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LL601 Contamination and Its Impact on U.S. Rice Prices

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LL601 is a genetically modified rice variety and unapproved for commercial use. Its presence was found in commercial shipments of U.S. rice in 2006. This article explores its impact on prices and volume marketed for both the United States and Thailand, the major export competitor. The results show a significantly adverse but short duration effect on the U.S. rice market and little to no effect on the Thai rice market.

Key Words: cointegration, error correction model, event study analysis, GM contamination, LibertyLink Rice 601, U.S. rice exports

JEL Classifications: C10, C32, Q11, A52

The United States is one of the primary rice exporters in the global market, accounting for 10–12% of the annual volume of international rice exports, and currently ranks fourth among major exporters, after Thailand, Vietnam, and Pakistan (Childs, 2009). Despite the steady expansion of U.S. domestic rice consumption over the past 25 years, almost half of U.S. rice is exported annually, making exports crucial to the well-being of the U.S. rice industry (Wailes, 2005).

Globally, the United States is reputed for its rough rice and high-quality milled rice. In addition, the United States is well known as one of the vanguards in the research and production of genetically modified (GM) crops and is home to some of the world's largest bio-technology companies. Because GM crops have advanced traits such as herbicide tolerance and insect resistance, the adoption of GM seeds has dramatically expanded in the United States According to estimates by the U.S. Department of Agriculture, in 2008, 80% of all corn and 92% of all soybeans planted in the U.S. were GM varieties, and more than 86% of U.S. cotton acreage was genetically modified (USDA, National Agricultural Statistics Service, 2008).

Import bans or restrictions of GM agricultural commodities have occurred in both Europe and some Asian countries, such as Japan and South Korea. Hoban (1998) reported that European consumers are seriously concerned about the potentially negative effect of GM foods on the environment and human health. In the past few years, intrusions of unauthorized GM products into commercial markets have led to a further decline in public support for GM foods.[1]

These unexpected GM contaminations have caused significant financial losses to the U.S. agricultural sector, and have negatively affected

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[1] By 2005, GeneWatch UK (2007) reported, on a global basis, 113 GM commercial contamination incidents and in their *GM Contamination Register Report 2007* an additional 28 incidents were reported. A total of 24 U.S. contamination incidents were recorded between 1996 and 2007.

the incomes of U.S. farmers, traders, and retailers. The most influential event of GM crops was the StarLink corn contamination event in 2000 (Carter and Smith, 2003).

The objective of this paper is to assess the impact of a similar contamination event involving an unapproved GM variety that was found in U.S. rice supplies. In 2006 LibertyLink Rice 601 (LL601) was found in commercial supplies. LibertyLink lines of rice (LLRice) were designed to be resistant to the Liberty herbicide sold by Aventis CropScience, which was later bought by the German company Bayer CropScience. Field research of LLRice was conducted in several states such as Louisiana and Arkansas between 1998 and 2001. Bayer did not petition for deregulation for LLRice 601. So it was significant that on July 31, 2006, Bayer reported to the USDA that traces of the unapproved LL601 were detected in commercial samples of long-grain rice in Arkansas and Missouri. Two and a half weeks later, on August 18, the USDA officially announced that unapproved GM rice had been found in supplies destined for human consumption and export.

Following that announcement, the U.S. rice industry experienced a loss of foreign markets. On August 20, 2006, Japan banned all U.S. long-grain rice imports. Three days later, the European Union (EU) announced it would not accept further shipments of long-grain rice from the United States unless the rice was tested and certified to be free of GM grains. This resulted in cancellations of some previous EU purchases and actually ended any further EU purchases of U.S. long-grain exports until 2008. In addition, South Korea and Russia also placed restrictions on U.S. rice imports.

On the day of the announcement, prices of long-grain rice futures contracts traded on the Chicago Board of Trade began to decline, and fell by nearly 10% in the following two days. U.S. rice trade was stopped or disrupted to the EU, Mexico, Japan, Taiwan and other markets; and an estimated 63% of rice exports were affected by certification, testing, labeling or outright bans (Blue, 2008). Consequently, rice growers, harvesters, processors, millers, and retailers all have claimed that they all have suffered serious losses. Many farmers have filed lawsuits against Bayer to recoup their losses.

