Journal of Agricultural and Applied Economics, 47, 2 ( 2015): 243–259
 doi:10.1017/aae.2015.7

# WELFARE EFFECTS OF U.S. LIBERTY LINK RICE CONTAMINATION

JADA THOMPSON*

*Graduate Student, Department of Agricultural and Resource Economics, Colorado State University*

ERIC WAILES

*Distinguished Professor, Department of Agricultural Economics and Agribusiness, University of Arkansas*

ALVARO DURAND-MORAT

*Research Scientist, Department of Agricultural Economics and Agribusiness, University of Arkansas*

AMANDA LEISTER

*Assistant Professor, Department of Agricultural and Resource Economics, Colorado State University*

**Abstract.** United States consumer confidence in food safety is an increasingly more prominent issue in food production and marketing. Estimating the welfare effects of a breakdown in the supply chain can provide a benchmark for the cost of potential future events. In 2006, United States long grain rice stocks were contaminated with an unapproved genetically modified rice variety causing trade disruptions predominantly between the United States and the European Union. Using a spatial partial equilibrium model the economic effects of European policy on bilateral trade flows and prices during this event was an estimated loss of $421.3 million US dollars.

**Keywords.** EU, genetic modification (GM), rice, spatial equilibrium model, trade, U.S

**JEL Classifications.** F11, F13, Q17, Q18

## 1. Introduction

Rice is a staple food for a majority of the world's population and is arguably the most important food crop in many regions. More than one billion people live in extreme poverty, and rice is a staple food item and a source of livelihood for many. Only 7% of global rice production, including every stage of processing—paddy, brown (husked), and white (milled)—is traded on the world market (Childs and Livezey, 2006), which creates a competitive environment for exporting countries. Although the United States is not the world's largest rice producer and only accounts for 2% of world production, it is a significant player in the world rice market. U.S. exports account for approximately 12% to 14%

*Email: Thompson.JadaM@gmail.com

of the annual volume of global rice trade (Childs and Livezey, 2006). Events that significantly affect rice production or trade flows in the United States have the potential to affect world markets and bilateral trade flows. Similarly, changes in the world market for rice affect U.S. rice prices, production, and trade.

The European Union (EU) is a major importer of U.S. long-grain[1] rice. The EU supplements internal production, which is centralized predominantly in Italy, Spain, and Portugal, with imports from world markets. Due to trade restrictions and import polices, the EU imports predominantly husked (brown) rice from the United States and then further processes rice imports within the EU. The trade relationship between the two states is of particular interest because of the relatively high value of rice trade between the EU and United States (US$101.5 million).

There was a genetically modified (GM) rice contamination event in the U.S. rice supply in 2006 that resulted in an import ban on U.S. rice into the EU (USDA/APHIS, 2007). Differing views on GM rice and differences between approval processes of GM food have led to a serious and sustained trade disruption between both regions. The differing policies regarding GM testing caused rice to be approved for export in the United States but denied at EU borders. This contamination event caused a backlash regarding differing GM policies between the two trading partners and resulted in substantial monetary losses for both U.S. rice producers and EU millers. This research employs a spatial partial equilibrium analysis to quantify the effects of the GM rice contamination event on the U.S., EU, and global rice markets that can be used as a case study for food contamination events on U.S. food supply.

## 2. Background

Rice demand in the EU is typically first satisfied by intra-European production and then supplemented by world markets. The United States comprised 28%[2] of the brown rice import market in Europe, until the EU shifted its trade to other countries after the 2006 contamination of the U.S. rice supply by a GM rice variety (Liberty Link).

To safeguard European markets, world rice imports are met with trade barriers and a tariff rate quota system that was first extended to the United States in 2005 as a most favored nation, and later in 2008, the Common Agricultural Policy

1 There are three broad categories of rice: long, medium, and short grain. Long-grain rice is longer in length, and cooked grains are separate and firm. Medium-grain rice includes shorter, wider varieties such as Arborio. Short-grain rice is short and almost round in appearance. Short-grain rice is often associated with sticky rice used in sushi. Fragrant rice is a distinct type of long-grain rice that is typically grown in India and Thailand.

2 Based on the 2005 marketing year for HS code 100620 from the UN Comtrade Database (United Nations, 2010).

https://doi.org/10.1017/aae.2015.7 Published online by Cambridge University Press

was amended. All imports are bound by an import duty for husked[3] or brown rice, which is set at €30, €45, and €65 per metric ton (t) (US$40, US$59, and US$86[4]), respectively, for each level of the tariff rate quota given ±15% of the reference quantity in the preceding 6-month period (437,678 t for the 2005/2006 season for the United States). If husked rice imports are 15% below the reference level in a given marketing year, the European Commission will apply a tariff of €30/t (US$40/t) for the following 6-month period. For imports that are 15% above the reference level, a tariff of €65/t (US$86/t) is applied. For imports at levels between −15% and +15% of the reference level, a tariff of €45/t (US$59/t) is applied (Commission of European Communities, 2009). Tariffs for brown rice are relatively lower than for wholly milled or white rice. Tariffs on milled rice depend on whether the 182,239 t limit is exceeded in the previous marketing year. If white rice imports exceed the limit in the previous year, the tariff is €175/t (US$231/t); if imports are below the reference level, the tariff is €145/t (US$191/t) (Commission of the European Communities, 2009). This tariff escalation structure explains the high level of brown rice that is exported to the EU and milled internally.

