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Economic Impacts of Fusarium Head Blight in Wheat

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Abstract

Fusarium Head Blight (FHB), commonly known as scab, has been a severe problem for wheat producers in recent years. This study estimates the economic value of crop losses suffered by wheat producers in the 1990s. Nine states and three wheat classes are included in the analysis, which considers the effects of scab on both production and average prices received. The cumulative value of losses (1991-97) in scab-affected regions is estimated at $1.3 billion. Two states, North Dakota and Minnesota, account for over two-thirds of these dollar losses.

Key Words: Fusarium Head Blight, scab, crop losses, wheat.

Highlights

Wheat producers in several states have experienced significant yield losses due to Fusarium Head Blight (FHB), or scab, in recent years. Losses have been especially severe in the spring wheat region, but soft red winter (SRW) producers have also experienced major outbreaks. This study measures the economic losses suffered by wheat producers in nine states and three wheat classes during 1991-97.

Losses are calculated as the decline in producer revenue due to FHB in affected crop districts. This entails estimating production losses (bushels) as well as the impact of FHB on net prices ($/bushel) received by producers.

In principle, the price impact of FHB can be either positive or negative. On the one hand, a production shortfall puts upward pressure on futures prices and can lead to higher premiums for protein and milling-quality wheat. On the other hand, a larger share of production may be discounted for poor quality. As a result, the average price received by producers in a given region can be lower than normal despite favorable quoted prices for benchmark grades.

For each crop district, production losses are estimated by comparing actual yields to regression forecasts, with adjustments (based on input from extension specialists) to account for the contribution of other factors to yield shortfalls. The analysis also considers the impact of FHB on the ratio of harvested to planted acres. Price impacts are estimated for both futures and basis. Regression models are used to quantify the (positive) impact of FHB-related supply reductions on futures prices. Impacts on basis (either positive or negative) are measured by comparing actual basis values in a scab year to historical averages.

During 1991-97, wheat producers in affected regions suffered cumulative losses of $1.3 billion, according to the analysis. Of this amount, hard red spring (HRS) wheat accounted for $806 million, or 61.8 percent. SRW wheat accounted for $425 million, or 32.6 percent of the total, and durum wheat accounted for $73 million, or 5.6 percent of the total. While aggregate price effects for HRS and durum wheat were largely positive, those for SRW wheat were negative in all years save 1996, due to lower-than-average basis values. Negative price effects were especially severe for SRW wheat in 1995.

Cumulative losses have been largest in scab-affected regions of North Dakota ($458 million) and Minnesota ($428 million). Other states with large cumulative losses include Illinois ($202 million), Ohio ($129 million), and Missouri ($86 million). Scab has added to financial stress in the farm sector, particularly in areas of North Dakota and Minnesota where crop losses have occurred repeatedly since 1993.

Economic Impacts of Fusarium Head Blight in Wheat

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1. Introduction

Fusarium Head Blight (FHB), commonly known as scab, has been a severe problem for U.S. wheat producers in recent years. Yield losses due to FHB have been widely reported.[1] However, there have been few attempts to quantify the economic losses suffered by producers in affected regions. That is the objective of this study.

Our analysis is focused on nine states where substantial FHB outbreaks have occurred during the 1990s and three wheat classes: soft red winter (SRW), hard red spring (HRS), and durum. For SRW wheat, the affected states include Illinois, Indiana, Kentucky, Michigan,[2] Missouri, and Ohio. In these states, significant yield losses attributed to FHB occurred in 1991, 1993, and 1995-96. For HRS wheat, the affected states are Minnesota, North Dakota, and South Dakota. In these states, major yield losses began in 1993 and continued through 1997. Outbreaks of FHB in durum wheat, largely in North Dakota, occurred during the same period.

For each wheat class and crop district, we develop estimates of the lost crop value ($ million) due to FHB. This entails estimation of two quantities: first, the production (bushels) that might have been expected under normal conditions, and second, the price ($/bushel) that might have been expected under normal conditions. The 'price effects' of FHB are an important component of our analysis, as these can either magnify or reduce the value of economic losses in individual regions.

The paper is organized as follows. Section 2 provides a brief explanation of our conceptual approach and delineates the 'price' and 'quantity' effects of FHB. Methodology and data sources are described in Section 3. Results of the analysis, i.e., estimates of economic loss by state, year, and wheat class, are presented in Section 4. The paper concludes with a short summary and discussion of implications.

2. Illustration of Price and Quantity Effects

To estimate the change in producer revenue due to FHB, it is not sufficient to know the size of a production shortfall; the impact on prices received must also be estimated. In principle,

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[1]See McMullen, Jones, and Gallenberg for an overview of FHB in small grains.

[2]Michigan also produces white wheat; however, this is not differentiated from SRW wheat in state-level price data.

scab can either raise or lower the net price received by producers. This depends on two conflicting factors. On the one hand, a production shortfall puts upward pressure on futures prices and can lead to higher premiums for protein and milling-quality wheat. On the other hand, in scab-affected areas, a larger share of production is discounted for poor quality. As a result, the price received by producers in a given region can be lower than normal despite favorable quoted prices for benchmark grades.

Potential impacts of FHB on producer revenue are illustrated below. In Figure 1, it is assumed that the price received by producers is higher than normal as a result of FHB-related production shortfalls. Thus, ps > pn, where ps and pn are prices in 'scab' and 'normal' years. The production shortfall is measured by (qn − qs), where qn is normal production, based on planted acreage and trend yields, and qs is the actual production in a scab year. The change in producer revenue due to scab is given by

$$\Delta R = (ps \times qs) - (pn \times qn) \qquad (1)$$

Producer revenue in a scab year is given by areas A + C, while producer revenue in a normal year is given by areas C + D. The change in revenue is A − D. Thus, producers would gain revenue if a positive price impact more than offset the value of lost production (i.e., if A > D).

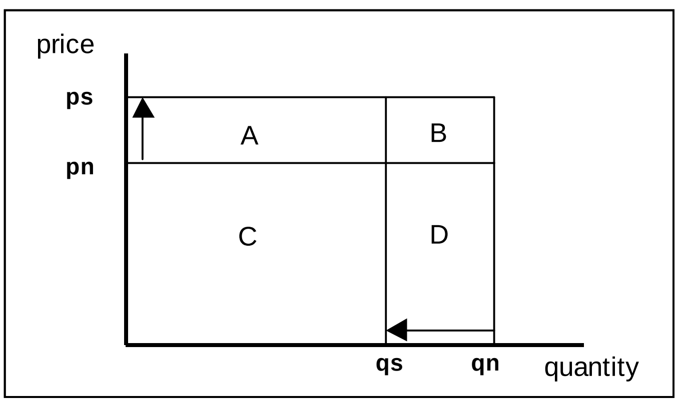

Figure 1. Change in Crop Value When Net Price Impact Is Positive

In Figure 2, it is assumed that the net price received by producers is lower than normal because of scab-related quality problems. Producer revenue in a scab year is given by area G, while producer revenue in a normal year is given by areas (E + F + G + H). The change in revenue is − (E + F + H), a negative amount. Producers lose two ways in this instance: from production shortfalls and lower prices.