A common approach to assessing the impact of events involving contamination has been to apply traditional event study methods, such as those outlined in MacKinlay (1997), using commodity or security price data. For example, Golub, Wilson and Featherstone (2005) examined stock price reactions to contamination of the corn supply with a genetically modified variety, StarLink, that had not been approved for human food use. Others have investigated events involving microbial or other contaminants that have resulted in food recalls on commodity prices or stock prices (Lusk and Schroeder, 2002; McKenzie and Thomsen, 2001; Thomsen and McKenzie, 2001).

More recently, time series techniques have been used to examine contamination events. For example Carter and Smith (2003) propose a forecasting model based on cointegration between two substitute commodity prices, one of which was impacted by an event. In their approach they look for event-induced departure from a stable underlying equilibrium relationship (assessed through structural break testing) to identify event dates and then base the magnitude of an event's impact using forecasts from an error correction model (ECM). Carter and Smith (2003) applied their approach to the Starlink contamination of the U.S. corn supply. Jin, Power, and Elbakidze (2008) also use cointegration techniques and structural break testing to assess the impact of Bovine Spongiform Encephalopathy (BSE) related events on cattle future prices. Again, they assess the impact of events on a vector error correction model to gauge the perturbation in long run price relationships.

Data and Methods

Our analysis uses weekly closing futures prices, observed each Monday, from the nearby[2] long-grain rough rice futures contract on the

[2] The term "nearby" refers to the futures contract closest to maturity. Contracts were rolled on the first trading day of the maturing contract month.

Chicago Board of Trade over the August 16, 2004 to October 2, 2006 time period.[3] Unlike Jin, Power, and Elbakidze (2008) or Carter and Smith (2003), we do not conduct formal tests for structural breaks because there is little evidence that news of the contamination leaked prior to the information becoming public in August of 2006. Instead, we specify the beginning of the postevent interval as July 17, 2006, two weeks prior to Bayer's disclosure to authorities that LL601 had been identified in commercial rice supplies in order to account for any preannouncement leakage. The pre-event interval contains 99 weekly observations from August 16, 2004 through July 10, 2006. We examine a postevent interval of 12 weeks from July 17, 2006 through October 2, 2006.

The approach used by Carter and Smith (2003) involves estimating a stable long-run relationship between the price of two commodities that are either substitutes in consumption or substitutes in production. In their application to the StarLink contamination event involving corn supplies, they identified sorghum as a close substitute for corn and found that logged prices of the two commodities were cointegrated with a (1, −1) cointegrating vector, implying that a stable long-run relationship exists. There is not a readily identifiable substitute commodity for rice. However, U.S. and Thai rice prices would likely exhibit a long-run relationship due to the fact that Thailand is the world's largest rice exporter and the main competitor of the United States on the global market for high quality long-grain rice. Consequently we estimated a long run equilibrium relationship between U.S. and Thai prices using the Engle-Granger cointegration approach. Thai prices are weekly average free on board (FOB) export prices of Thailand 100B rice collected from the *Thailand Grain and Feed Weekly Rice Price Update* published by the USDA, Foreign Agricultural Service.[4]

[3] Weekly prices were used because daily cash Thai prices are not published.

[4] Two Thai price observations were missing. These were for 10 July 2006 and 28 August 2006. SAS's EXPAND procedure was used to interpolate values for these missing prices based on a cubic spline.

Augmented Dickey-Fuller (ADF) tests were used to determine whether the data series contained unit roots over the pre-event interval. Logarithms of both U.S. and Thai prices were found to have a unit root. We proceeded to explore whether a stable long run relationship existed between the two series. The estimated cointegrating vector between Thai and U.S. prices was (1, −0.36) with an ADF test statistic of −3.11, which shows significance at the 10% level based on an Engle-Yoo critical value of −3.03 (Engle and Yoo, 1987).