The United States and the EU have differing views regarding acceptance of GM foods. The United States applies the policy of substantial equivalence; that is, if a product is similar in appearance, taste, nutrition, and safety to conventional products, it is treated as substantially equivalent to the non-GM products. On the other hand, the EU applies the precautionary principle as the basis for its policy on genetically modified organisms (GMOs). The EU considers GM foods as new or "novel" foods, without a means for redefining them as substantially equivalent foods, which is also a regulatory disparity between the United States and the EU. The differences between regulatory policies regarding GMOs have led to a longer and more difficult approval process in the EU than in the United States (Ahearn, 2009). The EU employs a near absolute zero limit (0.01%) in the case of GMO testing, whereas the United States imposes a testing limit of 0.1% for GM exports. The differences in regulations add to the cost of doing business on both sides of the Atlantic. Effectively, the costs of testing serve as nontariff barriers to trade with the EU (Ahearn, 2009). The differences in testing and approval have been a challenge between the EU and countries such as the United States and Argentina that have accepted production of certain GM crops. These policies limit bilateral trade and impose relatively high costs to exporters and importers.

Aventis, a bioscience company, initiated field trial testing of a variety of GM rice engineered to be tolerant to glufosinate-ammonium, the active principle of the Liberty herbicide. In 2002, Bayer CropScience bought Aventis and

3 There are two milling activities: dehusking and bran removal or full polishing. Dehusking takes paddy rice and converts it to husked rice, also called brown rice. Bran removal takes husked rice and converts it to white, fully polished rice.

4 All euro/U.S. dollar conversions are based on an exchange rate of US$1.32 per euro.

https://doi.org/10.1017/aae.2015.7 Published online by Cambridge University Press

subsequently abandoned field trials of Liberty Link 601, choosing not to pursue commercialization. LLRICE601, also known as Liberty Link rice, was never commissioned for commercialization for human or animal consumption, and Bayer never pursued deregulation for the rice variety. In August 2006, Bayer CropScience alerted the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) of contamination of nonapproved GM rice detected in long-grain samples. The United States deregulated Liberty Link 601 in November 2006 (USDA/APHIS, 2006). According to an APHIS report, LLRICE601 was only found to have contaminated the long-grain variety Cheniere; however, it was discovered that another regulated GM variety approved solely for animal consumption, LLRICE604, was found in March 2007 to have contaminated a different long-grain Clearfield variety, CL131 (USDA/APHIS, 2007). The CL131 rice variety is produced by BASF, a chemical company that sells its seeds and herbicides as a bundled Clearfield production package. Both of these rice varieties were contaminants that contributed to the total impact of the contamination event.

The immediate reaction from the U.S. rice industry was to notify importing countries of the possible contamination of U.S. rice exports. Many countries enacted reactionary policies as a result of this announcement including the EU, Russia, Japan, and South Korea. The EU initiated testing requirements effective October 23, 2006, for all imports originating from the United States, meaning that all rice had to be certified free from all GM products. During 2007, the higher risk of rejection due to the zero tolerance at European ports increased the cost burden on both the producers and importers causing trade disruptions (Office of the United States Trade Representative, 2008). Following the mandate, trade between the United States and the EU was disrupted. It was reported that as a result of Liberty Link testing there were blockages at the port of Rotterdam from the increase in shipments needed to be retested to ensure that no level of GMO would be entering the EU rice supply chain (Davidson, 2010).

Trade flow disruptions between the EU and the United States were further exacerbated by the disparity between testing levels. This discrepancy led to exports testing negative for contamination when being exported from the United States but testing positive upon arrival at ports in the EU, furthering the impact of this incident. With contaminated U.S. rice, European buyers were forced to look to other exporters to fill demand. India, Thailand, and Uruguay were the main suppliers that benefited from this shift in trade (United Nations, 2010). However, in 2010, the U.S. rice industry reported that the 2009 rice crop was free of the nonapproved genetic strain and petitioned for a reduction in the testing requirements for U.S. exporters to resume precontamination trade flows between the U.S. and European importers. The EU affirmed this finding, testing requirements were lowered, and rice trade flows subsequently resumed, but well below precontamination levels.

There have been few published impact studies of the Liberty Link rice contamination. The USA Rice Federation (2008) reported a 35% reduction in the value of exports from the United States to the EU from 2006 to 2007. Considering that U.S. rice trade to the EU was disrupted in the latter half of 2006, the actual decrease in trade resulting from the contamination is higher than the reductions included in the report. In 2008, an independent study performed by Brookes (2008) for GBC Ltd. on behalf of a coalition of European trade and industry organizations estimated the economic impacts of low levels of unapproved GMO contamination on the EU food sector. As part of this study, a case study was devoted to the Liberty Link contamination. The main focus of this research was on the effects of the Liberty Link contamination on European millers, estimating the cost to millers and purchasers. Brookes (2008) estimated the cost of market disruption to the rice industry from 2006 to early 2008 at €111 million (US$146.5 million). A study by Li et al. (2010) stated that the Liberty Link contamination had significant trade results including abnormal price changes for U.S. rice that were drastic but short lived (cumulative reduction of 0.54%) and no real change to the world market. This study did not look at the composition of bilateral trade and focused on the immediate price effects on futures markets. Li et al. concluded that due to the nature and size of the industry, other studies should be performed to fully encompass the total effect of this market disruption, and this study aims to fill this void.

