate the effect of the StarLink incident on the corn market, we need to estimate the path that corn prices would have taken had the incident not occurred. We do this using the equilibrium pricing relationship between corn and sorghum. Sorghum is the second most important U.S. feed grain behind corn. In the fall of 2000, the International Grains Council stated, "U.S. sorghum prices peaked in early November, coinciding with concerns about StarLink maize (corn). As a non-GM grain, traders saw some potential for greater domestic and export demand." Our analysis reveals that the relative price of corn and sorghum decreased sharply four months earlier in July.

We measure the long-term relationship between corn and sorghum prices by showing that they are cointegrated. A pair of time series is cointegrated when they have a common stochastic trend (Engle and Granger, 1987). This means that, when viewed individually, the series exhibit a stochastic trend or unit root. However, there is a linear combination of the series that has no trend. In the present case, cointegration between corn and sorghum could be represented by the model

$$c_t = \mu + \beta s_t + z_t \tag{1}$$

$$s_t = s_{t-1} + u_t$$

where c_t denotes the log price of corn, s_t denotes the log price of sorghum, and z_t and u_t are stationary error terms. The relationship in (1) is a long-term relationship because c_t and s_t have a common trend. The common trend is represented by s_t, and z_t represents the deviation from this trend in period *t*.

Because the prices of corn and sorghum are jointly determined, we will model them jointly. A convenient representation is found in the error correction mechanism (ECM). An ECM exists whenever there is cointegration in a set of time series. The ECM is

$$\Delta c_t = \alpha_c z_{t-1} + \gamma_c(L)\Delta c_{t-1} + \delta_c(L)\Delta s_{t-1} + \varepsilon_{ct}$$

$$\Delta s_t = \alpha_s z_{t-1} + \gamma_s(L)\Delta c_{t-1} + \delta_s(L)\Delta s_{t-1} + \varepsilon_{st} \tag{2}$$

where $\gamma_c(L)$, $\delta_c(L)$, $\gamma_s(L)$, and $\delta_s(L)$ are polynomials in the lag operator. The parameters α_c and α_s measure the response of corn and sorghum prices to deviations from the long-run trend. The closer α_c and α_s are to zero, the longer it takes for the series to revert to their long-run trend after a shock.

There are numerous examples of cointegration in commodity prices. Examples include tests for law of one price and level of integration of separate markets (Ardeni 1989, Goodwin and Piggott 2001). In these cases and for our purposes, it makes most sense for the coefficient β in (1) to be equal to one. This is because with β equal to one, the long run relative price is constant. This is a sensible model in a case where the two products are substitutes. It is less clear how to interpret a value of β that is not equal to one. We test for cointegration both with β a free parameter and restricting it to be equal to one.

There are two standard approaches to modeling with cointegrated variables. The two-step method of Engle and Granger (1987) involves testing the individual series for unit roots, or stochastic trends, using for example an augmented Dickey-Fuller test. If such trends are found, a regression like (1) is run and the residuals tested for a unit root. If no unit root is found in the residuals, the series are determined to be cointegrated. The method of Johansen (1990) involves simultaneously estimating the ECM and the cointegrating relationship by maximum likelihood. Johansen's method is more efficient because it uses information from the whole system in estimating the cointegrating relationship. In addition, it does not require that the cointegrating vector be normalized on one of the variables as it is in (1). However, given the large sample size that we have, there is likely to be little difference between the two methods.[4]

We begin by analyzing the relationship between corn and sorghum using data prior to the commercial production of StarLink and its release into the market. The data are daily spot prices and the sample begins in January 1989 and runs through August 2002. We use data up to the end of 1999 for the initial tests to determine the relationship between corn and sorghum before the StarLink event. There was no significant volume of StarLink in the market prior to the end of 1999. The corn prices are average daily processor bids on the central Illinois market and the sorghum prices are

[4] In fact, we use both methods and the results are the same.

average daily bids from the Louisiana gulf market.[5] The data source is the Commodity Research Bureau. The two price series are plotted in Figure 3, where it is evident that the two series move together.

The results from the cointegration tests are shown in Table 2. The Johansen and Engle-Granger procedures both strongly indicate that the prices of corn and sorghum are cointegrated. When β is constrained to be equal to one, the augmented Dickey-Fuller test indicates that there is cointegration. The estimated parameters of the ECM are shown in Table 3. Although the restriction that β=1 is rejected by a likelihood ratio (LR) test, the estimated parameters are very similar with and without this restriction.