According to Engle and Granger (1987), if variables are cointegrated, the residuals from the equilibrium regression can be used to estimate the error correction model (ECM). Following Granger (1986) a time series model of a cointegrating relationship may be rewritten in error correction form. Such a transformation renders the series stationary. The ECM useful for forecasting purposes may be specified as:

$$\text{(1a)} \quad \Delta P_t^{US} = \lambda + \rho u_{t-1} + \sum_{s=1}^{k} \beta_s \Delta P_{t-s}^{US} + \sum_{s=1}^{l} \gamma_s \Delta P_{t-s}^{Thai} + v_t,$$

$$\text{(1b)} \quad \Delta P_t^{Thai} = \lambda + \rho u_{t-1} + \sum_{s=1}^{k} \beta_s \Delta P_{t-s}^{Thai} + \sum_{s=1}^{l} \gamma_s \Delta P_{t-s}^{US} + v_t,$$

where P refers to logged prices; Δ is the difference operator; $u_{t\text{-}1}$ is the error correction term; k and l are numbers of lags; and v_t is a stationary, white noise, residual term. The number of lags was based on Akaike's information criteria. In the model for U.S. prices (equation 1a), the optimal number of lags was $k = l = 1$ for both price series. In the model for Thai prices, the optimal number of lags was $l = 0$ for U.S. prices and $k = 1$ for Thai prices. Results from the ECMs are shown in Table 1.

Results presented in Table 1 were used to forecast prices in the postevent window defined as July 17, 2006 through October 2, 2006. These price forecasts are used to conduct an event study using methods analogous to those outlined by MacKinlay (1997). The main difference is that instead of using the traditional

Table 1. Error Correction Model Estimates[a]

	Model	
	U.S. Price	Thai Price
Intercept	0.000	0.002
	(0.988)	(0.040)
Error Correction Term	0.104	−0.032
	(0.031)	(0.032)
Lagged U.S. price	−0.224	NA
	(0.020)	
Lagged Thai price	0.552	0.358
	(0.065)	(0.000)
R^2	0.125	0.177

[a] *p*-values are in parenthesis. Estimates are based upon weekly price data from August 16, 2004 through July 10, 2006, yielding 99 observations.

market model or mean-return model to establish normal price behavior–that which would have been expected in the absence of an event–we use the estimated ECMs to establish these benchmarks. Specifically abnormal price changes on any given day in the event window are measured as

$$AR_t^i = \Delta P_t^i - \Delta \hat{P}_t^i, \tag{2}$$

where $i \in$ (U.S., Thai) and $\Delta \hat{P}_t^i$ is the forecasted price change from the ECM. Abnormal price changes are cumulated over all potential intervals $\tau_1 \leq t \leq \tau_2$ of the postevent window where (October 2, 2006 $\geq \tau_2 \geq \tau_1 \geq$ July 17, 2006).

$$CAR(\tau_1,\tau_2) = \boldsymbol{\gamma}'\,\mathbf{AR}, \tag{3}$$

where $\mathbf{AR}$ is a 12×1 vector of abnormal price changes with rows corresponding to the 12 periods in the postevent interval and $\boldsymbol{\gamma}$ is a 1×12 vector with elements taking the value of one if $\tau_1 \leq t \leq \tau_2$ and taking the value of zero otherwise. According to Campbell, Lo, and MacKinlay (1997), the variance-covariance matrix of the forecasted $\mathbf{AR}$ is measured as

$$\mathbf{V} = \mathbf{I}s^2 + \tilde{\mathbf{X}}(\mathbf{X}'\mathbf{X})^{-1}\tilde{\mathbf{X}}'s^2, \tag{4}$$

where $\mathbf{X}$ is a $99\times$K matrix of regressors from the pre-event interval (99 pre-event observations) with K equal to the number of regressors in the ECM in question. $\tilde{\mathbf{X}}$ is a $12\times$K matrix of regressors used to compute forecasts and corresponding to the postevent interval. $\mathbf{I}$ is a 12×12 identity matrix and s^2 is the mean square error of the ECM. The variance of a cumulative abnormal price change is calculated as

$$\hat{\sigma}^2(\tau_1,\tau_2) = \boldsymbol{\gamma}'\mathbf{V}\boldsymbol{\gamma}. \tag{5}$$

