ESTIMATING THE POTENTIAL ECONOMIC IMPACT OF *PUCCINIA GRAMINIS F. SP. TRITICI TTKS* RACE (UG99) (WHEAT STEM RUST)

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Abstract

An agricultural sector model estimates impacts for hypothetical U.S. outbreaks of Ug99 wheat stem rust. Scenarios describe reductions in wheat output and exports beginning in 2013. The four year losses in the welfare of wheat producers range from $1.7- $11.6 billion (-15% to -107%). In scenarios reflecting alternate assumptions of disease spread, consumers benefit from embargoed crops remaining in the United States. The consumer surplus change varies between a gain of $4.6 billion (0.3%) when importing countries embargo U.S. wheat shipments and turn to other suppliers and a loss of $1.4 billion (-0.1%) when other countries continue importing the reduced supplies of U.S. wheat. Treatment costs are $139 million to $2.4 billion.

Keywords: Wheat Stem Rust, Economic Impacts, Trade

JEL Classification: Q02, Q13, Q17

Introduction

This research estimates the impacts of hypothetical incursions of an exotic disease of wheat -- *Puccinia graminis f. sp. Tritici TTKS* race (Ug99) a strain of wheat stem rust -- into the United States. Rusts are a diverse group of plant pathogens with over 120 genera and 6,000 species (DeWolf *et al.*). Wheat stem rust is particularly destructive to wheat and barley around the world because it can infect stems, leaves, and heads of the developing plants resulting in marked reductions in plant growth and yield (DeWolf *et al.*). Plants infected by wheat stem rust produce spores that are dispersed by wind to infect newly-emerged wheat seedlings. Since 1904, the United States has experienced 9 outbreaks of wheat stem rust. However Ug99 is one of the new genetic variants of rust discovered in Uganda during 1999 that is able to overcome the genetic resistance present for several decades in current wheat cultivars grown. (DeWolf *et al.)* During the 1953 and 1954 outbreaks, yield losses from wheat stem rust in Minnesota and the Dakotas were reported to be up to 35% for spring wheat, and 80% for durum wheat (Dubin *et al.*). The total loss in value of production in those two years was estimated at $3 billion (in 2009 prices) (Murray *et al.*).

Ug99 has rapidly spread across Northern Africa and the Middle East. How rapidly the disease spreads depends on rainfall, wind speed and direction, and crop maturity. Humans are also a potential transmission vector in North America of Ug99 (Murray *et al.*). Previous rust epidemics suggest that the spread will continue through Asia and North America in the next decade (Singh). Once introduced in North America, the fungus would likely move from Central America and Mexico each year to southern U.S. states where it would be able to survive the winter and spread north to the Great Plains as wheat crops mature. Risk mapping also suggests the highest potential risks from Ug99 for the United States are in the Northern and Central Plains

(Murray *et al*.). Detection of Ug99 would be difficult because it has the same morphology to other races that are already present in the United States.

Given the possible introduction of new races of wheat stem rust in the U.S., this quantitative assessment is conducted to show the range of possible impacts as a baseline to inform strategies for mitigating the threat from Ug99. The scenarios consider three hypothetical spread situations and two alternative accompanying export reactions. The spread ranges from a single event in North Dakota that can be controlled by fungicide treatments, to a multi-year, multi-state spread. The response by U.S. trading partners is altered according to whether or not other nations are assumed to also have Ug99. Currently the majority of importers of U.S. wheat and barley are not infected. Thus, U.S. wheat exports are assumed to be embargoed to a greater extent than if other nations are infected and cannot turn to rival exporters for their imports.

Modeling Approach

The analysis employs a partial equilibrium model where prices equilibrate the supply and demand of products in the event of a shock such as a pest incursion. The aggregate impact of a pest invasion is determined by measuring the change in economic welfare before and after the invasion.

The model results are the outcome of the interaction of the output and export reductions caused by the wheat rust. By itself an output reduction is a cut in crop supply in the United States and prices rise to ration the reduced production. In contrast, reduced exports by themselves are a cut in the demand for U.S. crops. As a result, prices fall to encourage expanded use of embargoed product inside the United States. The equilibrium price reached when these events occur simultaneously is determined by which of these two effects dominates. If the output reduction is stronger than the export reduction, the equilibrium price will be higher. If the export demand reduction dominates, the equilibrium price will be lower.