The error correction parameter for corn, α_c, is estimated to be –0.024. This indicates that on average the daily corn price adjusts to correct 2.5% of any deviation from the long-run trend. This reversion is slow but is significantly different from zero. The slow reversion indicates that corn and sorghum can deviate from their long-run relationship for long periods. The error correction parameter for sorghum is –0.005 and is not significantly different from zero. Thus, it is primarily the corn price that reacts to restore the long-run equilibrium relationship between these two commodities.

We have found a stable long-run relationship between corn and sorghum over the period from 1989-99. Next we expand the sample to include the StarLink period and test for stability in the cointegrating relationship. If there is a break in the cointegrating relationship, this indicates that whatever shocks caused the break had a lasting impact

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[5] These spot markets are among the most liquid in these two commodities and are the only daily spot price series published by the Commodity Research Bureau. Also by using corn prices from central Illinois elevators, we can measure the effect on the price received by farmers. Below, we test the robustness of our results to this choice of series.

on the long-run pricing relationship. We use two methods to test for breaks. First, we use the test in Hansen (1991), which is a sup-*F* test that is designed specifically to test for a structural break in a cointegrating relationship. The test statistic is the maximum *F*-statistic over all possible break points. In other words, it is the maximum value of the familiar Chow (1960) test. Because the break points are unknown and because the data are nonstationary, the null distribution of this test is nonstandard. Critical values are tabulated in Hansen (1991).

Hansen's test is designed to test for only one break. Methods have not yet been developed to test for multiple breaks in a cointegrating relationship. However, for the case when $\beta=1$, testing for a break in the cointegrating relationship entails testing for a break in the mean of the log relative price. The cointegration tests above indicated that the log relative price is stationary, so we can use the procedure of Bai and Perron (1998). This procedure searches for the number and the location of the breaks sequentially. First a test of the null hypothesis of zero breaks against the alternative of one break is conducted. If the null hypothesis is rejected, then the first break is taken as given and a test is conducted for a second break. The procedure continues until the null hypothesis of a further break is not rejected. All test statistics in this method are sup-*F* tests, (i.e., the relevant test statistic is the maximum *F*-statistic over all possible break points). We also report the double-maximum tests of Bai and Perron, which are the maximum *F*-statistics over all possible break points and over the total number of breaks. This provides a test against the alternative hypothesis of some unspecified number of breaks.

The results from breaks tests are given in Table 4. All tests provide strong evidence of a break in mid July of 2000. The *F*-statistic of Hansen is 823.88, far above the critical value of 15.2. The double maximum tests of Bai and Perron are similarly emphatic. The sequential procedure of Bai and Perron can be used to determine whether there are multiple breaks and, if so, how many. It suggests that there are two breaks, the first in July 2000, and the second in December 2001. The third most prominent break point was in February 1996, but this break was not statistically significant.

The findings of the breaks tests are corroborated by Figure 4, which shows the log relative price of corn and sorghum through the whole sample. Apart from a brief spike in 1996, the log-relative price never traveled far from its mean of 3.93 (which is the maximum likelihood estimate of the parameter μ when β=1). In July 2000, there was an abrupt drop of –0.15 to 3.78, which translates into approximately 15% drop in the relative price. This drop occurred within two weeks, beginning on July 17, as indicated in the breaks tests. It wasn't until December 2001 that the relative price began to creep up towards its previous value. By the summer of 2002 the average log relative price was up to 3.88, which is two thirds of the way back to its original point.

To test whether our results are robust, we obtained monthly data on corn prices in the Central Illinois, Kansas City, and Louisiana Gulf markets. We obtained monthly sorghum prices for Kansas City and the Gulf.[6] These data span 1975-2002, which is 14 more years of pre-StarLink data than are available at the daily frequency. This enables

[6] These data are publicly available from the USDA at http://www.ers.usda.gov. The Kansas City data measure truck bids for grain delivered to Kansas City and the Gulf data measure export bids for grain delivered to gulf export elevators.

us to test whether the relative price of corn and sorghum was stable not only for the 11 pre-StarLink years back to 1989, but the 25 years back to 1975. Also, by using corn and sorghum prices from the same markets, we can control for changes in the structure of the supply chain for these commodities.