To determine the potential extent of harm inflicted on producers, we examine the question of whether the marketings of rice were impacted by the event. We use a harmonic model (Hannan, 1963; Doran and Quilkey, 1972) applied to monthly rice marketing data to assess seasonal patterns in rice marketings. If U.S. rice producers increased marketings after the event, when prices were low, then there would be more evidence of economic loss. The seasonal model is specified as follows:

$$y_t = \alpha_0 + \alpha_1 t + \sum_{k=1}^{6} \beta_k \cos(\lambda_k t) + \sum_{k=1}^{5} \phi_k \sin(\lambda_k t) + \varepsilon_t \tag{6}$$

where t is a trend variable, $\lambda_k = 2\pi k/12$, and ε_t is an error term. Monthly marketings from January 1990 through July 2004 were used to estimate the model. Forecasted changes in marketings based on Equation (6) are compared with actual for several years surrounding the August 2006 event (September 2005 through July 2008) and are presented below.

Results

Cumulated abnormal price changes for the U.S. price are reported in Table 2. Note that the diagonal in Table 2 shows the abnormal price change for the week in question. If the date on column is greater than the date on the row, then the abnormal price changes are cumulated over the weeks in question. The results show that U.S. prices responded dramatically following the USDA announcement of GM contamination on Friday, August 18. However, the price response was short lived. As shown in Table 2, prices were down 7.36% from their forecasted level by Monday, August 21. Prices continued to decline and were 17.09% lower than forecast by Monday, August 28. These price declines are statistically significant but were relatively short lived. By September 4, the downward trend had

Table 2. Cumulative Abnormal Changes in U.S. Rice Prices Around the 2006 LL601 Event (% changes in price)[a]

Beginning Period (τ_1)	Ending Period (τ_2) 17-Jul	24-Jul	31-Jul	7-Aug	14-Aug	21-Aug	28-Aug	4-Sep	11-Sep	18-Sep	25-Sep	2-Oct
17-Jul	0.04	−3.42	−4.17	1.28	4.27	−3.09	−12.82	−9.16	−4.76	−1.63	3.45	3.74
	(0.013)	(−0.782)	(−0.772)	(0.203)	(0.604)	(−0.397)	(−1.518)	(−1.001)	(−0.492)	(−0.159)	(0.314)	(0.326)
24-Jul		−3.46	−4.20	1.24	4.24	−3.13	−12.85	−9.20	−4.80	−1.67	3.41	3.70
		(−1.125)	(−0.958)	(0.229)	(0.673)	(−0.443)	(−1.653)	(−1.079)	(−0.528)	(−0.173)	(0.327)	(0.339)
31-Jul			−0.74	4.70	7.69	0.33	−9.40	−5.74	−1.34	1.79	6.87	7.16
			(−0.241)	(1.069)	(1.422)	(0.053)	(−1.332)	(−0.731)	(−0.158)	(0.197)	(0.699)	(0.691)
7-Aug				5.44	8.44	1.08	−8.65	−5.00	−0.59	2.53	7.62	7.90
				(1.765)	(1.907)	(0.199)	(−1.381)	(−0.703)	(−0.077)	(0.3)	(0.825)	(0.808)
14-Aug[b]					3.00	−4.36	**−14.09**	−10.44	−6.04	−2.91	2.17	2.46
					(0.961)	(−0.989)	(−2.618)	(−1.652)	(−0.858)	(−0.375)	(0.254)	(0.269)
21-Aug						**−7.36**	**−17.09**	**−13.44**	−9.03	−5.91	−0.82	−0.54
						(−2.396)	(−3.879)	(−2.421)	(−1.433)	(−0.838)	(−0.105)	(−0.063)
28-Aug							**−9.73**	−6.08	−1.67	1.45	6.54	6.82
							(−3.082)	(−1.315)	(−0.305)	(0.231)	(0.909)	(0.87)
4-Sep								3.65	8.06	11.18	16.27	16.55
								(1.152)	(1.837)	(2.071)	(2.536)	(2.315)
11-Sep									4.40	7.53	12.61	12.90
									(1.409)	(1.688)	(2.243)	(1.994)
18-Sep										3.13	8.21	8.49
										(1.004)	(1.768)	(1.516)
25-Sep											5.08	5.37
											(1.549)	(1.191)
2-Oct												0.29
												(0.093)