The numerical model employed to quantitatively estimate the potential economic impacts of an incursion of Ug99 into the United State uses dynamic differential equations to describe deviations from a baseline. A comprehensive model presentation is in Paarlberg, Hillberg Seitzinger, Lee, and Mathews, Jr. The model includes the major livestock products, livestock, and feed crops for the United States, and it is solved quarterly relative to the observed data through 2011 and the USDA baseline released in the spring of 2012.

One set of differential equations relate a 10 X 1 column vector of changes in consumption, dln**C**, for final goods to a 10 X 1 column vector of logarithmic changes in final goods prices, dln**P**, via a 10 X 10 matrix of demand elasticities, $\boldsymbol{\varepsilon}$: $d\ln\mathbf{C} = \boldsymbol{\varepsilon} d\ln\mathbf{P}$. For the 10 final goods and soybeans there are zero profit conditions where competitive industries allocate changes in unit revenue (price) to determine changes in input costs, dln**W**, according to 38 X 11 matrix of unit revenue shares, $\boldsymbol{\theta}$: $d\ln\mathbf{P} = \boldsymbol{\theta} d\ln\mathbf{W}$.

There are five types of inputs for which changes in derived demands must be specified. The general form for the change in derived demand, dln**D**, links that change to the change in output, dln**Q**, via a matrix of changes in per unit input use, dln**A**: $d\ln\mathbf{D} = d\ln\mathbf{A} + d\ln\mathbf{Q}$. One input type is inputs obtained from the rest of the economy at exogenous prices. A second type is sector specific capital stocks. The third type is species specific livestock. The fourth type of derived demands describes species specific uses of feed. Finally there is crop land which is allocated among crops to equalize its return. Using the definition of the Morishima elasticities of substitution and envelop properties the changes in per unit input demands are the product of a matrix of unit revenue shares, $\boldsymbol{\beta}$, a matrix of substitution elasticities, $\boldsymbol{\sigma}$, and input prices: $d\ln\mathbf{A} =$

$\boldsymbol{\beta\sigma}\text{dln}\mathbf{W}$.

Imports of commodities from the United States are determined by excess demand expressions of the form: $\text{dln}\mathbf{M} = \boldsymbol{\eta}[\text{dln}\mathbf{P}, \text{dln}\mathbf{W}]$ where $\boldsymbol{\eta}$ is a 16 X 16 matrix of excess demand elasticities. Because some commodities are only traded as intermediates the price vector is partitioned.

Outputs of livestock result from the decisions to hold breeding animals and the decision to breed. Livestock producers determine the breeding inventory at a point in time based on the difference between the expected future return to a bred animal and its salvage value relative to the current cull price.

The remaining equations are market clearing identities. Exports are the difference between supply (beginning stocks and production) and demand determined from the demands for final goods, for intermediate input use, and ending stocks. Markets clear where exports equal imports. The model reports the percent changes in prices, quantities produced, consumed, and traded for the commodities included in the model that result from potential pest related shocks.

The model outcomes are used to calculate changes in economic welfare. The change in the economic welfare of producers consists of changes in several variables. One variable is the change in returns to capital and management from sales. For crop growers, returns to capital and management are quarterly market sales less purchased inputs and a land rent. This measures the residual monies available to cover payments to owned capital such as buildings and equipment, to pay taxes and other fixed costs, and for operator labor. Payments to land are separated from the returns to capital and management since crop producers may not own the land they operate. For livestock growers, returns to capital and management are market sales less feed costs. For livestock product producers, returns are calculated by subtracting purchased input costs, including animal costs, from market sales. The returns to capital and management for crop and livestock growers and livestock product producers measures the value added along the supply chain.

Another component of the change in producer economic welfare is any change in U.S. Government commodity program payments. The components of the change in producer economic welfare discussed use sales quantity. A final component of the change in producer welfare is the value of the crop lost. In the case of a disease outbreak growers plant a crop and incur the production expenses but experience a loss of output. An adjustment of the full value of the lost sales must be made since production expenses are sunk (Paarlberg, Lee, and Seitzinger).

Economic welfare of consumers is measured by the difference between what consumers are willing to pay and what they must pay for each unit consumed -- consumer surplus -- and is measured only on use for human consumption. Changes in economic welfare to livestock growers resulting from changes in feed costs are reflected in the returns to capital and management on animals sold.