## 3. Method

This research employs a multimarket, multiregion partial equilibrium framework to model bilateral trade relationships to analyze the effects of the Liberty Link 601 contamination of U.S. long-grain rice. The modified RICEFLOW model, created by Durand-Morat and Wailes (2010), was developed to improve upon the original RICEFLOW model specified by Takayama and Judge (1964). RICEFLOW was updated to specify the relevant behavioral equations to solve a system of first-order conditions derived from neoclassical economic theory with regard to maximization of utility from consumption and profits from production activities. The most important changes are nonlinearity of demand and supply functions and heterogeneous products differentiated by country of origin, given the Armington (1969) specification.

The nonlinear partial equilibrium model is written in a linearized form. Therefore, all variables are represented as percentage changes rather than nominal values to facilitate the calibration procedure, while still yielding the same results as "levels" models (Hertel, Horridge, and Pearson, 1991). Relevant sets, parameters (coefficients), variables, and linearized behavioral equations are included in Appendix 2 (online).

Production is specified as a two-stage budgeting process. The first production stage determines the conditional demand functions for the intermediates

https://doi.org/10.1017/aae.2015.7 Published online by Cambridge University Press

composite and the value-added composite. The derived demands for the value-added and intermediates composites are a function of the activity level, the technological characteristics of production, the producer price by activity,[5] and the composite price of value added and intermediates, respectively. The substitution effect resulting from the relative change in producer and composite prices is dictated by the elasticity of substitution, which takes on positive values in this work, indicating a constant elasticity of substitution (CES) function.

The model includes a number of productivity and technology-related exogenous variables that can be shocked as part of an experiment to represent augmenting technical changes in the productivity of factors, as well as value-added and intermediates composites by activity and region, respectively. The model also accounts for the effect of five policy variables, namely taxes/subsidies on production, on factors of production by activity, on intermediate inputs by activity, on bilateral exports, and on bilateral imports. The five policy variables account for all the taxation/support granted to the rice sector.

Derived demands for factors of production and intermediate inputs are determined as part of the value-added nest and the intermediate nest of production. These derived demands are obtained from a cost-minimization problem subject to a CES production function, given the assumption of constant returns to scale. RICEFLOW treats total factor supply as exogenous and differentiates factors based on their mobility. Perfectly mobile factors of production can move freely among activities in the pursuit of higher returns; consequently, at equilibrium, the perfect mobility of factors determines a unique factor market price for the entire market. Sluggish factors have differing market prices and supplies across activities specified by a CES function. This stylized specification implies that without changes in relative factor prices across sectors, increases in the endowment of factors will be allocated uniformly across activities (expansionary effect). The substitution effect triggered by relative changes in the price of sluggish factors across sectors is dictated by the elasticity of transformation.

By virtue of the zero-profit condition on production, the producer price by activity and region (after taxes/subsidies on production are accounted for) equals the cost of production by activity, which is a function of the value-added and intermediates composite prices and the respective shares of value added and intermediates in the total cost of production

Bilateral imports of commodities imperfectly substitute among each other based on sources, which is specified as a CES function. The market price of imports by commodity and region is estimated as the trade-weighted average of region-specific import market prices. The volume of domestic output marketed domestically and the volume of imports are imperfectly substitutable, as dictated

5 By virtue of the zero-profit condition, the producer price by activity equals the unitary cost of production.

https://doi.org/10.1017/aae.2015.7 Published online by Cambridge University Press

by the Armington elasticity of substitution (Armington, 1969). This allows for a production process that includes two inputs, domestic and imported commodities, which generates a composite commodity that is later allocated into final and intermediate consumption.

The preferences of final consumers are represented by a nonhomothetic, constant difference elasticity (CDE) functional form. The uncompensated own- and cross-price elasticities and income elasticities enter the final consumption equation. The calibration of this CDE function requires benchmark data on two parameters, namely, the substitution parameter and the expansion or income parameter, which can be obtained as outputs of a cross-entropy procedure with desirable, exogenous income and uncompensated own-price demand elasticities as targets (for more on this procedure, see Yu et al., 2004). These CDE parameters are used to estimate the substitution and income elasticities. Finally, the demand for final consumption of composite commodities adopts a general form independent of the functional form chosen to represent the demand system at this level, which associates the changes in retail prices and total rice expenditures to the respective substitution and income elasticities.

Microeconomic closures include zero pure-profits conditions for activities and producers of composite commodities to ensure that markets clear, as well as market-clearing conditions for factors of production. Finally, the market-clearing equations for composite commodities subject to intermediate and final consumption ensure that total demand equals total supply at equilibrium.