[a] t-ratios are in parenthesis. Numbers in bold are statistically significant at the 5% level for a one-tailed test of the null hypothesis that $CAR(\tau_1,\tau_2) \geq 0$.

[b] USDA made its announcement of the GM contamination event at the end of the August 14 week, Friday August 18.

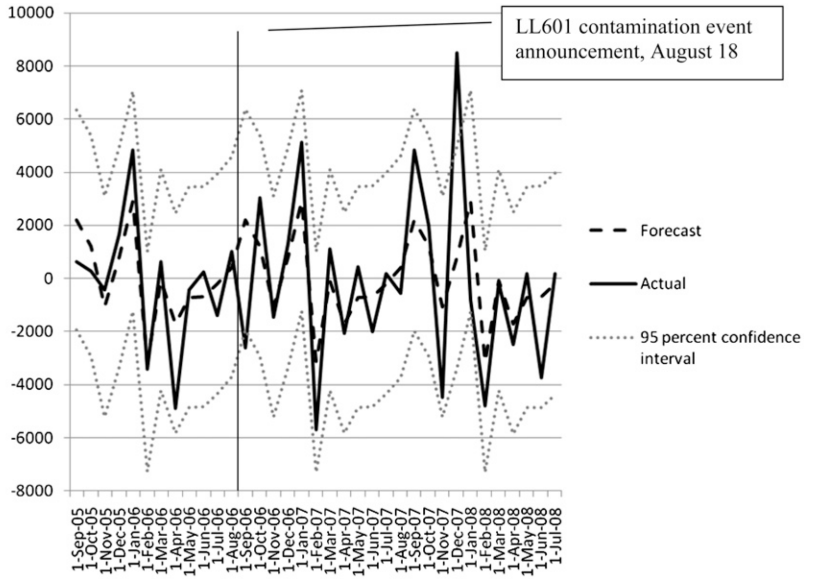

Figure 1. Month to Month Changes in U.S. Rice Marketings (thousands of hundredweights)

reversed, and prices had nearly recovered by the end of September. The cumulative abnormal price change from August 21 through October 2 was only 0.54% below forecast. Another interesting feature of the results in Table 2 is that there is no evidence of price reactions before the USDA announcement. Recall from above that Bayer disclosed the contamination to USDA on July 31, 2006, but the first significant price declines are seen only after the formal announcement by USDA.

The results suggest that price declines were transitory. Ultimately, producers that sold during these weeks when prices were abnormally low would have suffered economic harm attributable to the event. The magnitude of this harm, however, depends, to some extent, on whether rice marketings were above or below normal levels during the period of low prices. To explore this, month-to-month changes in forecasted marketings based on the harmonic model (Equation 6) and actual marketings are presented in Figure 1.[5] Based on Figure 1 there is evidence that producers reduced marketings after the event. In fact, actual changes in marketings fall just below a 95 confidence interval for the forecasts during the time when prices were abnormally low. So, if anything, producers delayed their sales in expectation of price recovery later in the season.

Table 3 reports cumulative abnormal changes in Thai prices. *A priori*, one would expect that Thai prices would benefit from the import bans placed on U.S. rice following the disclosure of GM contamination. However, there is no evidence of this based on the one-tail tests of cumulative abnormal price changes reported in Table 3. In fact, most of the abnormal price changes are negative over the post-event window. These negative values may be reflecting slightly lower Thai export prices, which followed domestic price decreases, based on relatively larger than normal season ending stocks as the Thai rice sector was moving into the main harvest season.