Plant Pest Scenarios

Critical drivers of the results are the supply reductions and trade interruptions caused by disease incursions. The supply reductions are introduced into the model by following a general process. First, the crop or crops affected must be identified. Then the means of introduction and location of detection are specified. Output reductions depend on the degree of infection, the yield effects, and any mitigation strategies. Based on the nature of the exotic pests, movement and spread indicate output reductions in subsequent years. Output reductions in the model are introduced in the quarter of harvest. Crop producers react to the previous season's return relative to alternative crops but do not anticipate continued infections.

Two potential spread situations are considered. For Scenarios 1 and 2 spread originates in a small area of North Dakota via a human vector and is a 1-year event because the rust cannot overwinter that far north. For Scenarios 3 and 4, Ug99 overwinters in Texas and spreads northward in multiple years.

For the single event outbreak the introduction is assumed to be an accidental release of spores in McLean County, North Dakota during the summer of 2013. This county is selected because risk mapping suggests potentially severe wheat output losses from introduction in that area of North Dakota (Murray, *et al.*). In Scenario 1, the output loss is confined to the point of introduction, so there is no significant output reduction from a national perspective. In Scenario 2, there is subsequent local spread within the high risk areas of North Dakota. The inability of the pathogen to survive the North Dakota winter means there are no outbreaks in subsequent years. Historical data is examined to determine hypothetical yield losses. For endemic outbreaks of wheat rust occurring during the years 1919, 1934, and 1954, output reductions for North Dakota were 35-40% (Murray *et al*.). North Dakota state wheat yields in 1954 were 43% lower than that for 1955 (USDA, *Agricultural Statistics, 1956*). For Scenario 2, 40% of the wheat grown in the counties affected is assumed lost which means a 7.2% reduction in U.S. spring and durum output for 2013 (U.S. Department of Agriculture, National Agricultural Statistical Service (USDA/NASS). *Statistics by State*.).

An alternative scenario is that Ug99 wheat rust overwinters in Texas and surges north as temperatures warm in a multi-year outbreak. Thus, the losses each year must be determined. Determining a multi-year outbreak pattern from historical data for Scenarios 3 and 4 is not straightforward. Epidemics of wheat rust occurred in the United States during 1919, 1935, 1953, and 1954 (Murray *et al*). Wheat production in 1919 was well above historical levels with an expansion of area into marginal growing regions in response to the price increases induced by the First World War. The epidemic of 1935 occurred during the Dust Bowl period of extreme drought.

Thus, the best information for constructing a multi-year outbreak comes from the 1950s outbreak experiences. National yields by wheat class for 1950-1960 reported in USDA, *Agricultural Statistics, 1962* show large and unusual declines for durum wheat in 1953 and 1954 and 1952's yield was also below trend. Spring wheat yields show significant declines in 1952 and 1954 with the yield in 1953 lower than most years of the decade but higher than yields in 1952 and 1954. The yield for winter wheat in 1953 is lower than that in 1952 but greater than yields in 1950 and 1951.

This historical yield patterns determine the U.S. output reductions for the rust outbreak analyzed in Scenarios 3 and 4. National yields for durum wheat for years 1-3 -- marketing years 2013/14, 2014/15, 2015/16 -- are reduced by 28%, 54%, and 78% based on years 1952 - 1954. Years 1955 and 1956 show recovery in durum wheat yields and output is not reduced from the baseline levels.

For spring wheat yields, a decline of 26% is used for year 1, 2013/14, of the simulated outbreak based on the yield decline between 1951 and 1952. Spring wheat yield in 1953 showed some recovery, a yield loss of 12% but fell 24% in 1954 and these reductions are used for years 2 and 3, 2014/15 and 2015/16 . Yields for spring wheat in 1955 and 1956 recovered so there is no reduction for 2016/17 and 2017/18.

National winter wheat yields do not change much and it is difficult to see impacts from wheat rust. The historical data suggests no winter wheat yield decline in 1951 with the yield for 1952 well above winter wheat yields in 1950 and 1951. The yield decline from 1952 to 1953 is 17% and this value is used for the simulated winter wheat output loss in year 2, 2014/15. Yields recover in 1954, but decline 8% in 1955 which corresponds to 2016/17. There is no yield loss for winter wheat in 1956. The different pattern for winter wheat may reflect its fall planting so that rust in the summer of one year affects winter wheat output the following summer.

