Crop Insurance Under Quality Uncertainty

by

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Abstract

Quality related yield and price losses have had significant impact on producer income and risks, and in some instances exceeded yield and price losses covered by conventional insurance instruments. However, there are no effective third party quality risk transfer mechanisms especially for barley growers. In this paper, we develop a framework to incorporate quality-related risk in crop insurance programs. Specifically, we derive the optimum equilibrium coverage levels and risk premium that suppliers of insurance and producers would be willing to provide when the yield and revenue insurance instruments explicitly incorporate quality losses. The results of our analysis provide several important contributions. First, the methodology illustrates how quality impacts could be incorporated into crop insurance types of contracts. Second, we explicitly incorporate the correlation effects of yield and price shortfalls due to quality. Though applied here in the case of malting barley and scab, this approach could be applied similarly in many regions, crops, and quality factors.

Key words: crop insurance, quality risks, Scab, equilibrium coverage levels.

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Crop Insurance Under Quality Uncertainty

Introduction

Crop insurance programs have escalated in importance as means to manage risks associated with unexpected events. Conventionally these have focused on two important sources of risk, namely yield and price level risk. For many crops and regions, the risks associated with quality are particularly important and at least heretofore have not been explicitly part of crop insurance programs. For instance, crop insurance payments for scab and vomitoxin-damaged barley, covered less than 2 percent of cumulative losses ($200 million dollars) to North Dakota farmers from 1993 through 1997 (GAO). This paper develops an insurance framework that incorporates quality risk in the case of malting barley.

Unexpected changes in crop quality have important impact on producer income and risks. There are two particularly important components of quality risk. These include the impact of quality on yield and price discounts. Both of these have a critically important impact on producer incomes in many crops. This paper analyses these problems in the case of vomitoxin in malting barley, which has devastated farmers' incomes in the Northern Great Plains. In this case yields have been severely impacted, and price discounts have been large due to buyers being averse to shipments containing greater than nil vomitoxin and related food safety regulations of the Food and Drug Administration. However, like problems have or are occurring in other crops and regions. These include, as examples, hard red spring wheat and durum in the northern plains, each of these grains in Canada, malting barley and the periodic outbreaks in recent years of Karnal bundt in hard wheat and durum in the southern plains. In each of these cases the diseases have had devastating impacts on yields, price discounts and marketability of the crops. In addition, one of the important aspects of marketing biotech crops is the

inadvertent contamination within the marketing system. The methodology presented here is applicable in each of these cases.

Vomitoxin evolved to be of great importance during the 1990s. Fusarium Head Blight (FHB) is the disease and Deoxynivalenol (DON) is a mycotoxin associated with FHB. Grain contaminated with DON (commonly known as vomitoxin) is subject to FDA advisory limits and is refused by many end-users and/or subject to severe discounts. Losses have been largest in scab-affected regions of North Dakota and Minnesota but in more recent years there has been significant incidence in other regions as well. Steffenson reported that over the past five years, FHB has devastated the barley crops in the Upper Midwest region and has caused serious food safety concerns. In malting barley DON causes gushing in beer production, affects taste profiles and consequently has been subject to severe market discounts.

DON results in risks to participants throughout the system including producers, end-users and marketers. Johnson, Wilson and Dierson, studied the impact of DON on logistical costs and procurement strategies in HRS wheat. Results illustrate how procurement strategies were impacted by the incidence of DON, and how grain flows were changed, as well as the increased costs and risks. Finally, it is notable that an important impact of the excessive risks of DON in malting barley has resulted in a sharp reduction in production within the United States, a radical shift in production away from traditional regions, and has induced a large amount of imports from Canada. According to the GAO report, U.S. maltsters and brewers, the traditional buyers of Northern Plains barley, have reacted to scab and vomitoxin by expanding their imports of malting barley from Canada by about 380 percent.

