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Economic Impact of Fusarium Head Blight in Malting Barley: Blending Margins and Firm-Level Risk[1]

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The Issue

The upper Midwest has traditionally accounted for most U.S. production of six-rowed malting barley. Beginning in 1993, this region experienced a prolonged outbreak of fusarium head blight (FHB), a fungal disease of small grains (wheat and barley) commonly known as scab. FHB led to major yield losses in Minnesota and North Dakota, as well as substantial price discounts for a quality factor, DON (*deoxynivalenol*), often associated with the disease. Johnson et al. (1998) reported that the direct and secondary economic impacts of FHB and DON for the United States were $1.3 billion for wheat from 1993 to 1997. The U.S. General Accounting Office (U.S. GAO) estimated direct FHB and DON losses for North Dakota barley growers over the same period to be $200 million. So prevalent was DON during the 1993-2000 crop years, and so severe the price discounts, that many Midwestern producers shifted out of barley acreage. Barley acreage in the Dakotas and Minnesota has fallen by over 50 percent during the past six years. In this paper, we provide estimates of FHB and DON losses for barley producers, develop a blending model to mitigate DON losses, and derive implications for the aggregate cost of DON. Challenges and pitfalls presented by firm-level risks (testing inaccuracies and advisory limits) are discussed.

Implications and Conclusions

FHB and DON present significant challenges to producers, grain elevators, and the brewing industry. Yield reductions and price discounts incurred by producers in North Dakota, Minnesota, and South Dakota averaged about $45.3 million annually during the years 1998 through 2000. Losses are more substantial when secondary economic impacts are considered. For every $1 of scab losses incurred by the producer, $2 in losses are incurred in other areas of rural and state economies.

One way of mitigating these losses is to blend barley with DON and barley without DON. Results from the grain blending model show a sharp decline of DON discounts and losses after blending. The average discount fell from $0.57/bu to $0.17/bu in 1998, $0.48/bu to $0.14/bu in 1999, and $0.38/bu to $0.15/bu in 2000. However, producers may not benefit from blending margins (gains from improved quality less blending costs) because these margins are the primary source of revenue for grain elevators. It should also be noted that the aggregate costs of DON to grain handlers are difficult to estimate because DON is subject to an unusual amount of measurement uncertainty, and penalties for excess DON pose an unusual level of risk.

What is the Economic Impact of FHB?

In the year 2000, the U.S. Wheat and Barley Scab Initiative received $4.3 million to conduct research in areas that will mitigate pathological and economic impacts of FHB and DON. These areas include biotechnology; chemical and biological control; epidemiology and disease management; food safety, toxicology, and utilization; germplasm introduction and enhancement; and variety development and uniform nurseries. FHB and DON cause direct and secondary economic losses in each of the sectors of the vertical chain (producers, grain handlers, and brewers). Direct losses are primary-producer lost income while secondary losses are losses induced, either directly or indirectly, in other sectors of the economy. For example, DON poses several problems for brewers. DON is water-soluble and heat-stable, so it survives throughout the malting and brewing process. DON in malt can cause unacceptable “gushing” of beer. Equally important is the problem of public perception. Anheuser Busch, the largest U.S. brewer, guards against any suggestion of toxicity in its products by refusing all barley with detectable levels of DON. Because of these problems, malt companies and brewers have reduced their reliance on U.S. Midwest barley supplies, shifting more of their procurement to western states and Canada. Anheuser Busch, which formerly used six-rowed barley malt for about 70 percent of its needs, is now using six-rowed and two-rowed malts in approximately equal proportions (western supplies of two-rowed malting barley have been less susceptible to FHB and DON).