A second critical driver is exports lost from the Ug99 incursion which depend on several factors. One factor is the location of the incursion and its subsequent spread. Scenarios 1 and 2 assume the Ug99 infestation in North Dakota is a single year event. In the historical outbreaks, rust arrived in North Dakota during the last week of June (Murray *et al*). Since the model used to analyze the outbreak is quarterly the export reductions begin in the July-September quarter of 2013.

The reactions of trading partners must be considered. The pathogen is currently limited to Africa and the Middle East. Although North Dakota borders Canada, wheat produced in Canada is assumed free of Ug99. The assumption is that exports of hard red winter wheat, western white wheat, and soft red winter wheat are not affected since the classes are segregated for export and the infection only occurs in regions growing spring and durum wheat. Spring and durum wheat represent about 23% of all U.S. wheat exports.

The assumption in scenarios 1 and 2 is that all of these exports are lost due to importers' decisions not to regionalize U.S. spring and durum wheat exports. That is, importers do not limit their embargoes on U.S. wheat to the infested area. Because the outbreak is assumed to be a single event, export reductions last through the April-June quarter of 2014, or marketing year 2013/14. Export recovery occurs with the new crop and is assumed to be a full recovery.

The varied pattern of output reductions in the multi-year infestation of scenarios 3 and 4 mean considering more complicated U.S. wheat export reductions. Scenario 3 is where the United States becomes affected by Ug99 while rival exporters and importing nations are free of the rust so buyers can shift to rival suppliers. The loss in U.S. exports is great and the recovery is slow. Scenario 4 is where other nations are assumed infested with Ug99. This means a smaller loss in U.S. exports because buyers cannot turn to rival exporters for unaffected supplies.

Since wheat rust moves from southern Texas up through the Great Plains, export losses are large for certain classes of wheat. Exports of soft red winter and white wheat are assumed unaffected by the rust outbreaks since they are produced in other regions. Exports of durum, spring wheat, and hard red winter wheat are assumed affected. Exports of durum wheat by the United States are small and production is regionally concentrated in the Northern Plains. U.S. durum wheat exports are assumed replaced by rival sources of durum wheat and cease throughout the simulation period. Exports of spring wheat by the United States compete with bread wheat exports by other nations, especially Canadian Western Red Spring (CWRS) exports. Again hard red spring wheat production is regionally concentrated where the infection is strong so hard red spring wheat exports are assumed to disappear for 2013/14, 2014/15, and 2015/16 when spring wheat is infected. Export recovery occurs slowly in subsequent years with a 50% recovery starting in July-September 2016.

The assumption for hard red winter wheat is that U.S. exports in the initial month of detection are halted while a quarantine and certification program is instituted. For the remaining duration of the outbreak U.S. hard red winter wheat by destination forms the basis of the export reduction. Because Mexico imports wheat by railcar and truck from the United States, it is assumed to be very restrictive and obtain wheat from alternative sources. For other buyers the historical pattern of purchases back through the 2000/01 marketing year are examined for minimum annual imports of hard red winter wheat from the United States (USDA/ERS, *Wheat Yearbook*). Imports from nations that imported roughly the same volume from the United States each year are assumed to maintain those imports. Many nations exhibit an inconsistent pattern where some years show no imports of hard red winter wheat. The assumption is that these nations can obtain alternative supplies from the European Union, Argentine, Canada, and Australia so those imports fall to zero during the Ug99 infection. Once the quarantine and certification program is in place, the effect of the assumed importer response is a reduction of U.S. hard red winter wheat exports of 60%.

When aggregated across the wheat classes, the reduction of U.S. wheat exports in the detection quarter, April-June of 2013, is 59% for Scenario 3. The export loss during the epidemic quarters, July-September 2013 through the April-June 2016, is 52%. New spring wheat crops harvested in the July-September quarter of 2016 are no longer infected so exports of those wheat classes begin to recover. U.S. wheat exports from that quarter through the second quarter of 2017 are 41% lower and exports continue to recover with a decline of 20% from the baseline for quarters 3 and 4 of calendar year 2017.