We applied the Bai-Perron tests to the relative price of corn to sorghum in the Gulf and the relative price of corn to sorghum in Kansas City. For both markets, the test procedure found only one break in the sample. This break was in July 2000. We also applied the Bai-Perron tests to the monthly relative price of central Illinois corn to Gulf sorghum. The results mirrored those for daily data with these markets and also indicated one break in July 2000. Thus, the relationship between corn and sorghum after July 2000 was different than it had been at any time since at least 1975. None of the monthly relative price series indicated a second break in December 2001, as found with the daily data. This is because December is too close to the end of the sample in the monthly data.

The break in the relative price of corn and sorghum occurred two months before the Washington Post report that StarLink had been found in taco shells. Given that the U.S. grain handling system was not prepared to handle the split licensing of StarLink, it is plausible that traders foresaw the impending disaster. This is corroborated by information early in 2000 suggesting possible contamination and by Japan's decision to start testing for StarLink from April 2000. These traders acted by substituting away from corn towards sorghum. Next, we use event study analysis to decompose the relative price change into the separate effects on the absolute prices of corn and sorghum. We do this for the model with β=1, although the results are the same if β is unrestricted.

Event Study Analysis to Decompose Relative Price Change

Event studies are often used in finance to assess the effect of a particular event or a series of events on the price of a financial asset. The approach is as follows (see MacKinlay, 1997). First, one defines an event window that includes the period of time over which the event may have affected the price. For each observation within the event window, the realized return from holding the asset is compared to the return that was expected had the event not occurred. The difference between these two quantities is labelled the abnormal return. The sum of the abnormal returns over the event window gives the cumulative abnormal return (CAR), which is a measure of the total effect of the event on the asset price.

Our case is different from the usual event study because we know from the cointegration analysis that the event had a significant effect on the corn and sorghum markets. There is no need to test whether the CAR is significantly different from zero.[7] There is also no need to estimate the duration of the effect on the markets. Because all shocks to these series are permanent, the effect on prices lasts until the next break point. The objective of the event study is to illustrate the path that the data took in moving to the new equilibrium with a 15% lower relative price. By observing the abnormal returns during the transition in July 2000, we can track the separate reactions of the corn and sorghum markets. We use the daily data to do this in order to most precisely estimate the transition dynamics.

[7] In a typical event study, one has a cross-section of repeated observations of the event in question, e.g., an earnings announcement. In our case, we have only one observation of the StarLink contamination event, which is why we used time-series methods to test for significance of the event.

We define the event window as beginning on July 17, 2000, which is the breakpoint that was discovered above. The end of the event window is August 25, six weeks after the breakpoint. This allows plenty of time for the series to settle at their new levels after the shock. We compute the abnormal return as the difference between the observed daily change in the log prices of corn and sorghum and the log changes predicted by the ECM above. In computing the predicted return, we only use observed corn and sorghum prices up to the beginning of the event window. This is because corn and sorghum prices after July 17, 2000 are both potentially affected by the event. Thus they should not be a part of the normal, or expected, component of returns. This differs from typical event studies where there are no dynamics and the variables used to compute expected return (e.g., the return on a market portfolio) are not affected by the event.

Beginning at the start of the event window, we use the ECM to compute forecasts $\hat{c}_t$ and $\hat{s}_t$ over the length of the window. The abnormal returns are then computed as $AR_t^c = \Delta c_t - \Delta \hat{c}_t$ for corn, and $AR_t^s = \Delta s_t - \Delta \hat{s}_t$ for sorghum. Summing over the event window yields the cumulative abnormal returns as

$$CAR^c = \sum_{t=s}^{k} \left(\Delta c_t - \Delta \hat{c}_t \right) = c_k - \hat{c}_k \qquad (3)$$

$$CAR^s = \sum_{t=s}^{k} \left(\Delta s_t - \Delta \hat{s}_t \right) = s_k - \hat{s}_k$$

where *s* signifies the start and *k* indicates the end of the event window. Thus, the CAR is just the error in a forecast of the commodity price at the end of the window, where the forecast is made at the beginning of the window.