Several studies (McMullen, Jones, and Gallenberg, 1997; Steffenson, 1998; Johnson et al., 1998; U.S. GAO, 1999; and Nganje et al., 2001) have been conducted to assess

Table 1 Direct Economic Impacts from Fusarium Head Blight in Barley in the Northern Great Plains, 1998 through 2000

State	Economic Effect	1998	1999	2000	Total 1998-2000
		------------------------------	$ X 1,000	----------------------------	
ND	Production loss	15,944	13,318	23,191	52,453
	Price effect	21,111	8,390	21,022	50,523
	Total	37,055	21,708	44,213	102,976
MN	Production loss	12,440	3,654	3,860	19,954
	Price effect	7,494	1,432	3,771	12,697
	Total	19,934	5,086	7,631	32,651
SD	Production loss	328	137	43	508
	Price effect	227	0	0	227
	Total	555	137	43	735
All States	Production loss	28,712	17,109	27,094	72,915
	Price effect	28,832	9,822	24,793	63,447
	Total	57,544	26,931	51,887	136,362
Total Direct and Secondary Economic Impact					
	North Dakota	114,067	66,826	136,100	316,993
	Minnesota	61,364	16,659	23,489	100,512
	South Dakota	1,709	421	133	2,263
	Total	177,140	82,906	159,722	419,768

Source: Nganje et al. (2001). U.S. GAO (1999) provides direct revenue losses from 1993-1997 for North Dakota. These losses total $201 million and range from a low of $20 million in 1995 to a high of $68 million in 1997.

direct economic impacts of FHB and DON in wheat and barley. Two of these studies (U.S. GAO, 1999; and Nganje et al., 2001) focus in particular on direct and secondary economic impacts. Results of both studies are summarized in table 1. Direct losses over the period were greatest in North Dakota ($103 million), followed by Minnesota ($33 million) and South Dakota ($0.7 million). Total direct losses in the three states were greatest in 1998 at $58 million, decreased in 1999 to $27 million, and increased again, to

Table 2 Market Discounts for DON, Midwest Six-Rowed Barley, 1995-2000

Marketing Year	Discounts Relative to Zero DON ($/bu)						Weighted Average Discount† ($/bu)
	0 - 0.5 ppm	0.6 - 1.0 ppm	1.1 - 2.0 ppm	2.1 - 3.0 ppm	3.1 - 4.0 ppm	> 4 ppm	
1995	0	0.35	0.40	0.45	0.55	1.05	0.66
1996	0	0.34	0.41	0.46	0.54	1.24	0.47
1997	0	0.58	0.88	0.93	0.98	1.48	0.79
1998	0	0.55	0.60	0.65	0.75	1.29	0.57
1999	0	0.35	0.40	0.45	0.50	1.04	0.48
2000	0	0.50	0.55	0.60	0.65	1.15	0.58

† Weights are derived from annual crop quality survey.

$52 million, in 2000. Total direct and secondary economic impacts in the tri-state region were estimated at $420 million from 1998 to 2000. Over this period, overall economic losses in the three states were greatest in 1998, followed closely by the losses experienced in 2000. About 75 percent or $317 million of the losses occurred in North Dakota.

Approximately 48 percent of the estimated losses in the three states was attributable to price losses. Price losses, or discounts, reflect the preferences (and costs) of malt companies and brewers. The following comment by Bruce Sebree (1998) of ADM Malting provides an industry perspective:

> In actuality, we are not really interested in the DON content of the malting barley we purchase. What interests us is the processing attributes of that barley into malt and the subsequent malt into beer ... . Luckily, the attributes we want appear to correlate fairly well with the DON content of the barley. This correlation is not perfect by any means, but allows us a certain “probability” that the barley will process into acceptable malt. This ... can change from crop year to crop year and growing area to growing area. In any event, in most years and from most regions, we find that barley up to about 1 part per million (ppm) DON will process into malt and beer relatively trouble free. When you increase the level up to 2 ppm, you effectively double the potential for problems. For barley between 2 and 3 ppm, the potential for trouble once again doubles, and on up to 4 ppm increases probably another 2-3 fold and is nearly unmanageable.