Scenario 4 simulates the loss in U.S. wheat exports when rival exporters and major import markets are infected with Ug99 wheat rust. If the Ug99 wheat rust is spread worldwide, the impact on U.S. wheat exports would be less severe because importers are less able to replace U.S. wheat. The assumption is that upon detection in the United States importing nations halt imports of hard red spring, hard red winter, and durum wheat for one month while a quarantine and certification system is introduced. Imports of white wheat and soft red winter wheat from the United States continue because these wheat classes are grown in regions where the rust infection is negligible. Mexico is assumed to ban imports of wheat classes grown in the U.S. Plains States. Other importers of these wheat classes are assumed to reduce imports from the United States by 10%.

In scenario 4, the total decline in U.S. wheat exports in the detection quarter, Q2-2013, is 32%. The reduction in U.S. wheat exports for the remaining quarters of the Ug99 epidemic is 12%. With the end of the infection in the United States for the spring wheat harvest of 2016 wheat exports recover. The total reduction in U.S. wheat exports for the 4 quarters starting in the July-September quarter of 2016 is 9%. With the winter wheat harvest in 2017 all U.S. wheat is free of Ug99 and the loss of U.S. wheat exports is 3%.

Single Year Outbreak Results

In Scenario 1 where the Ug99 infection occurs as a single event in a single location in North Dakota, the effects are concentrated in the wheat sector with few spillover effects on other commodities. The four year loss in returns to capital and management on market sales for feed, food, and export use by wheat growers is $1.7 billion, or a 15% reduction in producer returns (Table 1). Payments to land owners fall $706 million. The aggregate four year value disguises a pattern where producer losses are incurred in wheat marketing years 2013/14, 2014/15, and 2016/17 but returns in 2015/16 are higher (Figure 1). This pattern reflects the assumptions about timing of the export loss and recovery. The export loss of 23% starts in the third quarter of 2013, marketing year 2013/14, and it ends with the next spring and durum wheat harvest in 2014. The lower price for wheat in 2013 causes reduced spring and durum wheat output in 2014 which occurs at the same time as export demand recovers (Figure 2). The loss of exports in marketing year 2013/14 boosts carry-over stocks through marketing year 2014/15. Once the larger carry-over stocks are reduced the price of wheat starts to rise and moves above the baseline in 2015/16 which triggers an output expansion and a weaker price in 2016/17 (Figure 2).

The export reduction in Scenario 1 changes prices for wheat as well as prices for other commodities. Lower prices generate economic welfare gains for consumers with prices above the baseline causing losses in consumer surplus. The total gain in economic welfare for U.S. consumers over the 4 years is $913 million, or a 0.1% increase in consumer surplus.

The economic impacts are similar when the infection spreads within North Dakota and results in a 7.2% loss of U.S. spring and durum wheat -- Scenario 2. The total four year loss of returns to capital and management on wheat sales for feed, food, and exports of $1.7 billion is similar to the loss in Scenario 1. Land owners incur a loss in rent of $555 million. The difference in the losses is a result of direct crop losses, $241 million combined with a smaller loss for uninfected wheat growers of $1.4 billion. The smaller loss for those growers occurs because the output reduction dampens the wheat price decline (Figure 2).

Another consideration in this scenario is the cost of treatment. There currently exist fungicides with broad efficacy that are expected to work well at controlling wheat stem rust (Stein). Field trials using 6 types of fungicides conducted on a spring wheat variety in South Dakota suggest that the triozoles worked best to reduce yield loss. Depending on the method, the cost of application for all fungicide varieties is estimated to range from $7 to $10 per acre. Currently, fungicides are applied on grain fields at a maximum of two applications a season. ERS data on cost of production indicate that the 2008-2009 average cost of chemicals applied on wheat fields in the Northern Great Plains is $16.52 per acre. The national average for chemical use is $9.72 per acre. Except for the Great Plains, fungicides are not routinely applied because of the low margin of returns to wheat production. If all of the wheat area in North Dakota is given an added treatment the cost increase would be $139 million.

Adjusting the returns to wheat growers for the additional treatment costs gives a total loss of $1.8 billion (-17%). This value assumes all acres in North Dakota are treated, but wheat output still falls 40 percent as assumed. If the treatments are completely effective, the output loss would be as assumed in the no spread case. Consumers experience gains in economic welfare because the effects of the reduction of U.S. wheat exports dominate the effects of the output reduction and equilibrium prices fall (Figure 2). Compared to the situation where the infection does not spread in North Dakota, the four year consumer economic welfare gains in Scenario 2 at $721 million are smaller because the decline in output dampens the decline in prices.