Summary and Conclusion

This article investigated the impact of LL601 event on the U.S. and Thai rice market.

Results indicate a large and adverse U.S. price reaction that was very short lived. There

[5] Coefficient estimates of the harmonic model are not reported but are available upon request. Many of the sine and cosine coefficients were statistically significant, the trend coefficient was insignificant, and the overall R^2 was 0.485.

Table 3. Cumulative Abnormal Changes in Thai Rice Prices Around the 2006 LL601 Event (% changes in price)[a]

Beginning	Ending Period (τ_2)											
Period (τ_1)	17-Jul	24-Jul	31-Jul	7-Aug	14-Aug	21-Aug	28-Aug	4-Sep	11-Sep	18-Sep	25-Sep	2-Oct
17-Jul	−0.42	−0.42	−1.13	−1.63	−1.28	−1.59	−2.01	−0.98	−2.33	−5.66	−4.03	−4.22
	(−0.432)	(−0.308)	(−0.667)	(−0.832)	(−0.579)	(−0.652)	(−0.761)	(−0.346)	(−0.77)	(−1.763)	(−1.172)	(−1.177)
24-Jul		−0.01	−0.71	−1.22	−0.86	−1.17	−1.59	−0.57	−1.91	−5.25	−3.61	−3.80
		(−0.006)	(−0.518)	(−0.72)	(−0.439)	(−0.53)	(−0.655)	(−0.214)	(−0.674)	(−1.731)	(−1.106)	(−1.113)
31-Jul			−0.70	−1.21	−0.86	−1.16	−1.59	−0.56	−1.91	−5.24	−3.60	−3.80
			(−0.731)	(−0.884)	(−0.507)	(−0.593)	(−0.72)	(−0.23)	(−0.723)	(−1.845)	(−1.171)	(−1.172)
7-Aug				−0.51	−0.15	−0.46	−0.88	0.14	−1.20	−4.54	−2.90	−3.10
				(−0.527)	(−0.112)	(−0.272)	(−0.45)	(0.065)	(−0.495)	(−1.718)	(−1.004)	(−1.011)
14-Aug[b]					0.35	0.05	−0.37	0.65	−0.69	−4.03	−2.39	−2.59
					(0.368)	(0.036)	(−0.222)	(0.333)	(−0.315)	(−1.66)	(−0.892)	(−0.903)
21-Aug						−0.31	−0.73	0.30	−1.05	−4.38	−2.75	−2.94
						(−0.318)	(−0.533)	(0.176)	(−0.535)	(−1.991)	(−1.115)	(−1.107)
28-Aug							−0.42	0.60	−0.74	−4.08	−2.44	−2.64
							(−0.439)	(0.44)	(−0.439)	(−2.078)	(−1.086)	(−1.073)
4-Sep								1.03	−0.32	−3.66	−2.02	−2.21
								(1.063)	(−0.233)	(−2.163)	(−1.006)	(−0.991)
11-Sep									−1.34	−4.68	−3.04	−3.24
									(−1.394)	(−3.42)	(−1.76)	(−1.63)
18-Sep										−3.34	−1.70	−1.89
										(−3.448)	(−1.176)	(−1.089)
25-Sep											1.64	1.44
											(1.597)	(1.026)
2-Oct												−0.20
												(−0.203)

[a] t-ratios are in parenthesis. Numbers in bold are statistically significance at the 5% level for a one-tailed test of the null hypothesis that $CAR(\tau_1,\tau_2) \leq 0$.
[b] USDA made its announcement of the GM contamination event at the end of the August 14 week, Friday August 18.

was no evidence of an event induced impact on Thai rice prices. Considering that there are many other factors affecting the rice markets in both countries, such as the subsequent GM testing costs, we only computed the immediate effect of the GM event on both markets during a short period after the public disclosure of contamination. Thus, the actual losses accruing to the U.S. rice industry may be larger than our estimates would suggest due to the exclusion of various transactions costs associated with cleaning the U.S. rice supply chain, cost of testing for presence of GM contamination, and the restructuring of export shipments from countries who imposed bans to those that did not.

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