An example of the average market discount schedules used to compute price losses in table 1 is shown in table 2. Note that large jumps in the schedule occur between 0.5 ppm (maximum) and 1.0 ppm. The next jumps in the discount schedule, that is, for DON in excess of 1.0, 2.0, and 3.0 ppm, are relatively small. However, barley with DON in excess of 4.0 ppm is valued at the feed barley price. The last column in table 2 shows a weighted average discount for each year. The weights, in this case, are fractions of the six-rowed barley crop falling within indicated DON ranges. Grain elevators charge producers according to these discount schedules and, subsequently, blend purchased grains from different geographic locations to meet brewers' specifications and obtain higher prices in the process. The analysis in the subsequent sections explores further how price losses are affected by blending possibilities, with particular emphasis on DON.

How Does Grain Blending Affect DON Losses in Barley?

Grain blending is prolific at all levels of grain handling and merchandising (Rowley, Evans, and Marwick, 1985). The motivations for and scope of blending have been discussed by Fulton and Hucq (1996). However, the effectiveness of grain blending in mitigating FHB and DON impacts has not yet been analyzed. Before developing a grain blending model, it is appropriate first to identify whether blending opportunities do exist. Figure 1 shows the distribution of DON in each of the last ten crop years. Lines indicate the percentage of the crop with less than the indicated level of DON. Attention is drawn to the line for 0.5 ppm. When DON is at this level or below, it is considered "non-detectable" and no discounts apply. About 50 percent and 35 percent of the crop fell into this category in 1999 and 2000, respectively; these figures represent a marked improvement from earlier years. DON clearly has a more important impact on the value of barley sold for malting than on the value of barley sold for feed. Although high concentrations are to be avoided in livestock rations (especially for swine, but also for cattle), the grain handling industry has become adept at "blending off" the high-DON barley for feed use (Johnson et al.,1998). While the discount associated with DON in excess of 4 ppm reflects the malting-feed price spread, downgrading from malting to feed can also occur because of other quality factors. Not all barley with low DON levels would have been destined for the malting market. It is appropriate, therefore, for grain blending models to incorporate other quality characteristics.

The Blending Model

Blending models can provide some insight into the aggregate effects of DON (Rowley, Evans, and Marwick, 1985). The blending model used in this analysis draws upon annual regional crop quality surveys conducted by the Department of Cereal Science at North Dakota State University.[2] In this paper, the blending model is based on a linear programming formulation. The objective of the model is to maximize the value of the