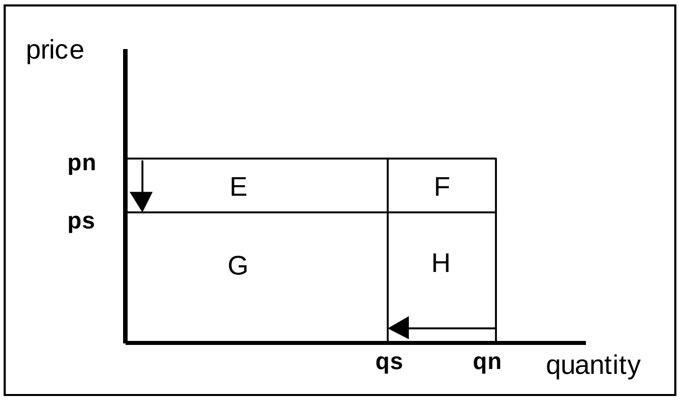

Figure 2. Change in Crop Value When Net Price Impact Is Negative

The revenue impact can be divided into separate price and quantity effects. Estimates of these effects vary, depending on whether actual prices (ps) or normal prices (pn) are used to value production shortfalls; the choice is somewhat arbitrary. In this study, we value production shortfalls at the average of the two prices. This means that area F in Figure 2 is divided equally between price and quantity effects. Thus, the price effect equals – (E + ½F) while the quantity effect equals – (½F + H). Similarly, when the net price effect is positive as in Figure 1, it is measured as (A + ½B), while the quantity effect is – (½B + D).

3. Methodology and Data

The analysis is based on production and price data for individual crop reporting districts (CRDs) where substantial FHB outbreaks occurred during the 1990s. These were identified with the help of researchers and extension specialists. The study area for spring wheat is shown in Figure 3, and the study area for SRW wheat is shown in Figure 4.

To estimate the economic losses due to FHB in a given CRD, it is first necessary to estimate the value of production under 'normal' conditions, i.e., if there had been no outbreak. Normal crop value is the product of two variables: pn, the price that farmers would have received, and qn, their expected production in absence of scab. For years of scab outbreak, both variables are unobserved and must be estimated. The lost crop value is then calculated as the difference between actual and normal crop value.

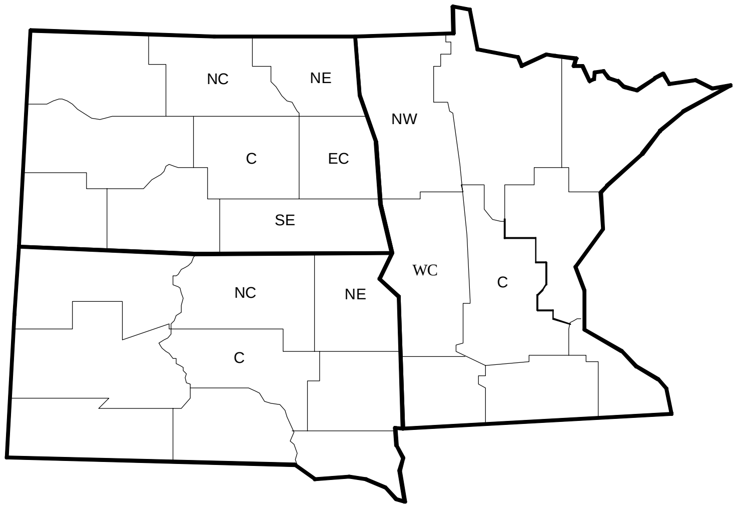

Figure 3. Crop Reporting Districts Included in Spring Wheat Study Area

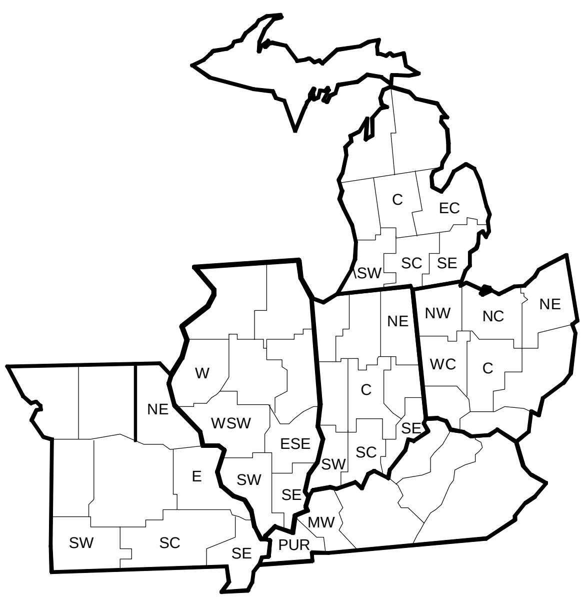

Figure 4. Crop Reporting Districts Included in Soft Red Winter Wheat Study Area

Estimating 'Normal' Production

The estimate of normal production has two components: yield and harvested acres. To derive yield in the absence of FHB, we estimated regression models of the form:

$$y_{it} = \beta_0 + \beta_1 R_{it} + \beta_2 T_{it} + \beta_3 t \qquad (2)$$

where y_{it} is harvested yield in region i, R_{it} is rainfall inches received during the growing season,[3] T_{it} is average temperature during the growing season, and t is the year. The last parameter (β_3) is a measure of trend yield growth. Separate equations were estimated for each crop-reporting district (CRD) using data for years preceding the FHB outbreak.[4] (Results are shown in appendix tables A1 - A3.) Regression models were then used to derive estimates of the yields that would have occurred in later years (given growing conditions) in the absence of FHB.

A complicating factor is that, in some producing regions, FHB occurred simultaneously with other wheat diseases or yields were reduced by flooding. It would be misleading to attribute all of the estimated yield shortfall in these regions to FHB. For that reason, we sought advice from researchers and extension specialists about the relative contribution of scab to yield shortfalls. Their judgments were incorporated as follows. Let yn_{it} denote the normal yield in absence of FHB in production region i and year t. Let yf_{it} denote the forecast value from the regression equation and ys_{it} the actual yield in a scab-affected year. The fraction of a yield shortfall attributed to scab is denoted α_{it} ($0 \leq \alpha_{it} \leq 1$). Normal yields (i.e., the estimated yields that would have occurred in the absence of FHB) are given by

$$yn_{it} = \alpha_{it} yf_{it} + (1 - \alpha_{it}) ys_{it} \qquad (3)$$

Normal yield is a weighted average of the regression forecast and actual yield. If $\alpha_{it} = 1$ for a given region and crop year, then normal yield equals the forecast value, and any estimated yield shortfall ($yf_{it} - ys_{it}$) is attributed entirely to FHB. If $\alpha_{it} < 1$, then normal yield lies between the regression forecast and actual yield, and part of the estimated yield shortfall is attributed to other factors. For example, suppose the yield forecast (yf_{it}) is 40 bu/acre, actual production (ys_{it}) is 28 bu/acre, but only 80 percent of the shortfall is attributed to FHB. Then (adjusted) normal yield is calculated as $yn_{it} = 0.8 \times (40) + (1 - 0.8) \times (28) = 37.6$ bu/acre.

Figure 5 shows actual yield, forecast yield, and the (adjusted) normal yield for two CRDs included in our study. The upper panel shows HRS yields in northeast North Dakota; in 1994 in that CRD, all of the estimated yield shortfall is attributed to FHB ($\alpha_{it} = 1$), so the 'predicted' and 'adjusted' yields coincide. The lower panel shows SRW yields in western Illinois; FHB was not a factor in yield shortfalls in 1992 or 1994 ($\alpha_{it} = 0$), and accounted for a minuscule fraction of the shortfall in 1993 ($\alpha_{it} = .03$). Adjustment factors for all producing regions are reproduced in appendix tables A4 - A6.

