Trade in CRISPR Wheat: A Partial Equilibrium Analysis

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Trade in CRISPR/Gene-Edited Wheat: A Partial Equilibrium Analysis

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Background

- Genome editing (GE) is a group of technologies that allow scientists to edit the DNA of many organisms
- Importance:
  - Increase the efficiency of food production (Bhalla, 2006)
  - Increase seed production and crop yields
  - Improved nutritional qualities (Bhalla, 2006; Davuluri et al., 2005; Singh et al., 2005; and Sakamoto et al., 2006)
- CRISPR/Cas9 are widely used GE technologies
  - Faster, cheaper, efficient, and accurate (Hsu et al, 2014; Wang et al, 2017; Barrangou et al, 2016)

Background

- Wheat is the third most-produced cereal crop after corn and rice
- Total global production: 683.15 million metric tons
- Major Producers: China, India, Russia, EU, and US
- Major Exporters: US, Russia, Canada, Australia, Argentina, and EU
- Major Importers: Japan, Egypt, Indonesia, Algeria, Bangladesh, Brazil, EU, South Korea, Mexico, Nigeria, and Philippines

Background

- About 95% of imported corn and 90% of imported soybeans by China are GM (Lucht, 2015)
- No GM wheat has been grown worldwide (Lucht, 2015, USDA, 2018)
- In Australia, genetic engineered wheat is in trial stage (LeMieux, 2018)

Statement of Problem

- Previous studies have analyzed how the adoption of genetically engineered or modified technologies have affected agricultural crops such as corn, soybeans, cotton, and barley without focusing on wheat
- Recently in Victoria the wheat supply declined by 70% due to severe drought conditions, leading to the state's loss of $300 million (ISAAA, 2018)
- AgWeb (2015) reported that continuing drought in Canada is expected to create a 12 million metric ton loss in wheat exports

Statement of Problem

- No studies have focused on drought tolerant (HB4) or CRISPR/gene-edited on wheat trade
- Biotechnology has focused on herbicide tolerant (HT), insect-resistance (BT), and glyphosate resistant but not on drought tolerant (HB4) or CRISPR/Gene-editing system
- This study analyzes the impact HB4 or CRISPR/Gene-edited technology on wheat trade

Research Questions

- What happens to global wheat trade when Argentina commercially produces HB4 or CRISPR wheat?
- What happens to global trade patterns if Australia adopts HB4 or CRISPR wheat from Argentina?
- What happens to global trade patterns if US, Canada, Australia, and Russia adopt HB4 or CRISPR wheat from Argentina?
- What are the welfare effects of HB4 or CRISPR wheat on producers and consumers of wheat?
- What are the effects of HB4 or CRISPR wheat on total welfare from trade

Literature Review

- Johnson, et al., (2005) investigated the economic and welfare impacts of commercializing HT wheat in North America. They found that marginal costs of segregation were borne by producers and consumers

- Taylor, et al., (2003) employed a spatial equilibrium model to evaluate the trade impacts associated with GM wheat adoption. The study found that both producer and consumer welfare increase slightly due to GM adoption

Literature Review

- Furtan, et al. (2003) developed an empirical model to analyze the impact of GM-HT wheat. The results show that production benefit realized by adopting GM-HT wheat is between $8.72 and 14.93 per acre

- Gruère, et al. (2007) analyzed the potential effects of introducing GM food crops in Bangladesh, India, Indonesia, and the Philippines. The study found that gains associated with GM adoption largely exceed any type of potential trade losses

Methodology

- To analyze the effects of trade implications of drought-tolerant (HB4) and CRISPR/Cas9 wheat, a spatial equilibrium model was employed

- The spatial equilibrium model is a multi-region partial equilibrium model which links producers and consumers from different locations or countries (Bouët, 2016)

- Allows analyzes of the impact on supply and demand, consumer and producer surpluses as well as world welfare (Bouët, 2016)

Model

- The study adopts the spatial equilibrium model employed by Taylor, et al. (2003)
- The objective function is to maximize total consumer and producer surplus less transportation costs.