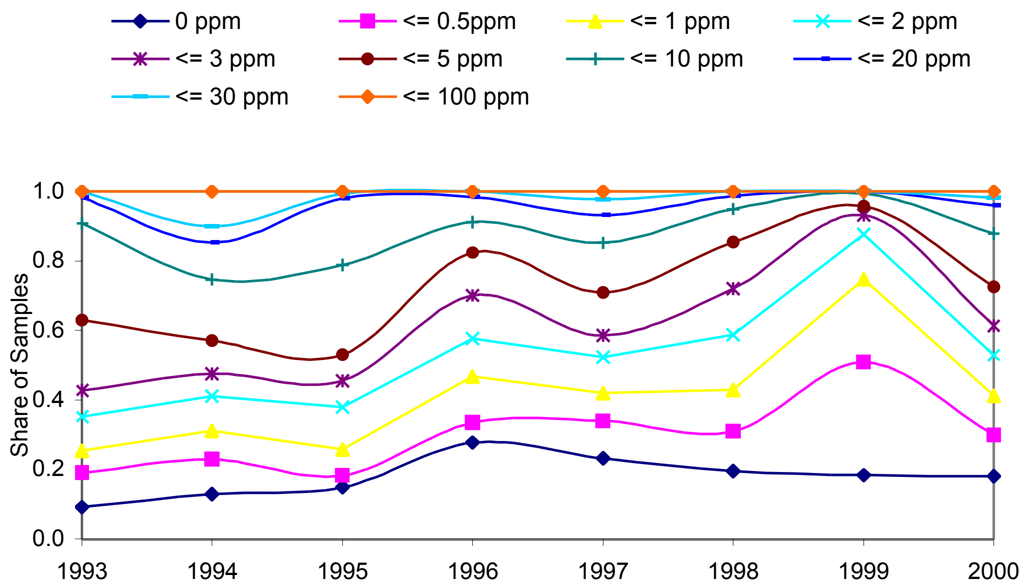

Figure 1 Distribution of DON in Midwestern six-rowed barley by crop year

crop from all barley producing crop reporting districts (CRDs) in the tri-state region (malting premium less discounts for DON, multiplied by quantity sold for malting use and an endogenous probability that the malting limit for DON is satisfied), subject to production and quality constraints. The endogenous probability of satisfying DON limits is specified as a normal cumulative density function, given by the ratio of the maximum allowable level of DON (without price discounts) less the weighted average of DON occurrence in a particular CRD to the weighted average of the variance on DON in the CRD (Johnson, Wilson, and Dierson, 2001).

Four quality parameters are included: percent protein, percent plump kernels, test weight (lb/bu), and DON (ppm). This is not an exhaustive list, but includes parameters of great interest to the malting industry. A major challenge faced in grain blending models is that several quality characteristics may be negatively correlated. Therefore, the goal of increasing quality for one characteristic would conflict with another. To overcome this limitation, we use Gaussian quadrature to identify representative barley samples in the crop quality survey data set that will maintain the properties of each quality distribution prior to and after the blend (DeVuyst, Johnson, and Nganje, 2001). Another advantage of the Gaussian quadrature formulation is that it allows probability weights to be selected so that fewer observations in a sample yield first and second moments identical to moments of the population. For example, of 158 observations (barley samples, representing our population) in the 1998 survey, we identify 15. Probability weights are selected so that

Table 3 Estimated Discount and Aggregate Price Effect after Blending

	1995	1996	1997	1998	1999	2000
Average selling discount for DON ($/bu sold for malting)	0.088	0.137	0.141	0.174	0.141	0.153
Price effect after blending (000s$)	-	-	-	6,444	2,447	5,437
Quantity sold as malting (million bu)	85	85	83	85	85	85
Percent fraction of crop sold as malting	72	51	70	70	71	68

these 15 observations yield first and second moments (for four quality variables) identical to those for all observations. The probability weights are converted into quantities (summing to total regional supply of six-rowed malting barley) for purposes of the blending analysis. In this way, we derive a blending model of manageable size that duplicates the distribution (up to second-order moments) of the four quality variables (protein, plump kernels, test weight, and DON) in the regional barley crop.

Barley sold for malting must meet industry quality requirements (constraints in our blending model). These are specified as the following: maximum 13.5 percent protein; minimum 70 percent plump kernels; and minimum 43 lb test weight. Discounts apply for DON in excess of specified limits (0.5, 1.0, 2.0, and 3.0 ppm). Discounts were obtained from an industry source. There are no discounts for DON less than 0.5 ppm. A quantity limit of 85 million bushels is imposed for total malting sales; that is approximately the annual U.S. utilization of six-rowed malting barley. The results of this regional blending model are discussed below.

Impact of DON with Grain Blending

Results for 1995 through 2000 are shown in table 3. The estimated selling discounts for DON are those received by grain handlers after they have blended available supplies to maximize the value of the Midwestern barley crop. These results show a sharp decline of the discounts after blending. The average discount falls from $0.57/bu to $0.17/bu in 1998, $0.48/bu to $0.14/bu in 1999, and $0.58/bu to $0.15 in 2000. These results indicate that grain blending may significantly reduce the aggregate cost of DON. The price effect of FHB and DON is reduced significantly after grain blending (table 3). For example, the aggregate price effect decreased from $28.8 to $6.4 million in 1998, $9.8 to $2.5 million in 1999, and $24.8 to $5.4 million in 2000, after blending. These results have significant implications for the secondary economic impacts of DON. Secondary economic impacts in table 1 may be exaggerated when blending margins are not incorporated into input-output secondary impact analysis, as losses to producers may be captured as gains to grain elevators and handlers.

However, such benefits may not be passed on to producers. An individual producer can only blend grains from his or her own farm, with limited quality variability of factors like DON. The results suggest that grain blending serves as a significant source of revenue for grain merchandisers and should be incorporated in aggregate FHB and DON impact analysis. Challenges presented by firm-level risks are discussed in the subsequent section.