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[3]For HRS and durum wheat growing areas, rainfall and temperature data are for April through July. For SRW wheat growing areas, these data are for March through June.

[4]Data from 1970-92 were used to estimate yield models for HRS and durum wheat. Data for 1970-90 were used for SRW yield models.

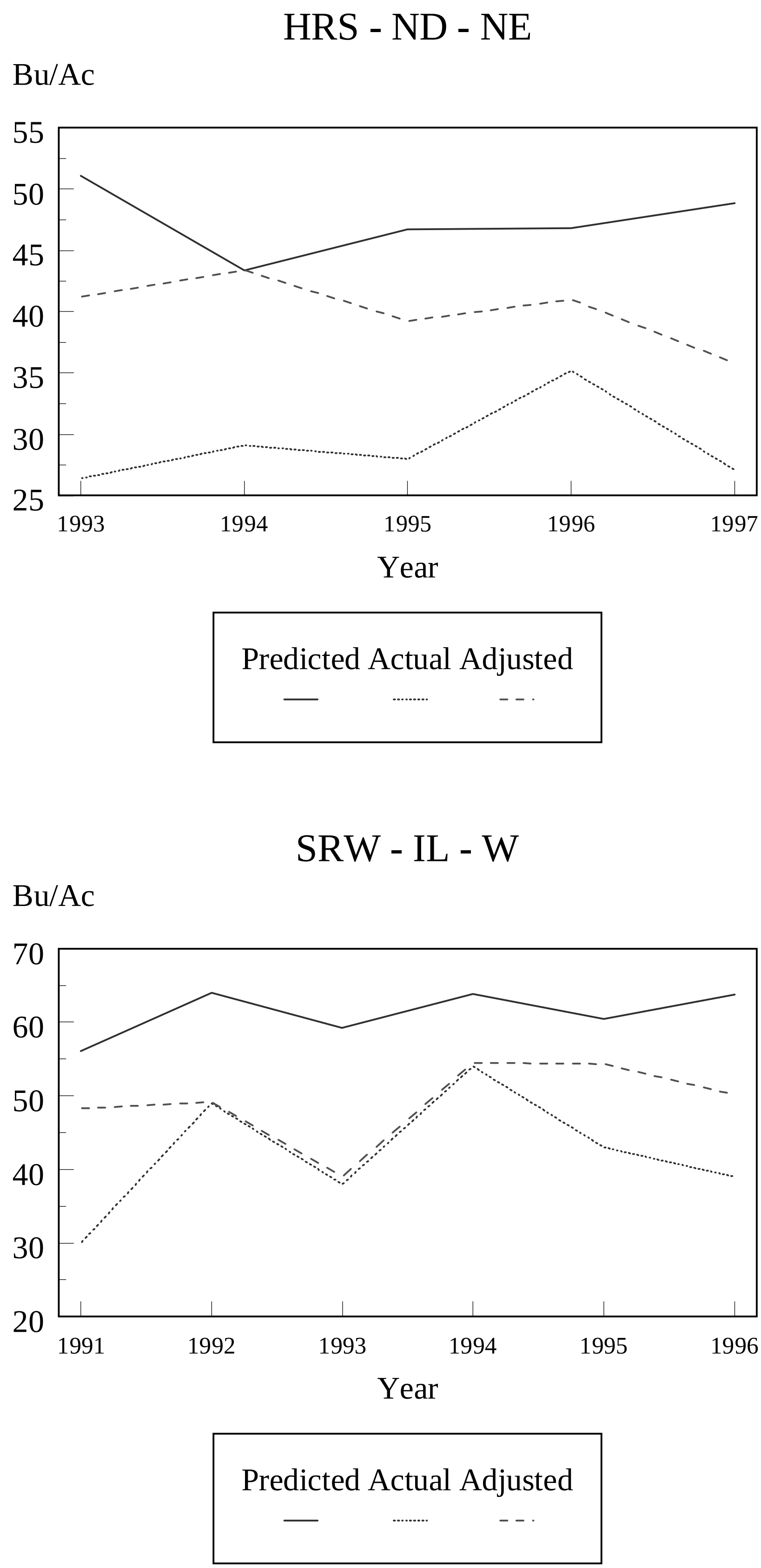

Figure 5. Predicted, Actual, and Adjusted Yields in Selected CRDs

FHB outbreaks can induce a higher-than-average rate of acreage abandonment. To account for this, we incorporated a 'normal' ratio of harvested to planted acres in our estimate of normal production. This was calculated as follows. Let R_i represent the olympic average[5] of the ratio (ah_{it} / ap_{it}), where ah_{it} denotes harvested acres and ap_{it} planted acres, using data from seven years preceding the FHB outbreak. The 'normal' ratio (for region i, year t) is calculated as:

$$Rn_{it} = \alpha_{it} R_i + (1 - \alpha_{it}) \frac{ah_{it}}{ap_{it}} \qquad (4)$$

This uses the same adjustment factor as was used to calculate normal yield. If $\alpha_{it} = 1$ for a given region and year, then the 'normal' ratio of harvested to planted acres is equal to the olympic average. Otherwise, if $\alpha_{it} < 1$, the supposition is that factors other than FHB contributed to an abnormal ratio, and Rn_{it} is adjusted accordingly. Normal production, denoted qn_{it}, is given by the following formula:

$$qn_{it} = [\max(yn_{it} \ , \ ys_{it})] \cdot [\max(Rn_{it} \ , \ \frac{ah_{it}}{ap_{it}})] \cdot ap_{it} \qquad (5)$$

The first bracketed term represents harvested yield. The second bracketed term is the ratio of harvested-to-planted acres. The product of the second term and acres planted (ap_{it}) equals normal harvested acres. The max function is used to correct for two types of data anomalies. If the estimated normal yield falls below actual yield in a scab year, i.e., $yn_{it} < ys_{it}$, the latter value is selected. Similarly, if the normal ratio falls below the actual ratio of harvested-to-planted acres, i.e., $Rn_{it} < (ah_{it} / ap_{it})$, the latter value is used. Thus, in the unlikely event that production is *higher* than normal during a scab year, the analysis will not (falsely) attribute a positive impact to the disease.

Estimating Price Impacts

In estimating the impact of FHB on the net price received by producers, two factors must be considered: first, the impact of a production shortfall on market prices; and second, the quality of the crop. To capture these effects, we divide the average price received into two components: futures and basis.[6] While an FHB outbreak is expected to have a positive impact on futures (by reducing wheat supply), the impact on local basis (averaged over all wheat sold) can be either positive or negative, depending on crop quality and the premiums and discounts assessed by elevators in a given region.

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[5]An olympic average omits the maximum and minimum values contained in a given sample. This is advantageous when the sample is small and select observations (e.g., 1988, a drought year) are viewed as exceptional or unrepresentative.

[6]Basis is defined as the difference between a local cash price and a futures price for the same commodity. As used here, basis refers to the difference between weighted average cash price received (net of premiums and discounts) and average futures during a marketing year.