- The objective function is shown below;

$$\sum_i \left(\frac{(Q_i^d)^2}{2b_i} - \frac{a_i Q_i^d}{b_i} \right) - \sum_i \left(\frac{(Q_j^s)^2}{2f_j} - \frac{e_j Q_j^s}{f_i} \right) -$$

$$\sum_i \sum_j q_{j,i}^s trans_{i,j} - \left(\sum_i \left(\frac{Q_i^d - d_i}{f_i} \right) * Q_i^d * def_i * sev_i \right) + \sum_j GE^S q_j^s \quad (1)$$

- To equate supply and demand for both GE and non-GE wheat, balance constraints are imposed. This is shown by equation (2)

$$q_{j,i}^s = q_{j,i}^d \forall_{i,j} \quad (2)$$

Model

- **The Analytical Model**

➢ Also, total production and consumption are expressed by (3) and (4)

$$Q_j^s = \sum_i q_{j,i}^s \forall_j ; \quad (3)$$

$$Q_j^d = \sum_i q_{j,i}^d \forall_i ; \quad (4)$$

➢ Export supply equations for each producing country is specified as follows:

$$Q_j^s = \alpha_j + \beta_j . P_j^{rec} \quad (5)$$

➢ The import demand equations for each importing country are specified as follows:

$$Q_i^d = \alpha_i - b_i . P_i^{paid} \quad (6)$$

Data

- Three year average, 2015-2017
- Five (5) producing and exporting regions: United States, Canada, Australia, Argentina, and Russia
- Sixteen (16) major wheat importing countries: Algeria, Belgium, Brazil, Indonesia, Egypt, Italy, Netherlands, Korea, Mexico, Turkey, Other Asia, Nigeria, Vietnam, China, Japan, Venezuela, and ROW
- Sources: UN COMTrade, ABARES, USDA, Resource Trade Earth, Canadian Grain Commission, Statistics Canada etc.

Scenarios

Scenario	Producers	Consumers
Baseline	No GE wheat production or imports	Only non-GE wheat
Scenario 1	Only Argentina produced GE wheat	Japan, Korea, Belgium, Netherland, and Italy import only non-GE wheat
Scenario 2	Only Argentina and Australia produced GE wheat	Japan, Korea, Belgium, Netherland, and Italy import only non-GE wheat
Scenario 3	Only Argentina and Australia produced GE wheat	~~Japan~~, Korea, Belgium, Netherland, and Italy import only non-GE wheat
Scenario 4	Only Argentina, Australia, and US produced GE wheat	Korea, Belgium, Netherland, and Italy import only non-GE wheat
Scenario 5	Only Argentina, Australia, US, Canada, and Russia produced GE wheat	Korea, Belgium, Netherland, and Italy import only non-GE wheat
Scenario 6	No restriction on production or imports	No restrictions

Results: Baseline

- Trade by Protein Level (non-GE)
  - HPW=19.95%
  - LPW=80.04%
- Trade Level (Exporters)
  - Russia = HPW (8.89%), LPW(46.83%)
  - US = HPW(37.75%), LPW(24.47%)
  - Canada = HPW(52.97%), LPW (2.95%)
  - Argentina= HPW(1.84%), LPW(9.77%)
  - Australia= HPW(5.62%), LPW (14.66%)

Results: Scenario 1

- Only Argentina produces GE wheat
- Japan, Korea, Belgium, Netherlands, and Italy import only non-GE wheat
- Trade by Protein Level (Total Trade)
  - HPW=18.99%
  - LPW=65.84%
- By Protein Level (GE Wheat)
  - HPW =9.96%
  - LPW=90.04%
  - Total GE Trade=3.69%
- Trade by Protein Level (Exporters)
  - Russia = HPW (9.23%), LPW(60.68%)
  - US = HPW (27.96%), LPW(29.42%)
  - Canada = HPW (55.04%), LPW (3.55%)
  - Argentina= HPW (1.93%), LPW(11.63%)
  - Australia= HPW (5.83%), LPW (17.63%)

Results: Scenario 2

- Only Argentina and Australia produce GE wheat
- Japan, Korea, Belgium, Netherlands, and Italy import only non-GE wheat
- Trade by Protein Level (Total Trade)
  - HPW=19.63%
  - LPW=80.37%
- Protein Level (GE Wheat)
  - HPW =20.68%
  - LPW=79.32%
  - Total GE Trade=7.46%
- Trade by Protein Level (Exporters)
  - Russia = HPW (9.21%), LPW(47.21%)
  - US = HPW(27.93%), LPW(24.91%)
  - Canada = HPW(54.99%), LPW (3.01%)
  - Argentina= HPW(1.93%), LPW(9.95%)
  - Australia= HPW(5.92%), LPW (14.93%)