## 4. Data

The baseline data for this research are for the 2005 calendar year, which are used to project values from 2006 to 2008 for both the updated baseline, which includes the policy effects of the Liberty Link contamination, and the scenario in which the policy effects of the contamination were ignored. The scenario allows for comparison of what prices and trade values would have been without the market disruption. The database and scenarios maintain production volumes, trade volumes and quantity, transportation, policy variables, as well as cost structures for 86 countries (Online Appendix 1). The countries chosen were based on a minimum trade volume of 50,000 t of rice for the 2005 calendar year. All values are reported in U.S. dollars, and volumes are reported in metric tons. The model was simulated to find market equilibrium prices and volumes for the 2006 marketing year, which became the base for the 2007 projection. The same iteration was performed for the 2008 marketing year. The marketing changes provided a basis for comparison when modeling the noncontamination scenario.

A set of exogenous variable shocks was applied to the baseline data for each region, including population changes for the years in question, expenditure changes, and actual changes in production as a proxy for changes in demand

https://doi.org/10.1017/aae.2015.7 Published online by Cambridge University Press

within each region. Gross domestic product (GDP) was used as a proxy for expenditure changes, assuming a high correlation between expenditure and GDP. Shocks to production include changes in land supply, yields, and stocks. The overall accuracy of model results was relatively low when all exogenous shocks were administered for each region. Therefore, shocks were administered for a subset of countries that represented the top 90% of global production[6] to increase the accuracy of results.

To model the trade policies employed by the EU with greater accuracy and without the need to calibrate for the equivalent ad valorem tariff, the tariff variable and the bilateral trade between the United States and the EU were swapped such that the bilateral trade was exogenous and the tariff variable was endogenized. This allowed for the observed change in trade flows to be imposed on the model so that the scenarios implemented more closely reflect reality. The increase in the transaction costs for U.S. exports accounting for the cost of testing was also included in the 2006 update. The cost of testing was estimated[7] at US$10/t, which equated to a 14% increase in the cost of exporting.

According to UN Comtrade data (United Nations, 2010), Uruguay was the largest benefactor of the Liberty Link contamination in terms of gaining trade shares in the EU. However, Uruguay has very small export values to the EU in the 2005 baseline. To better reflect what actually occurred, an augmentation of the baseline Uruguay-EU rice trade was imposed on the database, 25,948, 124,185, and 104,474 t for 2006, 2007, and 2008, respectively, as reported by UN Comtrade.

For the comparative analysis, the shocks to trade flows between the United States and the EU resulting from the contamination were excluded to model trade flows and price changes in the absence of the Liberty Link event. The same baseline shocks were employed including changes in population, factors of production, and expenditures. Results provide estimates of the level of trade, equilibrium prices, quantity of production, and level of input use that would have prevailed in the absence of contamination, and these estimates are compared with the baseline scenario for analysis and conclusions. The differences in output between the baseline that included the Liberty Link contamination and the scenario that removed the contamination effects, which is referred to as the "nonevent" scenario, were analyzed to estimate the effects of Liberty Link contamination on U.S. and EU rice markets.

6 Based on USDA PS&D data (2010). Countries include Bangladesh, Brazil, China, Egypt, EU25, India, Indonesia, Iran, Japan, Myanmar, Nigeria, Pakistan, Philippines, South Korea, Thailand, the United States, and Vietnam.

7 Based on internal cost estimates from industry experts.

**Table 1.** EU Impact Analysis

| | Differences[a] in Total EU Volume of Import (t) | | | |
|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2006–2008 |
| LGP[b] | 6,482 | − 910 | 20,238 | 25,810 |
| MGP | 0 | 0 | 0 | 0 |
| FRP | 0 | 0 | 0 | 0 |
| LGB | − 52,048 | − 358,868 | − 268,274 | − 679,190 |
| MGB | 2 | 13 | 4 | 18 |
| FRB | 0 | 0 | 0 | 0 |
| LGW | 8,436 | − 102,262 | 21,417 | − 72,409 |
| MGW | 29 | 117 | 0 | 147 |
| FRW | − 119 | − 1,896 | − 907 | − 2,922 |
| Total | − 37,218 | − 463,807 | − 227,522 | − 728,546 |
| | Differences[a] in Value of EU Imports from United States (thousand US$) | | | |
| | 2006 | 2007 | 2008 | 2006–2008 |
| LGP | 3,283 | − 133.8 | 11,885 | 15,034 |
| LGB | − 17,941 | − 80,854 | − 75,609 | − 174,404 |
| LGW | 11,882 | − 15,279 | 37,989 | 34,592 |
| Total | − 2,776 | − 96,267 | − 25,734 | − 124,777 |
| | Differences[a] in Total EU Value of Import (thousand US$) | | | |
| | 2006 | 2007 | 2008 | 2006–2008 |
| LGP | 3,287 | − 12 | 11,943 | 15,218 |
| MGP | 0 | 0 | 0 | 0 |
| FRP | 0 | 0 | 0 | 0 |
| LGB | − 17,239 | − 74,252 | − 71,182 | − 162,673 |
| MGB | 0 | − 1 | 0 | − 1 |
| FRB | 0 | 0 | 0 | 0 |
| LGW | 19,652 | − 8,973 | 44,461 | 55,141 |
| MGW | − 4 | − 90 | − 41 | − 135 |
| FRW | − 57 | − 1,532 | − 704 | − 2,294 |
| Total | 5,639 | − 84,859 | − 15,523 | − 94,744 |
| | Differences in Value of EU Imports for Selected Countries (US$) | | | |
| | 2006 | 2007 | 2008 | 2006–2008 |
| India | 342,600 | 2,650,100 | 1,963,400 | 4,956,100 |
| Thailand | 105,800 | 1,215,300 | 745,000 | 2,066,100 |
| Uruguay | 7,752,600 | 5,811,800 | 6,248,600 | 19,813,000 |