SRW wheat is generally priced with respect to wheat futures on the Chicago Board of Trade (CBT). To derive the impact of FHB on CBT wheat futures, we first estimated a regression equation. The regression explains the CBT futures price as a function of total wheat supply and the loan rate (a farm program parameter), using annual data from 1980 through 1996. The estimated equation follows, with t-ratios in parentheses:

$$LCBT = 11.250 - 1.074\ LTWS + 0.601\ LLR \qquad R^2 = .65$$

(7.989)* (−4.984)* (3.806)* Obs. 17

* significant at 1% level

Variables are defined as:

LCBT	logarithm of average CBT wheat futures price (c/bu), nearby contracts
LTWS	logarithm of total U.S. wheat supply (million bu), all classes
LLR	logarithm of loan rate for wheat (c/bu) in given marketing year

The coefficient of interest is that associated with total wheat supply (otherwise known as the 'flexibility' coefficient). This indicates that, for a 1 percent change in total wheat supply, the CBT price is expected to change (in the opposite direction) by 1.074 percent.

A similar equation was estimated for wheat futures on the Minneapolis Grain Exchange (MGE), which provides the standard reference for pricing of HRS wheat. In this case, we used HRS supply (in place of total wheat supply) as an explanatory variable. For MGE futures, the estimated equation follows, with t-ratios in parentheses:

$$LMGE = 9.570 - 0.856\ LHRS + 0.361\ LLR \qquad R^2 = .61$$

(6.161)* (−4.075)* (2.593)** Obs. 17

* significant at 1% level
** significant at 5%

Variables are defined as:

LMGE	logarithm of average MGE wheat futures price (c/bu), nearby contracts
LHRS	logarithm of HRS wheat supply (million bu)
LLR	logarithm of loan rate for wheat (c/bu) in given marketing year

The 'flexibility' coefficient is −0.856, indicating that for a 1 percent change in the supply of HRS wheat, the average MGE futures price is expected to change by 0.856 percent in the opposite direction.

Adjustment for Imports

If U.S. wheat supplies were determined solely by domestic production and beginning stocks, the change in supplies due to scab would be equal to the sum of estimated production shortfalls in affected CRDs. However, imports of wheat from Canada represent another component of U.S. supply. Canada is a large surplus producer of spring wheat (HRS[7] and durum), and the surge in U.S. imports since 1993 (Table 1) is partly explained by disease problems in the U.S. spring wheat region. With higher imports offsetting part of a U.S. production shortfall, the change in U.S. supply is less than it otherwise would be. This reduces the positive impact of a U.S. production shortfall on futures prices.

To account for the imports induced by scab, we begin with the assumption that 20 million bushels of HRS wheat would be imported annually from Canada under ordinary conditions. That is the average level of HRS imports during the three marketing years preceding 1993. Imports of HRS were smaller than estimated production shortfalls due to scab in four of five years; in 1996, imports exceeded the shortfall (Table 1). Of the imports exceeding 20 million bushels, only part can be attributed to scab. That is reflected in the formula for expected HRS supply in absence of a scab outbreak:

$$Qn_t^{HRS} = Qs_t^{HRS} + \delta_t^{HRS} - \min[\theta_t^{HRS}(M_t^{HRS} - 20)\ ,\ \theta_t^{HRS}\delta_t^{HRS}] \qquad (6)$$

where variables are defined

Qn_t^{HRS} hypothetical supply (million bushels) of HRS wheat in absence of scab outbreak

Qs_t^{HRS} actual supply of HRS during year of scab outbreak

δ_t^{HRS} estimated U.S. production shortfall of HRS wheat due to scab

θ_t^{HRS} proportion of production losses due to scab, a weighted average of adjustment factors α_{it} in HRS regions[8]

M_t^{HRS} actual imports of HRS wheat.

Table 1. Imports From Canada and Estimated U.S. Production Losses, HRS and Durum

	HRS wheat			Durum wheat		
Marketing year	Imports from Canada (million bu)	Estimated U.S. production losses (million bu)	Ratio of imports to losses	Imports from Canada (million bu)	Estimated U.S. production losses (million bu)	Ratio of imports to losses
1990	10	*	*	17	*	*
1991	15	*	*	18	*	*
1992	34	*	*	27	*	*
1993	62	122.39	0.51	30	10.18	2.95
1994	49	92.15	0.53	22	4.01	5.49
1995	30	49.12	0.61	18	6.39	2.82
1996	53	23.66	2.24	24	8.39	2.86
1997	54	69.26	0.78	26	4.38	5.94

* Not calculated for years of insignificant FHB losses.

[7]HRS is a U.S. classification; the comparable Canadian wheat is Canadian Western Red Spring (CWRS).

[8]For 1993-97, values of θ_t^{HRS} are 0.6985, 0.9116, 0.5267, 0.4068, and 0.5109.

The quantity selected by the min function represents imports attributable to scab; this partially offsets the impact of a production loss on U.S. supply of HRS wheat. The hypothetical supply of all wheat in absence of scab, Qn_t^{ALL}, is calculated as:

$$Qn_t^{ALL} = Qs_t^{ALL} + (Qn_t^{HRS} - Qs_t^{HRS}) + \delta_t^{SRW} \qquad (7)$$

where Qs_t^{ALL} is the actual U.S. supply of all wheat classes and δ_t^{SRW} is the estimated SRW production shortfall due to scab. Note that Qn_t^{ALL} reflects the production shortfall for SRW and supply reduction for HRS; it does not reflect reduced durum production. Based on recent history (Table 1), we assume that any lost U.S. durum production would be entirely offset by imports from Canada.

Impacts on Futures and Basis

Given the flexibility coefficients and supply estimates, the futures prices that would have been observed in the absence of a scab outbreak are estimated as follows:[9]

$$Fn_t^j = \frac{Fs_t^j}{\gamma_j \left(\frac{Qs_t^j - Qn_t^j}{Qn_t^j} \right) + 1} \qquad (8)$$

where j indicates the futures exchange (MGE or CBT) or appropriate supply category, and variables are defined:

- γ_j price flexibility coefficient (for indicated futures supply category)
- Qs_t^j actual wheat supply (HRS wheat for MGE futures, all wheat classes for CBT)
- Qn_t^j estimated supply in absence of scab outbreak
- Fs_t^j futures price (annual average, nearby contracts) in a scab year
- Fn_t^j estimated futures price in absence of scab outbreak

For soft red winter (SRW) growing regions, basis is defined as the difference between the average price received by producers and the average CBT futures. For HRS growing regions, basis is the difference between average price received and average MGE futures. Normal basis relationships for these wheat classes are represented by seven-year olympic averages, using data from years preceding the first scab outbreak.

Durum wheat was not traded on any futures exchange during the period under study. However, a long-term relationship has been observed between durum and spring wheat cash

[9]The price flexibility coefficient is defined: $\gamma = (\Delta P/P)/(\Delta Q/Q)$. The formula is derived by substituting (Fs − Fn)/Fn for the numerator and (Qs − Qn)/Qn for the denominator and rearranging to solve for Fn.

prices: durum tends to trade at about 50 cents/bushel above the spring wheat price.[10] This assumption is built into our estimate of the 'normal' cash price for durum.

Expected cash prices in absence of scab are calculated as follows:

$$\begin{aligned} \text{SRW:} \quad & pn_{it}^{SRW} = Fn_t^{C} + bn_i^{C} \\ \text{HRS:} \quad & pn_{it}^{HRS} = Fn_t^{M} + bn_i^{M} \\ \text{Durum:} \quad & pn_{it}^{D} = Fn_t^{M} + bn_i^{M} + 0.50 \end{aligned} \qquad (9)$$

where variables are defined:

- pn_{it} normal (expected) cash price in absence of scab for indicated wheat class
- Fn_t^C Chicago wheat futures price (annual average)
- Fn_t^M Minneapolis spring wheat futures price (annual average)
- bn_i^C normal (olympic average) SRW basis relative to CBT futures
- bn_i^M normal (olympic average) HRS basis relative to MGE futures

The analysis allows estimated basis effects to be either positive or negative in individual regions. Positive basis effects could arise because of large price premiums, induced by supply shortages, for wheat that meets milling specifications. Conversely, negative basis effects could result if quality-related price discounts apply to a larger-than-average portion of local production.