Results: Scenario 3

- Only Argentina and Australia produced GE wheat
- ~~Japan~~, Korea, Belgium, Netherland, and Italy import only non-GE wheat
- Results not significantly different from Baseline or scenario 2

Results: Scenario 4

- Only Argentina, Australia, and US produce GE wheat
- Korea, Belgium, Netherlands, and Italy import only non-GE wheat
- Trade by Protein Level (Total Trade)
  - HPW=19.11%
  - LPW=80.36%
- Protein Level (GE Wheat)
  - HPW =42.49%
  - LPW=57.51%
  - Total GE Trade=15.03%
- Trade Protein Level (Exporters)
  - Russia = HPW (9.40%), LPW(47.21%)
  - US = HPW(28.82%), LPW(24.91%)
  - Canada = HPW(56.48%), LPW (3.01%)
  - Argentina= HPW(1.99%), LPW(9.95%)
  - Australia= HPW(6.08%), LPW (14.93%)

Results: Scenario 5

- Only Argentina, Australia, US, Canada, and Russia produce GE wheat
- Korea, Belgium, Netherlands, and Italy import only non-GE wheat
- Trade by Protein Level (Total Trade)
  - HPW=19.06%
  - LPW=80.32%
- Protein Level (GE Wheat)
  - HPW =56.13%
  - LPW=43.87%
  - Total GE Trade=32.09%
- Trade Protein Level (Exporters)
  - Russia = HPW (9.55%), LPW(47.21%)
  - US = HPW(28.74%), LPW(24.91%)
  - Canada = HPW(56.92%), LPW (3.01%)
  - Argentina= HPW(0.47%), LPW(9.95%)
  - Australia= HPW(6.04%), LPW (14.93%)

Results: Scenario 6

- No restriction on production or imports
- Trade by Protein Level (Total Trade)
  - HPW=21.44%
  - LPW=78.55%
- Protein Level (GE Wheat)
  - HPW =50.67%
  - LPW=49.33%
  - Total GE Trade=32.09%
- Trade Protein Level (Exporters)
  - Russia = HPW (8.3%) LPW(47.21%)
  - US= HPW(35.22%), LPW(24.91%)
  - Canada= HPW(49.50%), LPW (3.01%)
  - Argentina= HPW(5.25%), LPW(14.93%)
  - Australia= HPW(1.73%), LPW (9.95%)

Results

- **Producer Welfare**

In scenario 5, when all producing countries adopt the GE technology, they all experience a positive change in their producer welfare.

Country	1	2	3	4	5	6
us	0.0	-0.3	-0.3	4.8	**2.9**	**2.9**
can	0.0	-0.4	-0.4	-0.5	**3.3**	**3.3**
aust	0.0	7.3	7.3	7.2	**2.7**	**2.7**
arg	3.1	3.1	3.1	3.1	**3.1**	**3.1**
rus	0.0	-0.3	-0.3	-3.4	**2.3**	**2.3**

Results

Results of Total Welfare from Trade

- Total welfare continues to increase moving from scenario 1 through scenario 6

- Adoption of CRISPR wheat is favorable to some producers and consumers

Scenarios	Total Welfare	% Change
Baseline	2,526,352,935	
Scenario 1	2,526,361,071	0.000322
Scenario 2	2,526,385,188	0.001277
Scenario 3	2,526,385,188	0.001277
Scenario 4	2,526,538,452	0.007343
Scenario 5	2,526,784,151	0.017069
Scenario 6	2,526,784,151	0.017069

Conclusions

- Argentina, Nigeria, Brazil, Egypt, Mexico, and Venezuela continue to consume low protein GE wheat in all scenarios
- When there are no restrictions on production or imports, Japan, Korea, Belgium, Netherland, and Italy still import high protein and low protein non-GE wheat
- Producer Welfare: All producing countries experience a positive producer welfare gain.
- Consumer Welfare: all consumers experience a welfare gain except Japan, Korea, Belgium, Netherland, and Italy

Conclusion

- Total Welfare: Total welfare from trade increases in all scenarios
- Overall: **CRISPR wheat trade promotes total producer and consumer welfare**

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