[a]Values are solved by the following: Baseline Value of Trade − Nonevent Value of Trade.
[b]B, brown; FR, fragrant; LG, long grain; MG, medium grain; P, paddy; W, white.

## 5. Results

The most notable impact of the Liberty Link contamination was its effect on trade, especially with respect to the EU (Table 1). The accumulated difference between the two scenarios for the value of bilateral trade between the United

https://doi.org/10.1017/aae.2015.7 Published online by Cambridge University Press

States and the EU was a reduction[8] of US$124.8 million from 2006 to 2008 for all rice trade. This value takes into account the gains from paddy and white (milled) rice markets minus the loss to the brown (husked) rice market. For example, the low level of 2006 long-grain paddy rice exports to the EU resulted in an increase in the long-grain paddy rice export market for the United States by US$3.3 million in 2006, or 30.4%, between the baseline and the nonevent scenario. Similarly, long-grain white rice imports to the EU had an increase from the baseline to the nonevent in which the value of white rice imports from the United States increased by US$11.9 million in 2006 (1.19%). However, the greater losses were to the long-grain brown rice market of US$17.9 million (6.8%) decrease for 2006. These differences were even more pronounced in 2007, for which the total difference between scenarios was −US$96.3 million. One of the causative factors for this decrease in value stems from the increase in the cost of exports from the United States to the EU, where additional costs of the GM protection policy occurred.

As a result of trade diversion from the United States to other country sources, EU import prices were impacted for both long-grain brown and white rice in 2006 as a result of the contamination (not reported in Table 1). From 2006 to 2008, EU long-grain brown rice import prices were 8.4% higher than if the contamination had not occurred and protective policies had not been imposed, creating a greater cost burden on EU milling importers and manufacturers. Although the economic effects on long-grain brown rice importers were negative, white rice importers in the EU benefited monetarily from the contamination. The price of long-grain white rice imports may have been 2.9% more if the contamination had not occurred, which represents an economic gain for EU white rice importers. Paddy rice importers also gained from the contamination in that paddy rice import prices were depressed as a result of the contamination. Model results show a shift from EU imports of processed rice from the United States to imports of less processed paddy rice from alternate sources such as Uruguay, India, and Thailand. There was an increase in import volumes of long-grain paddy rice and long-grain white rice in 2006, which would represent the initial onset of the contamination as well as general trade trends for that calendar year. These relationships are associated with the shocks to imports of U.S. rice that were administered to reflect trade reductions in 2006 and 2007, followed by an increase in trade in 2008 when normal trade flows resumed.

Despite the gains for EU importers of paddy and white rice, importers of long-grain brown rice experienced significant losses as a result of GM contamination. EU imports of brown rice for 2006 decreased by US$17.2 million (6.8 %) more than may have occurred without GM contamination. The total economic loss

8 The economic loss is solved by taking the baseline value of trade between the EU and United States minus the value of trade for the nonevent scenario, or $\sum_{ij}(BS_{ij} - NE_{ij})$, where BS = baseline scenario, NE = nonevent scenario, $i$ = years, and $j$ = commodities.

https://doi.org/10.1017/aae.2015.7 Published online by Cambridge University Press

for EU brown rice importers from 2006 to 2008 was US$162.7 million, which accounts for all losses and gains between the baseline and nonevent scenario. Long-grain brown rice importers were subjected to higher prices given the contamination, relative to what would have been paid had the contamination not occurred. The value of lost exports from the United States to the EU for brown rice amounted to US$174.4 million from 2006 to 2008, reinforcing the importance of the EU market for U.S. rice exporters. Table 1 provides full details of the estimated impacts on the volume and value of trade of the Liberty Link contamination on the EU market.

Uruguay benefited the most from the trade diversion by increasing exports to the EU by US$19.8 million from 2006 to 2008. India and Thailand also benefited by increasing exports to the EU by US$5 million and US$2 million, over the baseline, respectively. Global bilateral trade volumes for long-grain rice decreased as a result of the policies employed by the EU following the Liberty Link contamination. The greatest difference can be observed in long-grain brown rice volumes. Total trade volumes of long-grain brown rice decreased at the onset of the contamination, which amounted to a difference in total world import value of US$17.1 million less than the potential nonevent scenario (3.6% in 2006) (Table 2). The difference in 2007 was estimated to be a world loss of US$74.8 million (12.6%). The model endogenously determined that the EU would reduce consumption and increase domestic production to compensate for the loss of imports, which leads to a reduction in global long-grain brown rice exports. Other than the long-grain rice trade, medium-grain and fragrant rice were minimally affected by the contamination.