Data Sources

Data on temperature and precipitation by region were obtained from the National Climatic Data Center (U.S. Department of Commerce). Data on planted and harvested acres, harvested yield, production, and average prices received by producers were obtained from the National Agricultural Statistics Service (U.S. Department of Agriculture). Average CBT and MGE futures prices were derived from a database of weekly quotes collected from *Grain Market News* (U.S. Department of Agriculture) and the *Wall Street Journal*. Basis was calculated as the difference between average price received in a region and the average futures price. For North Dakota, prices received were available by crop reporting district; in other states, prices are based on state averages.[11] Prices for the 1997 marketing year were based on data available through February, 1998. Data on national wheat supplies are from the *Wheat Yearbook* published by the Economic Research Service of the U.S. Department of Agriculture.

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[10]That is approximately the price premium necessary to induce farmers to plant durum instead of HRS wheat, given differences in yield and risk factors.

[11]However, state average prices were used for North Dakota CRDs in 1997, as more detailed information was not yet available.

4. Results

Estimated production losses due to scab, by state and wheat class, are shown in Table 2. Aggregate losses were largest in 1993. Of the total estimated losses of 133.9 million bushels in1993, HRS wheat accounted for 122.4 million bushels.[12] HRS losses were also extremely large in 1994 and 1997. During the entire period (1991-97), HRS wheat accounted for 76 percent of scab-related production losses, SRW wheat 17 percent, and durum 7 percent. North Dakota and Minnesota had the largest cumulative losses, followed by Illinois.

Table 2. Production Losses Due to FHB by State, Class, and Year

State/Class	Year					
	1991	1993	1994	1995	1996	1997
	---million bu---					
HRS						
N. Dakota	-	63.26	39.65	27.18	16.29	38.85
Minnesota	-	47.07	50.58	21.42	7.37	29.28
S. Dakota	-	12.06	1.91	0.52	0.00	1.13
Total HRS	-	122.39	92.15	49.12	23.66	69.26
Durum						
N. Dakota	-	10.02	3.82	6.28	8.36	4.38
Minnesota	-	0.16	0.19	0.11	0.03	0.00
Total Durum	-	10.18	4.01	6.39	8.39	4.38
SRW						
Illinois	24.35	0.75	-	4.71	10.25	-
Indiana	0.00	0.00	-	0.06	1.16	-
Kentucky	0.00	0.02	-	0.02	0.01	-
Michigan	0.00	0.00	-	0.00	3.42	-
Missouri	8.67	0.26	-	2.76	3.26	-
Ohio	6.59	0.30	-	1.38	11.50	-
Total SRW	39.61	1.33	-	8.93	30.05	-
All Classes						
Total	39.61	133.90	96.15	64.44	62.10	73.64

[12]McMullen, et al. estimate a larger spring wheat (HRS and durum) production loss in 1993: 156 million bushels in the Dakotas and Minnesota, versus 132 million bushels in this study. However, their estimate appears to have been based on comparisons with 1992, a year of historically high yields in the region. Our estimates of yield loss are based on predictions from regression models.

Table 3 shows the estimated impact of scab-related production losses on futures prices. The CBT futures price reflects national wheat supplies, while the MGE futures price reflects HRS supplies. The estimated impact on MGE futures was generally more pronounced (except in 1996) because of differences in flexibility coefficients and larger proportionate changes in supplies of HRS wheat. In 1993, the year of largest production losses, the MGE futures price is estimated to have risen by 30 cents per bushel as a result of scab, while the CBT futures price is estimated to have risen by 10 cents per bushel.

Table 3. Estimated Impact of Supply Reductions on Wheat Futures Prices

	Chicago Board of Trade (CBT) Wheat Futures (cents/bu)			Minneapolis Grain Exchange (MGE) Spring Wheat Futures (cents/bu)		
Marketing Year	Actual futures price	Hypothetical price in absence of scab	Difference	Actual futures price	Hypothetical price in absence of scab	Difference
1991	354	351	3	*	*	*
1992	*	*	*	*	*	*
1993	332	322	10	346	316	30
1994	*	*	*	368	345	23
1995	493	482	11	503	479	24
1996	414	406	8	430	424	6
1997	*	*	*	384†	363	21

† 1997 price based on average of nearby contract prices through February 1998.
* Not calculated for years of insignificant FHB losses.

Estimated effects on basis are shown in Tables 4 and 5. These are calculated as the difference between actual basis and the olympic average basis (for years preceding scab outbreak) for each producing region. The effects vary substantially through time and across regions. In 1993, the basis in HRS regions was higher than the olympic average—by as much as 106 cents per bushel in north central North Dakota and by 12 cents in Minnesota. The variation across regions reflects differences in the (weighted) average of premiums and discounts received by producers at local elevators. Some regions appear to have benefitted from unusually high premiums for milling quality wheat in 1993. In other years, mixed effects are evident. Negative effects can arise because of steep price discounts and poor average quality. In SRW producing regions, the estimated effects on basis were strongly negative in 1991 and 1995, but positive in 1996.

Table 4. Basis in Scab-affected HRS Regions†

	NC-ND	NE-ND	C-ND	EC-ND	SE-ND	SD	MN
Year	Actual basis in scab-affected regions (cents/bu)						
1993	67	−6	62	3	11	12	−16
1994	−33	−44	−19	−23	−12	−6	−35
1995	−23	−41	−31	−33	−24	−21	−33
1996	−29	−9	−28	−2	−12	−23	−6
1997	−30	−30	−30	−30	−30	−28	−24
	Olympic average basis for HRS regions prior to scab outbreak (cents/bu)						
	−39	−29	−21	−23	−17	−18	−28
Year	Difference (actual basis minus olympic average) (cents/bu)						
1993	106	23	83	26	28	30	12
1994	6	−15	2	0	5	12	−7
1995	16	−12	−10	−10	−7	−3	−5
1996	10	20	−7	21	5	−5	22
1997	9	−1	−9	−7	−13	−10	4

† Basis calculated as average spring-wheat price received by producers minus average MGE futures for specified marketing year. Prices received are only available at the state level for Minnesota and South Dakota. See text for derivation of expected durum price.

Table 5. Basis in Scab-affected SRW Regions†

	IL	IN	KY	MI	MO	OH
Year	Actual basis in scab-affected regions (cents/bu)					
1991	−98	−82	−103	−70	−117	−61
1993	−51	−54	−49	−28	−65	−39
1995	−104	−97	−109	−83	−109	−97
1996	−2	−8	19	−23	−2	−20
	Olympic average basis for SRW regions prior to scab outbreak (cents/bu)					
	−24	−31	−28	−34	−30	−23
Year	Difference (actual basis minus olympic average) (cents/bu)					
1991	−74	−51	−75	−36	−87	−38
1993	−27	−23	−21	6	−35	−16
1995	−80	−66	−81	−49	−79	−74
1996	22	23	47	11	28	3

† Basis calculated as average wheat price received by producers minus average CBT futures for specified marketing year.

Actual prices received, by class and region, are compared to the hypothetical 'normal' prices (in absence of scab) in Tables 6-8. For HRS and durum wheat, actual prices are generally higher than 'normal' prices, as higher basis values (particularly in 1993) reinforce the positive impact on futures. For SRW wheat in most years (1996 is an exception), actual prices are lower than 'normal' prices, as lower basis values more than offset the futures impact.