Cumulative abnormal returns for corn, sorghum are shown in Figure 5. The total CAR in the relative price is also shown in this figure. It is evident that the initial shock manifested itself in the sorghum market. On Monday and Tuesday July 17th and 18th, 2000, the price of sorghum jumped to 8% above what was expected. It wasn't until the following week that the corn price reacted, dropping by 6.5% in the week of July 24-28. On Friday July 28, two weeks after the initial shock, the log corn price was 0.064 below its initial value and log sorghum was 0.081 above its initial value. By this time, the total CAR was –0.145, which is close to the total relative price change estimated in the breaks analysis above. Because these numbers measure log changes and are small, they can be interpreted as approximate percentage changes. Both variables stayed at these levels through the end of the event window, indicating that an 8% rise in Sorghum and a 6.5% drop in corn provide a reasonable decomposition. [8]

It is customary in the event study literature to begin the event window some time before the date of the event. In the week before July 17, both corn and sorghum drifted down by about 4%. This means that, starting the event window a week before the event (as is customary in the event study literature) leads to CAR's of –0.105 for corn and 0.04 for sorghum on July 28. However, because corn and sorghum drifted in the same direction in the week of June 10-14, it is clear that the StarLink effect began on the 17th, not the 10th.

To illustrate the precision of the CAR estimates, we computed confidence

[8] If the event window is extended into September, both the corn and sorghum prices begin to increase. However the relative price of the two commodities remains approximately constant. This indicates that the shocks that caused the post-August price increases are not due to the StarLink effect and thus should not be included in the event window.

intervals. It is not our objective here to make inference about whether the sequence of corn and sorghum prices in this period was abnormal relative to other periods. We determined that it was abnormal with the breaks tests above. Rather, our aim in this section is to illustrate the path taken by the corn and sorghum markets through the break period. Thus, we compute confidence intervals for the CAR conditional on the observed sequence of corn and sorghum prices in July 2000. It follows that the only uncertainty emanates from the model parameters that were used in computing the forecast.

Because the forecasts are a nonlinear function of the parameters, we use a bootstrap simulation to obtain the confidence intervals (see Schumacher, 2002, and Gredenhoff and Jacobson, 2001). We do this by drawing a new sample of errors from the residuals of the ECM. This sample is used to generate pseudo corn and sorghum series. The ECM is the estimated on the pseudo data and the event study is conducted. We did this 5000 times, each time saving the estimated CAR on July 28. The result is that in 95% of the random draws, the log corn price dropped by between 0.057 and 0.071 and the log sorghum price rose by between 0.075 and 0.086.

Discussion and Conclusion

The estimated 6% drop in the price of corn translates into an approximate loss of $500 million to the non-StarLink corn growers. As described above, the greatest market disruption occurred prior to the U.S.-Japanese agreement on testing protocol in late December 2000. During the July to December 2000 time period, the average farm price of corn in the U.S. “corn belt” was around $1.70 per bushel. So a 6% erosion of price due to StarLink contamination of the entire U.S. corn crop translated into about a 10¢

per bushel price decline. From July to December 2000, an estimated 5 billion bushels of "non StarLink" corn was sold by U.S. farmers, giving an estimated loss totalling $500 million. The class action case brought by non-StarLink growers settled for $110 million, which is much less than the total damages. Bebchuk's asymmetric information (AI) model suggests several potential explanations for this low settlement.

In the AI model, one party knows the probability of success at trial. The other party only knows the distribution of success probabilities. Both parties are risk neutral. The less informed party makes a take-it-or-leave-it settlement offer and if the offer is rejected the case goes to trial. The AI model predicts that the settlement amount depends on the size of the total damages, the litigation costs, and the nature of the information held by the parties involved. To apply the AI model to the StarLink case let us assume that the defendant, Aventis, knew its degree of liability and therefore knew the probability of success at trial, p. Suppose that the plaintiff knew only that p lay in the interval (a, b) and was distributed with a density function $f(\cdot)$. Further, suppose for now that that the judgement upon success at trial would equal the total amount of the damages, W. Using W = $500 million implies that the observed settlement of $110 million was only 22% of the damages.

In the AI model, the plaintiff knows that the defendant will definitely accept a settlement offer that is less than $C_d + aW$, where C_d denotes the defendant's litigation costs. This is because $C_d + aW$ is the lowest possible cost to the defendant if the case goes to trial. The defendant will not accept a settlement offer that is greater than $C_d + pW$, which is the expected cost should the case go to trial. The plaintiff does not know p, but does know that the defendant will not accept an offer that is greater than $C_d + bW$. Thus, a rational plaintiff will offer a settlement between $C_d + aW$ and $C_d + bW$.