Multiple Year Outbreak -- Results

The four year changes in returns to producers when there is a multiyear Ug99 infestation and the United States is the only nation affected are reported in Table 1. Because little wheat is fed to animals there are few spillover effects to other commodities beyond acreage shifts in response to relative producer price changes. Outside of the wheat sector the magnitudes of impacts from this multiyear infection of Ug99 on other agricultural producers are small. In the wheat sector the economic effects are large for Scenario 3 with the total four year loss at $11.6 billion, or-107%, of which $4.6 billion (40%) represents the value of wheat lost to the pest. Rental payments to land owners are $2.2 billion (-1.5%) lower. Returns to capital and management for market sales by wheat growers with wheat not infected with Ug99 fall $7.0 billion (-110%) for the four year period because of the lost export sales. Despite the lost wheat output U.S. farm prices for wheat are sharply lower because of the large decline in export sales (Figure 2). Returns to growers are lower throughout the 4 years (Figure 1).

There are treatment costs to include. If all wheat acres in the Plains States from North Dakota to Texas are treated, the annual cost would be $605 million or over $2.4 billion for the four year period.

The total four year loss to wheat growers rises to $14.0 billion, or a decline in producer returns of 130% (not shown in table). The annual pattern reported in Figure 1 shows the largest annual decline of over $4.3 billion occurs during the crop season for wheat year 2015/16 when nearly one-third of spring wheat is lost. The second largest decline occurs in 2013/14 with a loss of over 26% of U.S. spring wheat. The loss of $2.7 billion in 2014/15 is nearly as large as that in 2013/14 but is spread across growers differently because both spring and winter wheat are affected.

Turning from producer returns to consumer welfare, Figure 2 shows that the wheat price falls below the baseline because the large loss in exports dominates the lost output. Lower wheat prices cause sympathetic price declines for other commodities. Thus, the total increase in the economic welfare of U.S. consumers over the period is $4.6 billion, a 0.3% increase in consumer surplus.

Scenario 4 considers the situation if the disease spread is worldwide. The wheat price changes are much different. Initial detection triggers a smaller export loss than for Scenario 3 that nearly exactly offsets the output loss. The large output effects dominate the export loss. As a result, the price is above the baseline in three of the four years (Figure 2). The total four year loss to the wheat sector is $3.2 billion (-2%) (Table 4). However, land owners gain $2.6 billion (1.8%) from higher crop prices. Thus, the smaller reduction in exports means the loss to the wheat sector is $8.3 billion less than in Scenario 3, or a difference of 72%. The output losses are the same so the difference in the results is because wheat growers not infected with Ug99 experience increases in the returns to capital and management on sales for feed, food, and export. In Scenario 3, those growers lost $7.0 billion (-110%) as importers turned to alternative suppliers, but when other nations are infected their gain is $1.3 billion (20%) due to continuing exports.

Again, there are other changes in economic welfare to recognize. Treatment costs are over $2.4 billion for the four year period. The changes in U.S. consumer welfare are different in Scenario 4 compared to the previous situations because the disruption of U.S. wheat exports is less, and the output effects dominate. The economic welfare of U.S. consumers falls $1.4 billion (-0.1%) for the 4 year period in Scenario 4.

Summary

This analysis estimates the economic impacts of hypothetical infections of Ug99 in the United States. The scenarios consider three spread situations and two alternative export reactions. The spread ranges from a single event with no spread, to a single event with spread in North Dakota where risk maps suggest the greatest potential for infection, to a multi-year, multi-state spread. The response by U.S. trading partners is altered according to whether or not other nations also have Ug99. The results demonstrate a wide range of economic costs to U.S. agricultural producers, from $0.6 billion (-0.1%) to over $14 billion (-3%) spread over a four year period.

Large sources of the losses are the value of crops lost, reduced payments to land owners, and treatment costs. In every scenario the value of crops lost is a major component of the losses to producers. Treatment costs can increase economic losses for producers depending on how extensive the added fungicides are applied.

Spillover effects to other sectors occur, but are not very large for each of the scenarios. Most spillover effects result from the decline in land rent to land owners.