The Federal Agricultural and Improvement Act of 1996 (FAIR) ushered in a new environment

for US growers. The Federal Crop Insurance (FC) provides growers with insurance protection against yield losses from a variety of natural causes affecting revenue losses (Banett and Coble). Crop insurance is a federally sponsored risk management program. The programs include Multiple Peril Crop Insurance (MPCI), Group Risk Plan (GRP), Crop Revenue Coverage (CRC), Revenue Assurance (RA), and Income Protection (IP). None of these programs explicitly provide any form of coverage for unexpected quality deviations. The MPCI and GRP provide coverage for production shortfalls while the CRC, RA and IPC provide coverage for revenue shortfalls. The MPCI has supplements, but these equally do not explicitly protect against crop quality shortfalls.

With the absent of any form of quality insurance, risks in these markets have been handled in a fairly inadvertent and inefficient manner. There are several ways in which these risks have been dealt with. First, a significant component of the escalation of disaster payments from the federal government since 1996 has been attributable to losses associated with these crop quality issues. In each of these there were crop disaster payments in affected regions and in each case a substantial portion of the losses were attributable to quality related risks. Second, there were some ex post interpretations of the CRC program in the case of durum to account for crop quality losses. Third, in many cases growers have simply absorbed the risks internally. However, given that these crop quality risks in some cases are nearly as great or exceed other forms of risks, the fact that growers have absorbed these risks internally has resulted in a shift in production. Finally, in concept it is possible to envision that these risks could be transferred to end-users via some type of contracting mechanism. However, at least so far, this has not been a common practice. Indeed, part of risk of quality deviations are absorbed implicitly by end-users through higher prices in the case of malting barley and durum but heretofore,

these take the form of ex post price adjustments to ration limited supplies of non-disease tainted supplies in contrast to ex ante premiums/price differentials in contracts and more explicit risk transfer. Likely, the implicit premium necessary for end-users to absorb these risks would be fairly large. It is important that none of these alternatives has resulted necessarily in desirable outcomes and have been fairly costly ways to deal ex-post with crop losses. Ultimately, a third-party quality risk transfer could be a desirable alternative for grain producers.

The objective of this paper is to develop a framework to incorporate quality-related risk in crop insurance programs. Specifically, we derive the optimum equilibrium coverage levels and risk premium that suppliers of insurance and producers would be willing to provide when the yield and revenue insurance instruments explicitly incorporate quality losses. The results of our analysis provide several important contributions. First, the methodology illustrates how quality impacts could be incorporated into crop insurance types of contracts. Though applied here in the case of malting barley, it could be applied similarly in many regions and crops. Second, we explicitly incorporate the correlation effects of yield and price shortfalls due to quality. This has been a major limitation in the design of CRC, RA, IP, and other insurance instruments (Goodwin, Roberts, and Coble).

The paper is divided into five sections. Section 2 provides a survey of current insurance instrument for barley, the IP, MPCI, and RA, and their limitation with quality coverage. In section 3, we develop the framework used for the analysis and discuss the sources of data. Section 4 contains the empirical model and results. Finally, the core findings are summarized in section five and policy implications are discussed..

Review of Insurance Schemes and Previous Studies

The Risk Management Agency (RMA) of the U.S. Department of Agriculture (USDA) designs and rates federal crop insurance products that are then sold and serviced by private sector insurance companies. The RMA also subsidizes premiums that crop growers pay for federal insurance policies. As indicated earlier, basically two types of agricultural insurance are available to US growers: the traditional yield insurance, MPCI and GRP; and new revenue insurance programs, CRC, RA, and IP. Only the MPCI, IP, and RA are available for barley growers (Rain and Hail Insurance Service Inc.). However, the RA only provides revenue protection for feed barley.