Bebchuk derives the optimal settlement offer for the plaintiff by setting the expected marginal benefit of increasing the offer equal to the expected marginal cost. If the density $f(\cdot)$ is uniform over the interval (a, b), then a settlement offer of $bW – C_p$ satisfies this first order condition, where C_p denotes the plaintiff's litigation costs. Thus, the optimal settlement offer for the plaintiff is the greater of $C_d + aW$ and $bW – C_p$. Scaling by the total amount of the damages, we have the optimal settlement percentage:

$$s^* = \max(c_d + a, b - c_p), \tag{4}$$

where $c_c = C_d / W$ and $c_p = C_p / W$. Given that the defendant never accepts settlement offers greater than $C_d + pW$, we can infer from an accepted settlement that the true probability of success at trial was greater than $s^* – c_d$.

In the StarLink case the actual settlement percentage was $s^* = 0.22$. With low litigation costs of 5% for both parties, this settlement implies that $b \leq 0.27$, i.e., the plaintiff believed that that the probability of success at trial was no greater than 0.27. Given that Aventis accepted the settlement, we have $p \geq 0.17$. Similarly, if litigation costs were 20% for each party, then an accepted settlement implies $0.02 \leq p \leq 0.42$. The AI model implies that the defendant's litigation costs cannot be greater than 22%. While higher litigation costs make the defendant more likely to accept a settlement, the plaintiff knows this and will make a higher settlement offer. It is unlikely that the litigation costs for the two parties would be substantially different from each other. Thus, even if we allow litigation costs of about 22% of the damages, the implied probability of success at trial is low.

It is possible to extend the AI model to the case where the size of the judgment is uncertain as well as the defendant's liability. If the plaintiffs perceived the probability of success at trial to be high but the potential judgment to be low, then they would make a low settlement offer that would be accepted by the defendant.

The AI model implies that the StarLink case was unlikely to succeed at trial. This is consistent with Clermont and Eisenberg (2002), who state "cases that clearly favor the plaintiff or the defendant tend to settle readily." The low probability of success at trial could be because, although the damages were high, there is considerable doubt as to whether Aventis was at fault. The U.S. grain handling system was not equipped to keep StarLink and non-StarLink corn separate (Uchtmann, 2002), so at least some of the damages could be attributed to flawed regulation. As a result of the StarLink incident, the U.S. Environmental Protection Agency no longer issues split licenses for any bioengineered crops.

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Table 1: Monitoring for the Presence of StarLink in Japan's Feed Corn Imports

Time Period	Positive Ratio	Commingling Concentration
April to September 2000	20/30 (66.7 %)	0.51 %
October 2000 to March 2001	34/72 (47.2 %)	0.17 %
April to September 2001	8/53 (15.0 %)	0.05 %
October 2001 to March 2002	5/45 (11.1 %)	0.09 %
April to September 2002	4/42 (9.5 %)	0.10 %

Source: U.S. Embassy, Japan "Update on Japan's Biotechnology Safety Approval and Labeling Policies" GAIN Report #JA3002, February 28, 2003.

Table 2: Cointegration Tests

	Test Statistic	5 % Critical Value	Conclusion
Augmented Dickey-Fuller Tests			
Corn	–1.72	–2.86	Unit Root
Sorghum	–1.93	–2.86	Unit Root
Log Difference	–4.33	–2.86	Cointegration
OLS Residual	–5.13	–4.71	Cointegration
Johansen Tests			
Trace: $r = 0$	51.58	19.96	Cointegration
Trace: $r = 1$	5.36	9.24	
Max-Eig: $r = 0$	46.22	15.67	Cointegration
Max-Eig: $r = 1$	5.36	9.24	

ADF: Intercept, no trend, lags = 2 (conclusions robust), log difference is log(*C/S*), OLS residual is $c_t - \hat{\mu} - \hat{\beta} s_t$

Johansen: *r* is cointegrating rank

Table 3: Error Correction Mechanism Estimates

	$\beta = 1$		β unconstrained	
	Corn	**Sorghum**	**Corn**	**Sorghum**
α	–0.024 (0.005)	–0.005 (0.005)	–0.026 (0.005)	0.002 (0.006)
γ_1	0.040 (0.024)	0.294 (0.027)	0.039 (0.024)	0.291 (0.027)
γ_2	–0.002 (0.025)	0.096 (0.027)	–0.005 (0.025)	0.094 (0.027)
δ_1	–0.003 (0.022)	–0.298 (0.025)	–0.006 (0.023)	–0.292 (0.025)
δ_2	0.001 (0.022)	–0.102 (0.024)	0.001 (0.022)	–0.098 (0.022)
μ	3.93 (0.01)		3.62 (0.07)	
β	1.00		1.20 (0.04)	