Grain Blending and Firm-Level Risk

The decline in the discounts may be exaggerated since our analysis assumes that blending takes place on a regional scale, yet ignores the spatial distribution of crop quality parameters, testing and production uncertainties, and costs of grain movement. Another limitation of the analysis is that it focuses on total discounts received by grain handlers (after blending), rather than total discounts received by producers. These are not necessarily the same. Indeed, discount schedules provide profit opportunities for handlers, even if the same schedules apply for grain purchases and sales.[3] However, testing and production uncertainties can affect discount schedules and blending margins for a characteristic grain elevator.

The estimated discount schedules that incorporate blending could be used to re-estimate the price effects of DON. However, there is little evidence that blending margins trickle down to barley growers. Also, DON presents significant challenges to the grain handling industry. The tests used by most country elevators are not very accurate at low DON concentrations (i.e., less than 1.0 ppm), yet it is in this range that the largest price discounts apply. For malting barley, price discounts between 0.5 ppm and 1.0 ppm have ranged between $.35 and $.60 per bushel in recent years, depending on crop conditions. Producers of malting barley are justifiably concerned about testing accuracy when an error of 0.1 or 0.2 ppm can significantly lower the price they receive for malting grade relative to feed value. Similar risks apply to elevators on the selling side: contracts are generally settled on the basis of destination grades (i.e., after shipment to the malt plant), and there are large penalties for shipping DON in excess of specified limits.

Discussion

Yield losses due to FHB, combined with poor grain quality (represented by price discounts associated with DON), have been devastating for many producers, processors, and regions. FHB has expanded geographically, pushing north and west from its original locus in eastern North Dakota and western Minnesota. Manitoba and parts of Saskatchewan have also experienced FHB outbreaks in spring wheat and barley.

Traditionally, malt companies have segregated barley on the basis of variety and protein levels; they now must do so on the basis of DON ranges as well. This increases the required bin storage combinations, leading to less efficient use of available bin space. Apart from the direct expense of testing, there may be demurrage charges for barley on rail cars while the malt company awaits test results. Processing costs are also higher due to the reduced value of malting byproducts, increased water usage, wastewater disposal costs, and additional staffing and process control equipment. Further, Sebree (1998) noted that the presence of FHB-induced factors in the malt appears to make the beer matrix less stable. Thus, the FHB epidemic has had important effects not only on barley producers, but on the processors (malting and brewing industries).

Grain blending may significantly lower the aggregate costs associated with DON. One approach is to use regional crop quality data to determine the extent to which barley with high DON concentrations can be blended with barley with low DON concentrations without exceeding the cut-off concentrations at which major price discounts occur. The analysis in this paper shows there are significant benefits to be had from blending. However, DON costs to producers are difficult to estimate because average discount schedules for producers may be significantly higher than average discount schedules received by elevators, which can blend grains from different geographic regions and handle larger quantities of grain. Although grain blending may significantly reduce aggregate DON losses, it is uncertain how this risk management strategy affects producers. This is an area that requires further investigation. Also, caution must be taken when blending margins are incorporated at the processors' level because of spatial limitations, capacity limitations, and blending uncertainties.

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Endnotes

[1] Our thanks go to Cheryl Wachenheim, William Wilson, and two anonymous reviewers for their constructive comments. This research was conducted under the U.S. Wheat and Barley Scab Initiative, USDA-ARS Grant # 59-0790-1-074.

2 The annual crop quality survey covers major barley growing regions (crop reporting districts) of North Dakota, Minnesota, and South Dakota. Since 1993, the Department of Cereal Science has been collecting between 155 and 310 samples annually from crop reporting districts and field experiments in major barley producing regions in the three states.

[3] In general, grain handlers and elevators buy grains with alternative DON levels for a discount (table 2). However, when grain handlers blend grains more volume of grain may satisfy end-users' DON specifications. This implies that even though the discount schedules in table 2 still apply when end-users purchase grains from grain handlers, more grain is sold at a lower discount schedule, resulting in blending margins.