Table 6. Prices for HRS Wheat in Scab-affected Regions

	ND-NC	ND-NE	ND-C	ND-EC	ND-SE	SD	MN
	Actual price received for HRS wheat (cents/bu)						
1993	413	340	408	349	357	358	330
1994	335	324	349	345	356	362	333
1995	480	462	472	470	479	482	470
1996	402	422	403	429	419	408	425
1997	354	354	354	354	354	356	360
	Estimated 'normal' price in absence of scab (cents/bu)						
1993	277	287	295	293	299	298	288
1994	305	316	324	321	327	326	317
1995	439	450	458	455	461	460	451
1996	384	395	403	400	406	405	396
1997	324	334	342	340	346	345	335
	Price difference (actual minus normal) (cents/bu)						
1993	136	53	113	56	58	60	42
1994	20	8	25	24	29	36	16
1995	41	12	14	15	18	22	19
1996	18	27	0	29	13	3	29
1997	30	20	12	14	8	11	25

Table 7. Prices for Durum Wheat in Scab-affected Regions

	ND-NC	ND-NE	ND-C	ND-EC	ND-SE	MN
	Actual price received for durum wheat (cents/bu)					
1993	480	424	460	406	462	576
1994	470	434	436	397	518	598
1995	530	515	550	448	533	703
1996	440	397	512	406	431	574
1997	507	507	507	507	507	505
	Estimated ‘normal’ price in absence of scab (cents/bu)					
1993	327	337	345	343	349	338
1994	355	366	374	371	377	367
1995	489	500	508	505	511	501
1996	434	445	453	450	456	446
1997	374	384	392	390	396	385
	Price difference (actual minus normal) (cents/bu)					
1993	153	87	115	63	113	238
1994	115	68	62	26	141	231
1995	41	15	42	−57	22	202
1996	6	−48	59	−44	−25	128
1997	133	123	115	117	111	120

Table 8. Prices for SRW Wheat in Scab-affected Regions

	IL	IN	KY	MI ‡	MO	OH
	Actual price received for SRW wheat (cents/bu)					
1991	256	272	251	284	237	293
1993	281	278	283	304	267	293
1995	389	396	384	410	384	396
1996	412	406	433	391	412	394
	Estimated 'normal' price in absence of scab (cents/bu)					
1991	327	320	323	317	321	328
1993	298	291	293	288	291	298
1995	458	452	454	448	452	459
1996	382	376	378	372	376	383
	Price difference (actual minus normal) (cents/bu)					
1991	−71	−48	−72	−33	−84	−35
1993	−17	−13	−10	16	−24	5
1995	−69	−56	−70	−38	−68	−63
1996	30	30	55	19	36	11

‡ Includes both SRW and white wheat.

The magnitude of price effects, especially in the HRS and durum regions, makes it important to qualify our estimates of economic losses due to scab. Some regions where scab was present experienced relatively small losses in their average yields. An example was north central North Dakota in 1993. In that CRD, estimated production losses due to scab represented only 6.8% of the 'normal' HRS production in 1993, and producers benefitted from an extremely favorable basis (due to premiums for protein and milling quality). In this instance, producers gained more from higher prices, on average, than they lost through reduced yields. The aggregate measures of economic loss include all regions where production was reduced by scab, even those for which positive price effects more than offset the value of lost production.

Table 9 shows estimates of lost crop value ($ million) due to FHB, by year and wheat class. For the period under study, 1991-97, total losses were $1.3 billion. Of this amount, HRS wheat accounted for $806 million, or 61.8 percent. SRW wheat accounted for $425 million, or 32.6 percent of the total, and durum wheat accounted for $73 million, or 5.6 percent of the total. While aggregate price effects for HRS and durum wheat were largely positive, those for SRW wheat were negative in all years save 1996, due to lower-than-average basis values. Negative price effects were especially severe for SRW wheat in 1995.

Table 9. Lost Crop Value Due to FHB by Year and Wheat Class

	1991	1993	1994	1995	1996	1997	Total
	---$ million---						
HRS							
Production Effect	*	-389.95	-299.59	-225.60	-96.56	-239.83	-1,251.53
Price Effect	*	225.51	54.77	49.16	60.04	55.22	444.70
Total	*	-164.44	-244.82	-176.44	-36.52	-184.61	-806.83
Durum							
Production Effect	*	-39.52	-16.17	-32.70	-36.47	-19.46	-144.32
Price Effect	*	32.06	12.45	9.39	-1.47	18.41	70.84
Total	*	-7.46	-3.72	-23.31	-37.94	-1.05	-73.48
SRW							
Production Effect	-115.61	-3.85	*	-37.75	-117.58	*	-274.79
Price Effect	-73.40	-16.52	*	-111.08	50.50	*	-150.50
Total	-189.01	-20.37	*	-148.83	-67.08	*	-425.29
All Classes							
Production Effect	-115.61	-433.32	-315.76	-296.05	-250.61	-259.29	-1,670.64
Price Effect	-73.40	241.05	67.22	-52.53	109.07	73.63	365.04
Total	-189.01	-192.27	-248.54	-348.58	-141.54	-185.66	-1,305.60

* Losses due to FHB not significant.

Tables 10 and 11 show estimates of lost crop value by state.[13] North Dakota experienced the largest cumulative losses during the period ($458 million, HRS and durum), followed by Minnesota ($428 million), Illinois ($202 million), Ohio ($129 million), and Missouri ($86 million).

Table 10. Lost Crop Value for Spring Wheat by State

	1993	1994	1995	1996	1997	Total
	--------------------------------$ million----------------------------------					
HRS						
North Dakota						
Production Effect	-204.93	-128.69	-124.51	-66.33	-134.13	-658.59
Price Effect	155.96	24.32	28.24	38.18	27.52	274.22
Total	-48.97	-104.37	-96.28	-28.15	-106.60	-384.37
Minnesota						
Production Effect	-145.48	-164.31	-98.63	-30.23	-101.75	-540.40
Price Effect	38.30	15.15	15.06	21.86	22.28	112.65
Total	-107.18	-149.16	-83.57	-8.37	-79.47	-427.75
South Dakota						
Production Effect	-39.54	-6.59	-2.46	*	-3.96	-52.55
Price Effect	31.25	15.30	5.86	*	5.41	57.82
Total	-8.29	8.71	3.40	*	1.45	5.27
Durum						
North Dakota						
Production Effect	-38.79	-15.27	-32.04	-36.31	-19.46	-141.87
Price Effect	31.30	11.60	8.55	-1.78	18.41	68.08
Total	-7.49	-3.67	-23.49	-38.08	-1.05	-73.78
Minnesota						
Production Effect	-0.73	-0.90	-0.66	-0.17	*	-2.46
Price Effect	0.76	0.85	0.84	0.31	*	2.76
Total	0.03	-0.05	0.18	0.14	*	0.30

* Losses due to FHB not significant.

[13]State totals are for scab-affected CRDs only.