In the immediate term, consumers benefit when export reductions outweigh supply reductions of the infections. If there are strong export reductions relative to the supply reductions as in Scenarios 1, 2, and 3, prices fall and consumer welfare increases by up to $4.6 billion (0.3%). When the supply reductions dominate the export reductions, as in Scenario 4, consumer welfare declines by $1.4 billion (-0.1%).

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Figure 1.

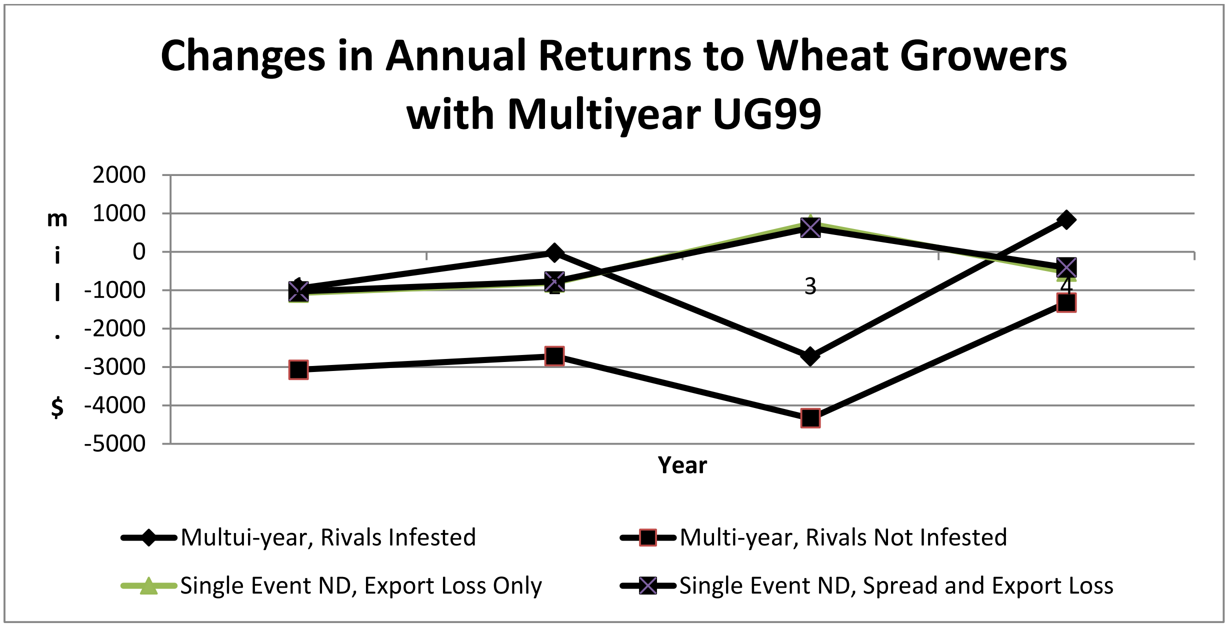
Changes in Annual Returns to Wheat Growers with Multiyear UG99
2000
1000
0
-1000
-2000
-3000
-4000
-5000
mil. $
3
4
Year
Multui-year, Rivals Infested
Multi-year, Rivals Not Infested
Single Event ND, Export Loss Only
Single Event ND, Spread and Export Loss

Figure 2.