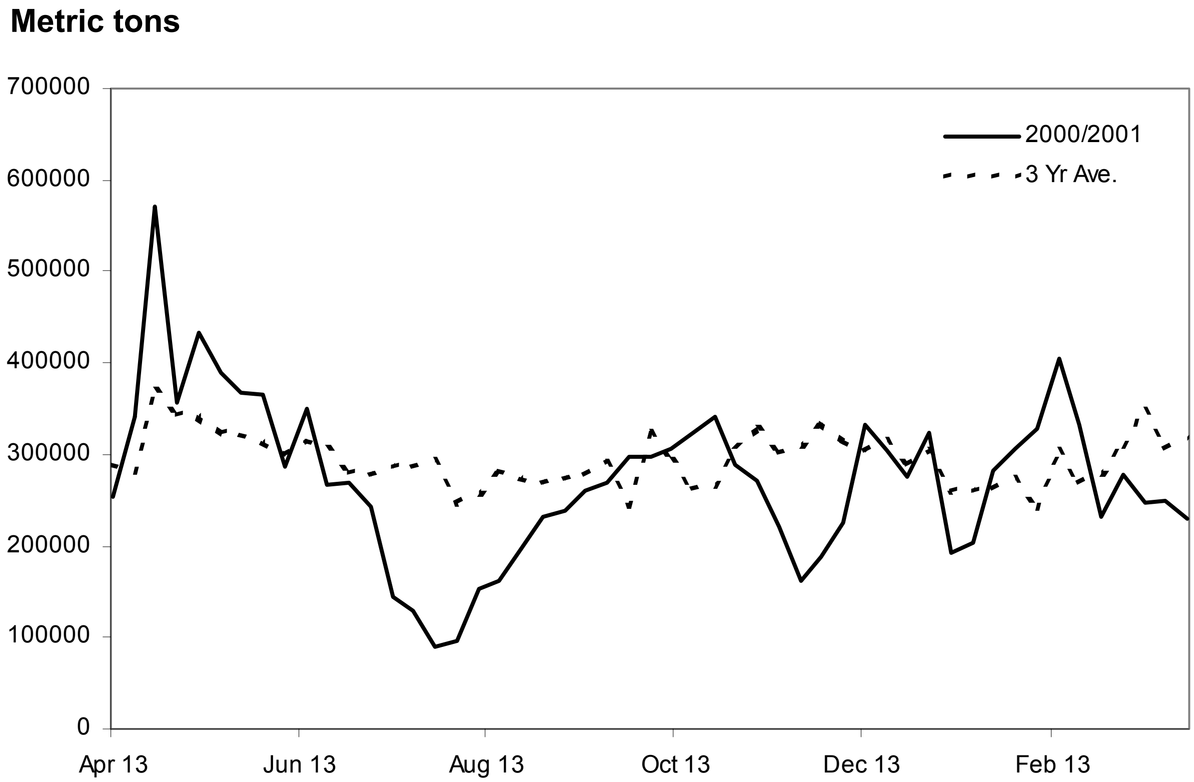
To add: LR test for beta=1, LL value, tests for serial correlation

Table 4: sup-*F* Tests for Breaks in the Cointegrating Relationship

	Statistic	5% Critical Value	Date of maximal *F*-statistic	Conclusion
Hansen (1991) Test				
sup-*F*	823.88	15.2	07/18/00	Break exists
Bai-Perron (1998) Tests				
UDmax	148.65	10.17	-	# breaks $\in$ {1,2,3,4,5}
WDmax	162.12	10.91	-	# breaks $\in$ {1,2,3,4,5}
sup-*F*(1|0)	148.65	9.63	7/17/00	At least 1 break
sup-*F*(2|1)	28.57	11.14	12/14/01	At least 2 breaks
sup-*F*(3|2)	3.49	12.16	2/16/96	2 breaks