The accumulated loss in the CIF (Cost, Insurance, and Freight) value of the global rice trade amounted to US$22.5 million. The largest difference between scenarios was in 2007, which may be due to the fact that there were effectively no U.S. imports allowed into the EU and this trade was diverted. Import prices were also affected by the Liberty Link contamination. Average FOB (Free on Board) export prices were slightly higher for husked long-grain rice exports in the baseline than the nonevent scenario, reflecting the transaction costs of having to revert to higher-cost export suppliers. Table 2 shows the relationship of the average world FOB prices. Most of the prices were equivalent across scenarios; however, the long-grain brown rice market shows a slight increase in the composite world export price across time periods. The world average FOB long-grain brown rice price was 1.5% higher in 2006 and 2007 and 2.2% higher in 2008 than the nonevent scenario, which translates to an economic loss to global importers.

Total export losses for the U.S. rice industry as a result of GM contamination amounted to US$400.8 million, and the loss attributed to reduction in exports to the EU market amounted to US$124.8 million (Table 3). This value consists of the potential revenue that was not earned by U.S. exporters due to contamination and the subsequent protectionist policies implemented by the EU. The other

**Table 2.** Global Impact Analysis

| | Difference in Cumulative Percent Change in World Trade Volumes (t), 2006–2008[a] (percentage points) | | |
|---|---|---|---|
| | 2006 | 2007 | 2008 |
| LGP[b] | 0.58% | 1.65% | 2.01% |
| MGP | 0.00% | 0.01% | 0.00% |
| FRP | 0.00% | 0.00% | 0.00% |
| LGB | −3.58% | −12.58% | −11.97% |
| MGB | 0.05% | 0.34% | 0.09% |
| FRB | 0.00% | 0.00% | 0.00% |
| LGW | 0.07% | −0.48% | 0.20% |
| MGW | 0.05% | 0.35% | 0.10% |
| FRW | 0.00% | −0.03% | −0.02% |
| | Total Value of World Import between Scenarios 2006–2008[a] | | |
| | 2006 | 2007 | 2008 |
| LGP | 3,120,300 | −1,272,200 | 11,557,700 |
| MGP | 0 | 200 | 100 |
| FRP | 0 | 0 | 0 |
| LGB | −17,139,800 | −74,840,500 | −70,653,800 |
| MGB | −1,800 | −9,200 | −2,500 |
| FRB | 0 | 0 | 0 |
| LGW | 11,884,000 | −14,991,000 | 38,163,000 |
| MGW | −15,400 | −91,600 | −27,000 |
| FRW | −3,300 | −920,200 | −551,500 |
| Total | −2,155,000 | −92,125,000 | −21,514,000 |
| | Difference in Cumulative Percent Change in Average World FOB Price 2006–2008 (percentage points) | | |
| | 2006 | 2007 | 2008 |
| LGP | −0.2% | −2.2% | −0.6% |
| MGP | 0.0% | 0.0% | 0.0% |
| FRP | 0.0% | 0.0% | 0.0% |
| LGB | 1.5% | 1.5% | 2.2% |
| MGB | −0.1% | −0.4% | −0.1% |
| FRB | 0.0% | 0.0% | 0.0% |
| LGW | 0.2% | 0.4% | 0.4% |
| MGW | −0.1% | −0.4% | −0.1% |
| FRW | 0.0% | 0.0% | 0.0% |

[a] Values are solved by the following: Baseline Value of Trade − Nonevent Value of Trade.
[b] B, brown; FR, fragrant; LG, long grain; MG, medium grain; P, paddy; W, white.

substantial and second largest market revenue loss for U.S. exporters was to Mexico with a total loss of US$21.8 million when comparing the baseline with the nonevent scenario for the time period 2006–2008 (not reported in the tables). Mexican import prices for U.S. rice decreased, whereas total imports and imports from the United States increased under the event scenario relative to the baseline.

https://doi.org/10.1017/aae.2015.7 Published online by Cambridge University Press

**Table 3.** U.S. Export Impact Analysis

| | Differences[a] in Value of U.S. Exports between Baseline and Nonevent Scenario (thousand US$) | | | |
|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2006–2008 |
| LGP[b] | 2,094 | – 78,747 | 7,713 | – 68,904 |
| MGP | 0 | 0 | 0 | 0 |
| FRP | 0 | 0 | 0 | 0 |
| LGB | – 13,622 | – 87,248 | – 61,770 | – 162,640 |
| MGB | – 14 | – 6,866 | – 32 | – 6,912 |
| FRB | 0 | 0 | 0 | 0 |
| LGW | 10,452 | – 151,401 | 31,616 | – 109,333 |
| MGW | – 91 | – 52,694 | – 223 | – 53,008 |
| FRW | 0 | 0 | 0 | 0 |
| Total | – 1,182 | – 376,955 | – 22,696 | – 400,833 |

[a]Table based on countries with differences between baseline and nonevent scenario.
[b]B, brown; FR, fragrant; LG, long grain; MG, medium grain; P, paddy; W, white.