Table 11. Lost Crop Value for SRW Wheat by State

	1991	1993	1995	1996	Total
	---------------------------$ million----------------------------				
Illinois					
Production Effect	-70.99	-2.18	-19.97	-40.72	-1,33.87
Price Effect	-33.10	-8.82	-36.85	10.71	-68.07
Total	-104.09	-11.00	-56.83	-30.01	-201.93
Indiana					
Production Effect	*	*	-0.27	-6.29	-6.56
Price Effect	*	*	-6.19	6.02	-0.18
Total	*	*	-6.47	-0.27	-6.73
Kentucky					
Production Effect	*	-0.06	-0.07	-0.04	-0.17
Price Effect	*	-0.57	-4.65	12.46	7.24
Total	*	-0.63	-4.73	12.43	7.07
Michigan					
Production Effect	*	*	*	-13.04	-13.04
Price Effect	*	*	*	4.59	4.59
Total	*	*	*	-8.44	-8.44
Missouri					
Production Effect	-24.18	-0.72	-11.55	-12.86	-49.30
Price Effect	-22.50	-4.66	-20.72	10.75	-37.13
Total	-46.68	-5.38	-32.27	-2.10	-86.44
Ohio					
Production Effect	-20.44	-0.89	-5.88	-44.65	-71.86
Price Effect	-17.80	-2.47	-42.65	5.96	-56.97
Total	-38.25	-3.36	-48.54	-38.69	-128.83

* Losses due to FHB not significant.

5. Summary and Discussion

During the 1990s, wheat producers in FHB-affected regions have suffered cumulative losses of $1.3 billion, according to our analysis. This represents the estimated change in crop value after accounting for reduced yields, higher abandoned acres, and price impacts on futures and basis. The economic losses have been most severe in the spring-wheat growing regions, particularly North Dakota and Minnesota. These two states account for 67.9 percent of the estimated total losses.

One of the main difficulties in measuring economic losses due to FHB is estimating the price effects. While supply reductions tend to increase the futures price, the effects on average basis (difference between local cash price and futures) are less certain. Shortages of milling-quality wheat can induce large price premiums, which favor producers who have high quality wheat to sell. However, many producers in scab-affected regions face quality discounts due to damaged kernels, low test weight, or vomitoxin. The average basis in a region depends on the quality of wheat sold by all producers and the premiums and discounts applied by local elevators.

To measure the impact of scab on basis, we used deviations from olympic-average basis values in years preceding the scab outbreak. Results indicate that the effects on basis were primarily negative in the SRW regions (except in 1996), more than offsetting gains in futures prices. In spring wheat regions, the impacts on basis varied by CRD and year. However, large positive basis effects were estimated in 1993, the year of largest production shortfalls. Combined with the impact on MGE spring wheat futures, this helped to offset much of the economic loss due to scab in that year.

The positive price effect for spring wheat that we estimated for 1993 draws attention to what may be termed an ‘aggregation problem.’ Our analysis used CRD-level production data and CRD or state-level price data to derive the economic losses suffered by producers. Data at this level of aggregation do not convey the severity of losses for individual producers whose yields and price were lower than average. Moreover, in some CRDs where producers benefitted (on average) from higher prices, scab-related production losses were fairly small or localized. Our estimates of economic loss are affected, unavoidably, by the inclusion of positive price effects for all wheat sold in a CRD—even wheat sold by producers who suffered no yield losses.

This problem notwithstanding, it is clear that many CRDs have suffered major economic losses as a result of FHB. These losses are bound to have broader repercussions at state and regional levels, as producers’ losses are felt throughout the economy. Based on results from a state-level input-output analysis for North Dakota (Dean Bangsund and Larry Leistritz, personal communication), the ‘multiplier effect’ of lost crop value is substantial: for each dollar of lost crop value, state-level economic activity declines by $3.68, after accounting for sectoral linkages and spending patterns within the state economy. If the same multiplier held for other states considered in this study, the cumulative economic impact of FHB during 1991-97 would be $4.8 billion.

There is other, more tangible evidence of economic distress in scab-affected regions. Net farm income for 1997 in the north central region of North Dakota was the lowest since 1989, down 34 percent on average from 1996, according to North Dakota Farm Business Management

(FBM) records (North Dakota Farm Business Management Record Program). Net farm income averaged $22,528 during 1997, far short of the $35,000 that FBM records indicate is the typical amount spent per farm for family living (including taxes) in the region. The 20 percent least-profitable farms averaged a negative $16,620 net farm income.

Income losses have resulted in a reduction in farm numbers. About 2,000 farms were lost in North Dakota during 1992-1996, versus 500 during the previous four years, according to North Dakota Agricultural Statistics. This trend may be accelerating during 1998. Auction sale listings (for Mid-March through May) were up 55 percent over a year ago in the March 16 issue of *AGWEEK*, an agricultural publication serving the northern Red River Valley (Johnson).

Loan activity by the Farm Service Agency (FSA) in northwest Minnesota has doubled since 1997 (Carr). FSA loans are made to farms that do not qualify for regular bank operating loans. This region, one of the hardest hit by FHB, represented 48 percent of FSA loan activity for Minnesota as of mid-March.

Revenue shortfalls are occurring at a time of rising production costs. Operating costs between 1991 and 1996 increased by 60 percent, according to FBM records for North Dakota. Meanwhile, government assistance is declining. Disaster payments are no longer available to the extent that they were during the early years of the disease infestation, and multi-peril crop insurance programs provide less of a safety net since they are based on average yields, which have fallen in the last several years. These factors accentuate the problem facing producers who have suffered repeated losses due to scab.

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Appendix Tables

Table A1. HRS Wheat Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
ND - NC	94.227	0.32133	-1.4173	0.64874	0.4029	0.2976	21
	(3.305)	(1.685)	(-2.890)	(1.297)			
ND - NE	85.402	0.5673	-1.0613	0.47697	0.3101	0.1883	21
	(2.285)	(2.337)	(-1.698)	(0.7834)			
ND - C	75.725	0.33886	-1.0997	1.0742	0.4323	0.3321	21
	(2.423)	(1.669)	(-2.103)	(2.110)			
ND - EC	93.574	0.63324	-1.2613	0.60845	0.3619	0.2493	21
	(2.415)	(2.590)	(-1.922)	(1.138)			
ND - SE	78.095	0.40425	-1.0025	0.26589	0.2333	0.098	21
	(1.935)	(1.803)	(-1.511)	(0.5233)			
MN - NW	70.111	0.72676	-0.88439	1.0175	0.4083	0.3039	21
	(1.522)	(2.842)	(-1.157)	(1.528)			
MN - WC **	46.37	0.61307	-0.54676	1.2211	0.3581	0.2448	21
	(0.9857)	(2.788)	(-0.7331)	(2.189)			
MN - C **	-26.752	0.20103	0.91152	0.46975	0.1508	0.001	21
	(-0.4797)	(0.6544)	(1.017)	(0.9343)			
SD - NC	79.998	0.36576	-1.134	0.58488	0.3396	0.223	21
	(1.714)	(1.710)	(-1.571)	(0.8920)			
SD - NE **	36.78	0.47997	-0.47984	1.2704	0.3232	0.2037	21
	(0.8842)	(2.576)	(-0.7205)	(2.563)			
SD - C	84.557	0.32151	-1.1035	-0.047464	0.291	0.1659	21
	-1.702	-1.289	(-1.452)	(-0.079)			