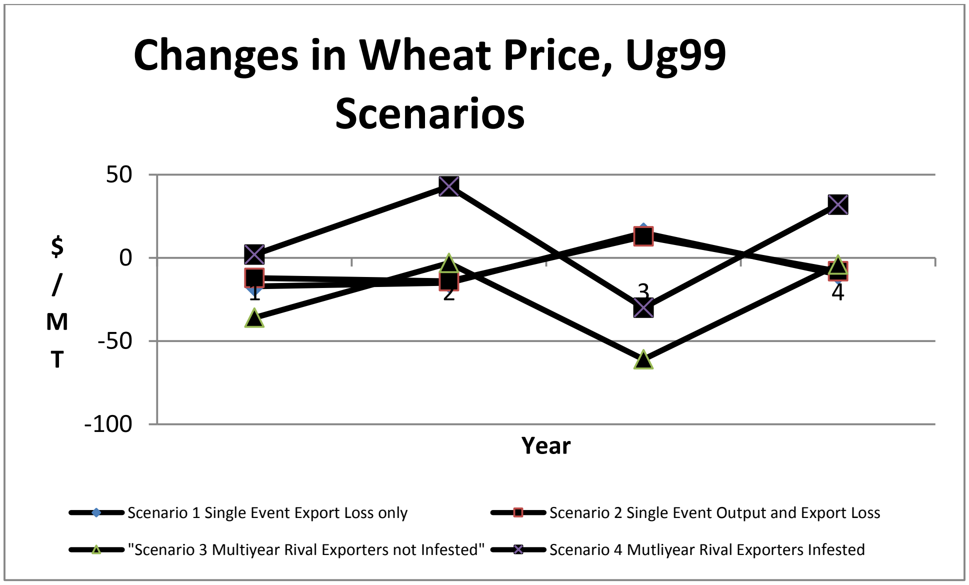
Changes in Wheat Price, Ug99 Scenarios
50
0
-50
-100
$ / M T
1
2
3
4
Year
Scenario 1 Single Event Export Loss only
Scenario 2 Single Event Output and Export Loss
"Scenario 3 Multiyear Rival Exporters not Infested"
Scenario 4 Mutliyear Rival Exporters Infested

Table 1. Changes in Returns to Capital and Management in Agriculture under Alternate Ug99 Potential Introduction Scenarios[1,2]

	Changes in Returns to Capital & Management			Value of Crop Lost	Change in Total Sector Returns	Change in Consumer Surplus	**CHANGE IN TOTAL WELFARE**	Change in Sector Returns	Change in Consumer Surplus	Change in Total Welfare
	Market Returns	Government Payments	Total Returns							
	a.	*b.*	*c.=(a+b)*	*d.*	*e. = (c+d)*	*f.*	*g. = (e+f)*			
	Million dollars							*Percentage*		
***Scenario 1: ND no spread, Export Loss*[3]**										
Wheat	-1,666	0	-1,666	0	-1,666	779	-887	-15.4	1.2	-1.2
Other grains & livestock	-1,117	66	-51	0	-51	134	83	0.0	0.0	0.0
Land owners	-706	0	-706	0	-706		-706	-0.5		-0.5
Total	***-2,489***	***66***	***-2,424***	***0***	***-2,424***	913	-1,511	-0.5	0.1	-0.1
***Scenario 2: ND spread, Export & Output Loss*[3]**										
Wheat	-1,357	0	-1,357	241	-1687	658	-1,029	-15.6	1.0	-1.4
Other grains & livestock	-96	66	-30	0	-11	63	52	0.0	0.0	0.0
Land owners	-555	0	-555	0	-555		-555	-0.4		-0.4
Total	***-2,008***	***66***	***-1,942***	***241***	***-2,253***	721	-1,532	-0.5	0.0	-0.1
***Scenario 3: Multi-year Event, Only U.S. Infected*[4]**										
Wheat	-7,009	0	7,009	4,574	-11,583	3,060	-8,424	-107.1	4.8	-11.4
Other grains & livestock	-759	66	-693	0	-693	1,526	833	-0.2	0.1	0.0
Land owners	-2,167	0	-2,167	0	-2,167		-2,167	-1.5		-1.5
Total	***-9,934***	***66***	***-9, 868***	***4,574***	***-14,442***	4,585	-9,858	-3.0	0.2	-0.4
***Scenario 4: Multi-year Event, Other Nations Infected*[4]**										
Wheat	1,337	0	1,337	4,574	-3,238	-1,289	-4,527	-29.9	-2.0	-6.0
Other grains & livestock	10	66	76	0	76	-154	-78	0.0	0.0	0.0
Land owners	2,560	0	2,560	0	2,560		2,560	1.8		1.8
Total	***3,907***	***66***	***3,973***	***4,574***	***-601***	***-1,444***	-2,044	-0.1	-0.1	-0.1

***See notes on the next page.

[1]Results are for 4 wheat marketing years.
[2]Returns to capital and management are sales plus U.S. commodity program payments less purchased inputs. For crops a rental price is assumed for land.
[3]Excludes the cost of one additional treatment of $139 million for acres in North Dakota.
[4] Excludes the cost of one additional chemical treatment for ND, SD, NE, WY, CO, KS, OK, and TX of $2.4 billion.