Although exports of U.S. rice to Mexico increased, the price effects outweighed the gains in import volumes causing an overall reduction in revenue for U.S. exporters in the Mexican rice market. Although there were a few bilateral trade relationships that provided minimal increases in U.S. export revenue for rice, these relatively small increases are vastly overshadowed by the substantial losses realized in the EU and Mexican markets.

U.S. processing levels were impacted as a result of contamination. The largest effect occurred at lower processing levels, primarily at the first milling stage that entails husk removal. The total reduction in potential processing for long-grain paddy to brown rice from 2006 to 2008 amounted to 4.3%. This accounts for the shift in U.S. exports from brown to paddy rice. The United States shifted brown rice exports to other importing countries when access to EU markets was denied, and many new destination countries chose to import paddy rice as a means of bolstering their domestic milling industries. The economic losses in paddy to brown rice processing in the United States were also compounded by the increase in paddy rice imports, which translates into lost revenue from U.S. domestic processing as paddy rice requires little to no domestic processing and commands a lower market price.

U.S. producers were negatively impacted as all domestically produced rice prices decreased as a result of the contamination. Table 4 shows the differences in prices that producers received from 2006 to 2008. As there was a sufficient supply from competitive export markets and domestic prices decreased across both long- and medium-grain rice, we did not see a shift in production types. The estimated loss to producers is US$5.58/t for long-grain paddy rice and US$4.74/t for medium-grain paddy rice at the height of contamination in 2007.

https://doi.org/10.1017/aae.2015.7 Published online by Cambridge University Press

**Table 4.** Changes in U.S. Production Values and Prices of Rice

| | Differences[a] in U.S. Producer Prices ($US/t) | | |
|---|---|---|---|
| | 2006 | 2007 | 2008 |
| LGP[b] | −$0.78 | −$5.58 | −$1.60 |
| MGP | −$0.67 | −$4.74 | −$1.37 |
| | Differences[a] in U.S. Volumes of Production (t) | | |
| | 2006 | 2007 | 2008 |
| LGP | −14,946 | −113,518 | −34,870 |
| MGP | 2,904 | 21,134 | 6,300 |
| | Differences[a] in U.S. Value of Production (thousand US$) | | |
| | 2006 | 2007 | 2008 |
| LGP | −8,640 | −63,354 | −18,669 |
| MGP | −355 | −2,694 | −805 |

[a]Values are solved by the following: Baseline Value of Trade − Nonevent Value of Trade.
[b]LG, long grain; MG, medium grain; P, paddy.

The total revenue loss to U.S. producers for the 3-year period amounts to US$90.6 million for long-grain paddy rice and US$3.9 million for medium-grain paddy production.

There were relatively large reductions in U.S. long-grain rice production volumes (Table 4). Without contamination, long-grain rice production may have increased an estimated 15,000 t in 2006 and 113,500 t in 2007. Although producers were estimated to grow more medium-grain rice, there was an overall decrease in total U.S. rice production as a result of contamination.

U.S. consumer welfare was also impacted by the Liberty Link contamination. Wholesale and retail prices decreased given contamination relative to the nonevent scenario in the United States and other countries (Table 5). The U.S. final consumption price for long-grain white rice was estimated as a gain to consumers with a 0.4% lower consumer price for 2006. Like long-grain rice consumption prices, medium-grain white rice markets expressed reductions relative to the nonevent scenario. Medium-grain rice prices were 0.2% lower in 2006 and 1.4% lower in 2007.

Consumer demand for final consumption (Table 5) was also higher in the United States than it would have been without the contamination, expressing gains to consumers as a result of the contamination. For long-grain white rice, final consumption demand was 0.3% higher in 2006 and 2.4% higher in 2007. The total gain to consumers is estimated at US$385,000 for long- and medium-grain rice. However, as stated previously, U.S. exporters lost revenue due to decreased exports that amounted to approximately US$400.8 million. The loss to producers far exceeds the gains to consumers in the United States.

**Table 5.** U.S. Consumer Impact Analysis 2006–2008

| | Differences in Cumulative Percent Change[a] in U.S. Retail Final Consumption Prices | | |
|---|---|---|---|
| | 2006 | 2007 | 2008 |
| LGW[b] | −0.4% | −2.4% | −0.7% |
| MGW | −0.2% | −1.4% | −0.4% |
| FRW | 0.0% | 0.0% | 0.0% |
| | Differences in Cumulative Percent Change[a] in U.S. Demand for Final Consumption | | |
| | 2006 | 2007 | 2008 |
| LGW | 0.3% | 2.4% | 0.6% |
| MGW | 0.2% | 1.3% | 0.4% |
| FRW | 0.0% | 0.1% | 0.0% |

[a]Percent change is a cumulate percent change from the 2005 baseline.
[b]FRW, fragrant white; LGW, long-grain white; MGW, medium-grain white.

## 6. Conclusions

Liberty Link contamination of U.S. rice supplies had numerous impacts on trade, prices, and overall producer and consumer welfare. By employing a spatial partial equilibrium model, this research analyzes the market distortions caused by this event. U.S. exporters lost an estimated US$400.8 million in potential revenue from 2006 to 2008 as a result of this event. The majority of this loss came from losing the large market share that the United States previously held for the high-value EU long-grain brown rice market. The United States was able to market the diverted rice to other importing countries but did so at lower prices, causing an overall negative impact resulting from the contamination.