Numbers in the parentheses are t-values

** Indicates error structure corrected for first order autocorrelation

Table A2. Durum Wheat Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
ND - NC	98.817	0.32251	-1.4729	0.70589	0.4058	0.3009	21
	(3.332)	(1.625)	(-2.887)	(1.356)			
ND - NE	84.35	0.36631	-1.1761	0.82275	0.3616	0.2489	21
	(2.798)	(1.829)	(-2.275)	(1.475)			
ND - C	82.668	0.46442	-1.2943	1.3865	0.5387	0.4573	21
	(2.616)	(2.263)	(-2.449)	(2.693)			
ND - EC	94.682	0.85496	-1.3889	0.87211	0.4673	0.3733	21
	(2.348)	(3.360)	(-2.033)	(1.567)			
ND - SE	65.407	0.5025	-0.89617	0.83324	0.3908	0.2832	21
	(1.750)	(2.420)	(-1.459)	(1.771)			
MN - NW	61.129	0.6421	-0.82059	1.4907	0.4763	0.3838	21
	(1.416)	(2.678)	(-1.145)	(2.387)			
MN - WC **	35.806	0.42769	-0.39002	1.2589	0.4217	0.3197	21
	(1.044)	(2.674)	(-0.7170)	(3.084)			

Numbers in the parentheses are t-values

** Indicates error structures corrected for first order autoregression

Table A3. SRW Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
IL - W	56.233	1.2241	-0.24502	-0.58471	0.6816	0.6179	19
	-1.279	-4.483	(-0.3298)	(-1.742)			
IL - WSW	75.505	0.93293	-0.4845	-0.61913	0.6284	0.5541	19
	-1.783	-3.799	(-0.6918)	(-1.884)			
IL - ESE	35.662	0.85432	0.21217	-0.73802	0.6479	0.5775	19
	-0.8517	-3.77	-0.3069	(-2.286)			
IL - SW	80.715	0.80986	-0.55467	-0.83165	0.6176	0.5412	19
	-1.86	-3.643	(-0.7916)	(-2.814)			
IL - SE	-2.2713	0.79954	0.7623	-0.62178	0.5553	0.4664	19
	(-0.04404)	-3.272	-0.9269	(-1.910)			
IN - NE **	70.906	0.89601	-0.57457	-0.17975	0.6339	0.5606	19
	-2.351	-6.03	(-1.111)	(-0.4213)			
IN - C **	90.46	1.0548	-0.7959	-0.36563	0.7873	0.7447	19
	-3.339	-9.376	(-1.763)	(-1.292)			
IN - SW	29.112	0.76875	0.22551	-0.39652	0.4521	0.3426	19
	-0.5295	-3.081	-0.2547	(-1.101)			
IN - SC **	42.918	0.66552	-0.16107	-0.073021	0.4488	0.3386	19
	-1.015	-3.651	(-0.2327)	(-0.2520)			
IN - SE	33.704	0.90967	0.013917	-0.25987	0.6554	0.5864	19
	-0.7634	-4.818	-0.01932	(-0.8592)			
KY - PUR **	4.975	0.74822	0.46648	-0.27356	0.5624	0.4749	19
	-0.0909	-2.577	-0.5423	(-1.060)			
KY - MW	63.983	0.6774	-0.40115	-0.37702	0.4075	0.2889	19
	-0.8769	-2.169	(-0.3477)	(-0.8993)			
MI - C	46.362	0.7124	-0.33776	0.51998	0.3094	0.1713	19
	-1.105	-2.529	(-0.4099)	-0.9605			
MI - EC	33.645	1.3381	-0.087447	0.79063	0.6995	0.6394	19
	-0.9666	-5.78	(-0.1301)	-1.771			
MI - SW	57.557	0.88435	-0.52123	0.093666	0.4865	0.3838	19
	-1.543	-3.208	(-0.7884)	-0.1458			
MI - SC	76.68	0.88382	-0.8258	0.013682	0.4688	0.3626	19
	-1.805	-3.181	(-1.081)	-0.02038			
MI - SE	54.808	0.99427	-0.46167	0.36915	0.6047	0.5257	19
	-1.64	-4.657	(-0.7414)	-0.6588			
MO - NE **	76.348	0.74045	-0.58409	-0.51745	0.3678	0.2414	19
	-1.543	-2.953	(-0.7318)	(-1.294)			

Table A3 (Cont.)

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
MO - E	42.048	0.54152	-0.005345	-0.47311	0.4246	0.3095	19
	-0.9438	-2.516	(-0.007128)	(-1.783)			
MO - SW	95.491	0.48229	-0.96776	-0.43828	0.4027	0.2832	19
	-2.16	-2.27	(-1.333)	(-1.645)			
MO - SC	38.84	0.58563	-0.10129	-0.38543	0.4907	0.3888	19
	-1.002	-3.128	(-0.1553)	(-1.670)			
MO - SE **	53.13	0.18257	0.0076974	-0.89689	0.3791	0.255	19
	-1.803	-0.8101	-0.01441	(-2.865)			
OH - NW **	11.227	0.88812	0.42239	0.55772	0.5406	0.4487	19
	-0.258	-4.883	-0.5589	-0.899			
OH - NC **	14.405	0.95953	0.41396	0.0062829	0.6824	0.6188	19
	-0.4492	-6.564	-0.7199	-0.01602			
OH - NE **	0.68114	0.88102	0.60395	-0.077001	0.7398	0.6877	19
	-0.0267	-8.242	-1.282	(-0.2230)			
OH - WC **	30.901	0.92016	0.24147	-0.29203	0.6805	0.6166	19
	-0.9204	-6.548	-0.4161	(-0.9234)			
OH - C **	17.405	1.0137	0.4663	-0.5433	0.8358	0.803	19
	-0.6465	-11.11	-1.031	(-2.278)			
Numbers in the parentheses are t-values							
**Indicates error structures corrected for first order autoregression							

Table A4. Fraction of SRW Yield and Area Loss Attributable to FHB (α_{it}), by State and Year

Year	IL	IN	KY	MI	MO	OH
1991	0.7	0	0	0	0.7	0.7
1992	0.01	0	0.02	0	0.01	0.01
1993	0.05	0	0.05	0	0.05	0.05
1994	0.05	0	0.01	0	0.05	0.05
1995	0.65	0.1	0.05	0	0.65	0.65
1996	0.45	0.16	0.01	0.2	0.45	0.45

Source: Extension Specialists

Note: fractions for Missouri and Ohio were assumed to be identical to those for Illinois

Table A5. Fraction of HRS Yield and Area Loss Attributable to FHB (α_{it}), by CRD and Year

Year	ND-NC	ND-NE	ND-C	ND-EC	ND-SE	MN-NW	MN-WC	MN-C	SD-NC	SD-NE	SD-C
1993	0.5	0.6	0.6	0.6	1	0.8	0.7	0.7	0.7	0.7	0.7
1994	0	1	1	0.8	0	0.9	1	1	0.2	0.5	0.2
1995	0.2	0.6	0.25	0.2	0.1	0.6	0.1	0.1	0.1	0.1	0.1
1996	0.33	0.5	0.33	0.25	0	0.35	0	0	0	0	0
1997	0.5	0.4	0.25	0.6	0.2	0.6	0.2	0.2	0.2	0.2	0.2

Source: Extension specialists.

Table A6. Fraction of Durum Yield and Area Loss Attributable to FHB (α_{it}), by CRD and Year

Year	ND-NC	ND-NE	ND-C	ND-EC	ND-SE	MN-NW	MN-WC
1993	0.35	0.7	0.7	0.7	1	0.7	0.7
1994	0	0.6	0.5	0.7	1	0.6	0.7
1995	0.3	0.5	0.5	0.7	0.8	0.5	0.7
1996	0.7	0.6	0.7	0.7	0.8	0.6	0
1997	0.4	0.55	0.7	0.7	0.8	0	0

Source: Extension specialists.