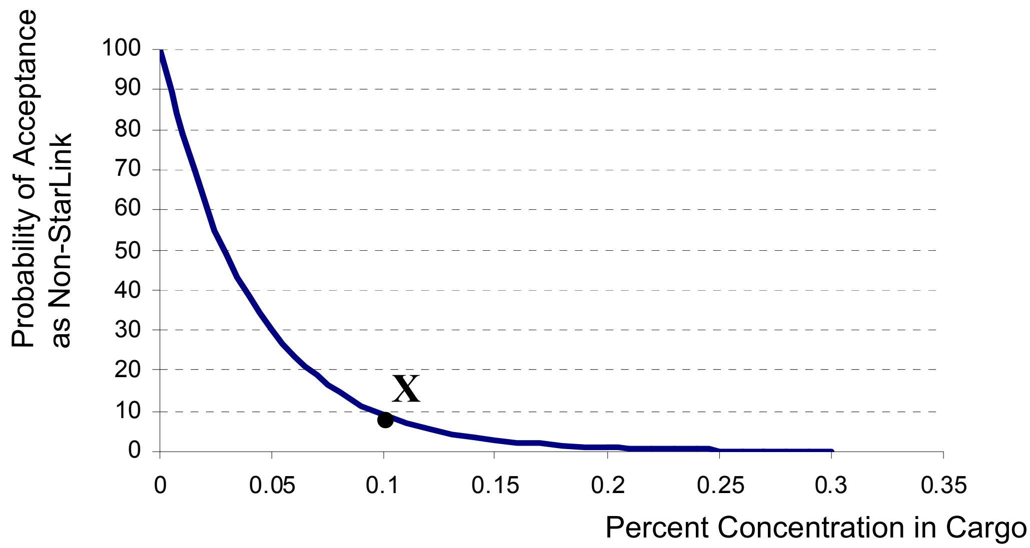
Robust standard errors used for all tests. Hansen test is based on free β and tests against alternative of one break. Bai-Perron tests apply for β=1 case and estimate number of breaks.

Figure 1: Weekly U.S. Corn Export Sales to Japan



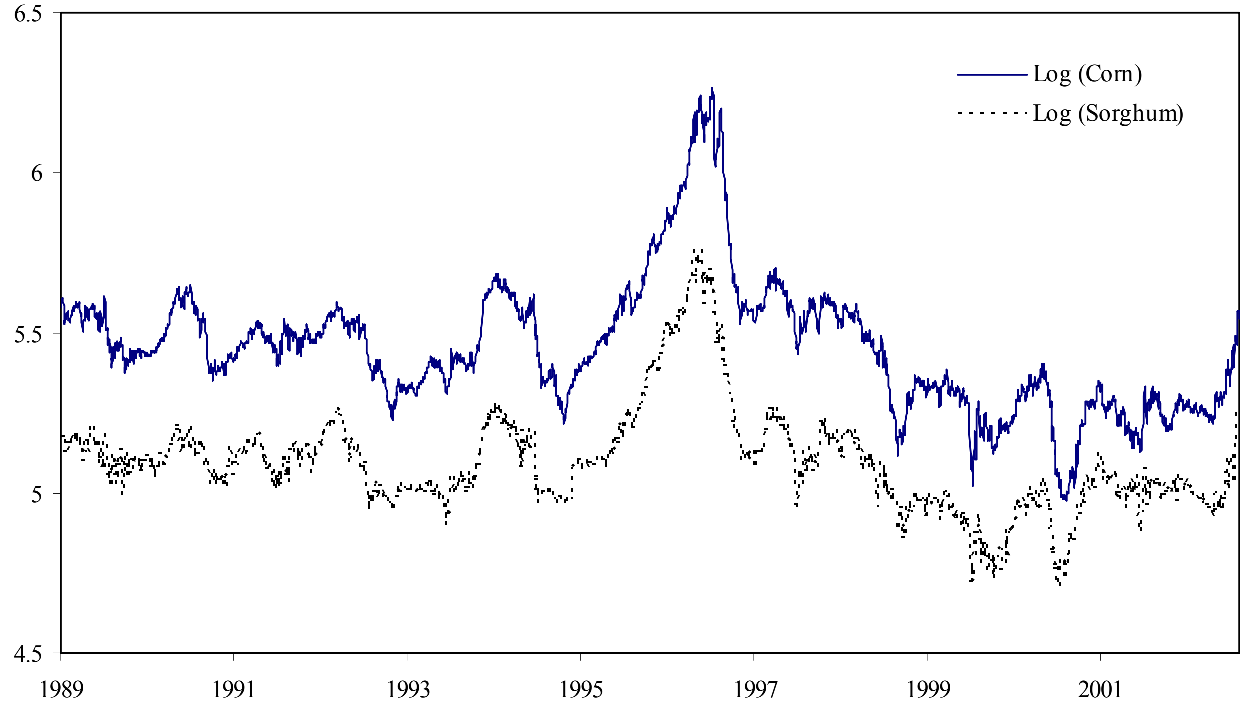
Note: The three-year average is for the three years prior to 2000/01. The data source is the USDA, FAS.