The near zero tolerance policy employed by the EU increased the cost of exports for the United States and disrupted bilateral rice trade.[9] The Liberty Link contamination led to monetary losses, especially for U.S. producers. The EU market also suffered economic losses due to importing rice from more expensive sources. Countries that were able to capture the EU market demand, as well as counties that were able to import rice at lower prices due to the increase in supply on world markets experienced an economic gain as a result of the contamination. Consumers gained in that the retail price of final consumption was lower in the contamination than the price in the absence of contamination. Although there was a gain to consumers and importers other than the EU, the net effect of the Liberty Link contamination is an economic loss, primarily attributable to losses experienced by EU importers and U.S. exporters. Resulting

9 No account was made to value the costs associated with the physical diversion of shipments to the EU that were rejected. These costs would have added to the total cost of the contamination event.

from this work's inclusion of additional time periods, higher economic losses were estimated than those reported in the literature, such as Brookes (2008), which only focused on EU impacts. Further research would contribute to the understanding of the impacts of the Liberty Link contamination by modeling the effects of contamination on other sectors of the agricultural economy, specifically focusing on substitute products. The economic losses of this contamination have been great and highlight the importance of the EU-U.S. rice trade relationship as well as the implications for supply chain contamination on trade.

## Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/aae.2015.7

## References

Ahearn, R.J. *Transatlantic Regulatory Cooperation: Background and Analysis*. Washington, DC: Congressional Research Service, 2009.

Armington, P.S. "A Theory of Demand for Products Distinguished by Place of Production." *IMF Staff Papers* **16**(1969):159–78.

Brookes, G. "Economic Impacts of Low Level Presence of Not Yet Approved GMOs on the EU Food Sector." Briefing Document, Dorchester, UK: GBC, 2008.

Childs, N., and J. Livezey. *Rice Backgrounder*. Washington, DC: U.S. Department of Agriculture/Economic Research Service, Outlook Report, 2006.

Commission of the European Communities. *Directorate General for Agriculture and Rural Development Working Document*. Brussels: European Commission, 2009.

Davidson, J. "GM Plants: Science, Politics and EC Regulations." *Plant Science* **178**(February 2010):94–98.

Durand-Morat, A., and E. Wailes. *Riceflow: A Multi-Region, Multi-Product, Spatial Partial Equilibrium Model of the World Rice Economy*. Fayetteville, AR: Department of Agricultural Economics and Agribusiness, University of Arkansas, Staff Report SP-03–2010, 2010. Internet site: http://purl.umn.edu/92010 (Accessed August 2, 2010).

Harrison, W., and K. Pearson. *An Introduction* to *GEMPACK*. GEMPACK Document No. 1 (GPD-1), 6th ed. Melbourne: Monash University, 2002a.

Hertel, T., J. Horridge, and K. Pearson. "Mending the Family Tree: A Reconciliation of the Linearization and Levels Schools of CGE Modeling." Impact Project Preliminary Working Paper IP-54, Melbourne: The University of Melbourne, 1991.

Li, Y., E.J. Wailes, A. McKenzie, and M. Thomsen. "LL601 Contamination and Its Impact on U.S. Rice Prices." *Journal of Agricultural and Applied Economics* **42**,1(February 2010):31–38.

Office of the United States Trade Representative. *European Union*. Washington, DC: Office of the United States Trade Representative, 2008. Internet site: http://www.ustr.gov/sites/default/files/uploads/reports/2008/NTE/asset_upload_file991_14650.pdf (Accessed December 21, 2009).

Takayama, T., and G. Judge. "Equilibrium among Spatially Separated Markets: A Reformulation." *Econometrica* **32**(October 1964):510–24.

United Nations. *UN Comtrade Database*. Internet site: http://comtrade.un.org/ (Accessed May 14, 2010).

USA Rice Federation. *Submission of the USA Rice Federation for the 2009 Annual National Trade Estimate Report on Foreign Trade Barriers*. Arlington, VA: USA Rice Federation, 2008.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA/APHIS). *Report of Liberty Link Rice Incidents*. Washington, DC: USDA/APHIS, 2007. Internet site: http://www.aphis.usda.gov/newsroom/content/2007/10/content/printable/RiceReport10–2007.pdf (Accessed September 23, 2009).

———. *USDA Deregulates Line of Genetically Engineered Rice*. Washington, DC: USDA/APHIS, 2006. Internet site: http://www.aphis.usda.gov/newsroom/content/2006/11/rice_deregulate.shtml (Accessed July 2, 2010).

U.S. Department of Agriculture, Foreign Agricultural Service. *Production, Supply and Distribution* Online. Washington, DC: USDA/FAS, 2010. Internet site: http://apps.fas.usda.gov/psdonline/ (Accessed July 2, 2010).

Yu, W., T.W. Hertel, P.V. Preckel, and J.S. Eales. "Projecting World Food Demand Using Alternative Demand Systems." *Economic Modelling* **21**(January 2004):99–129.