Figure 2. Probability (%) of accepting a cargo of corn as Non StarLink, at various levels of concentration (% of corn kernels containing Cry9C protein) based on a 2400 kernel sample size



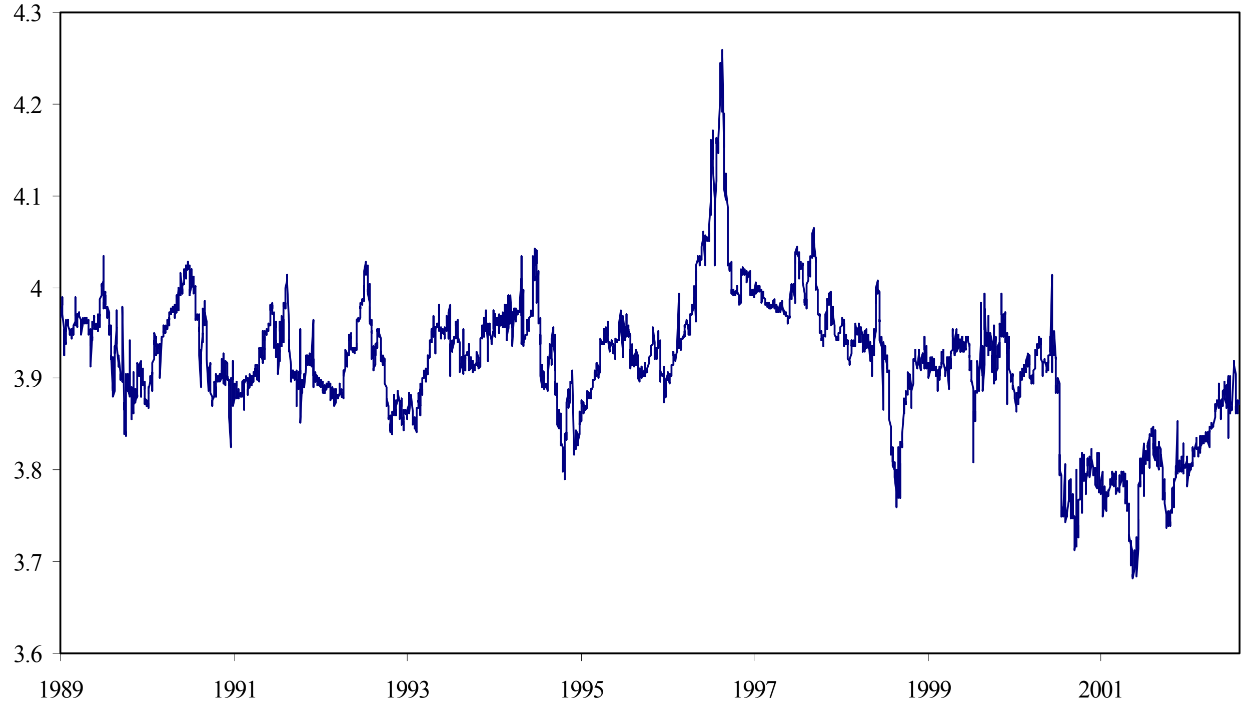
Source: Grain Inspection, Packers, and Stockyards Administration (GIPSA) of USDA, http://www.usda.gov/gipsa/biotech/starlink/cry9cdetection.htm.

Figure 3: Log Prices of Corn and Sorghum



The corn series measures mean daily bids in the central Illinois market. The sorghum series measures mean daily bids in the Louisiana Gulf. Corn is measured in cents per bushel and sorghum is measure as cents per cwt. The raw sorghum price was multiplied by 35 for this figure to put it on a similar scale to corn.
Source: Commodity Research Bureau.

Figure 4: Log Relative Price of Corn and Sorghum



The corn series measures mean daily bids in the central Illinois market. The sorghum series measures mean daily bids in the Louisiana Gulf. Corn is measured in cents per bushel and sorghum is measure as cents per cwt.
Source: Commodity Research Bureau.

Figure 5: Cumulative Abnormal Returns