The Multi-Peril Crop Insurance (MPCI) is the traditional federal crop insurance yield product. Available since 1938, a revised form of the MPCI was introduced in 1980 covering most crops in the U.S. It is a yield-based insurance and the current version is typically referred to as the Actual Production History (APH) program. The MPCI provides protection against shortfalls in a grower's expected yields (or a predetermined yield known as Guarantee). Buschena and Ziegler (1999) noted that historically producers could insure crop yields of up to 75% of average historic yield (with 80-85% available in limited areas). Losses are paid when the actual yield is less than guarantee (Rain and Hail Insurance Inc., 2000). The expected yield is calculated using at least four years of the grower's actual verifiable production records[1]. With the APH, the federal government presently provides low level protection known as catastrophic (CAT) coverage and growers must experience a yield loss of at least 50% to receive an indemnity (Barnett and Coble). However, MPCI and CAT do not explicitly cover quality losses, especially in the case of scab.

Since 1996 the RMA started offering revenue insurance and also allowed private insurance

firms to develop other insurance products, which were accepted for subsidy and re-insurance (Buschena and Ziegler). The revenue insurance products deal with both price and yield risk. The products all provide protection against growers' gross revenue (product of yield and price). These products (CRC, RA, and IP), however differ primarily in the level of protection offered and the rating methods employed. The insurance indemnity payment may be triggered by, low yields, low prices or the combination of low yields and low prices (Barnett and Coble).

The CRC is an approved alternative to MPCI, but is currently not available for barley growers (Stokes)[2]. However, the IP offers barley growers protection against revenue losses caused by low price, low yield or any combination of the two. The IP eliminates farmers' concerns with MPCI that low prices can adversely affect their overall revenue or profitability even when yields are high. The IP provides downside price protection for barley, by multiplying the APH and the projected county price. The CRC, IP, and RA are very similar in design. They are all reinsured, subsidized by the USDA, and use harvest-month futures prices at sign-up and at harvest to compute losses (Coble, Heifner, and Zuniga). The APH on which the IP policies is dependent does not presently consider the reduction in the production to count when the quality of the appraised and/or harvested production is reduced. The GAO report (p. 5), states that the current insurance instruments for barley, MPCI and IP, have not been effective mechanisms to manage quality risk, and as a result the Northern Plains State have experience more than 380 percent imports from Canada.

Previous crop insurance studies lay solid foundations to model the demand and supply for crop insurance under catastrophic risk. Of particular interest in this paper is the optimum equilibrium model for catastrophic risk developed by Duncan and Myers. They developed theoretical models to show

how catastrophic risk may affect the nature and existence of crop insurance market equilibrium. Our analysis in this paper uses scab data to empirically validate or contradict their findings. Since 1993, scab has been a catastrophe for barley growers in the Northern Plains States and its incorporation into MPCI and IP will presumably have similar effects. The three major challenges in designing actuarily fair schemes are to effectively determine the distribution of price and yield risk, develop a framework that explicitly captures the correlation between price and yield, and evaluate moral hazard and adverse selection problems (Duncan and Myers; Goodwin, Roberts, and Coble; Stokes). These issues become even more critical in developing models to incorporate quality risk. The framework proposed herein attempts to capture some of these issues, in the case of barley crop quality insurance.

Theoretical Model

The expected utility maximization framework adopted from Duncan and Myers is used to develop the equilibrium demand and supply for IP when yield and price risks due to scab are considered. The base model has three parts: a model to derive the demand for insurance, a model to derive the supply of insurance, and a competitive equilibrium model equating demand and supply to derive optimum coverage levels and premiums. A variant between the model developed here and that developed by Duncan and Myers is that a crop reporting district (CRD) rather than individual farmers is used. This approach has several advantages. An example is that data for CRD are publicly available and problems of moral hazards and adverse selection can be regulated[3]. Such information can be used as control to farm-level data, so that the individual indemnities do not differ significantly from the CRD indemnities. Following the specifications of Duncan and Myers, the demand model for a CRD that

buys insurance is presented in a mean-variance framework as in equation 1[4]. The basic assumption is that the probability of loss, P is known by all participants. This assumption is realistic in the study because of CRD data availability. This enables the model to abstract from problems of adverse selection and moral hazards. The end-of-period income per acre for a particular CRD:

$$(1) \qquad MaxU = M - wj_d - (1-j_d)\bar{l} - 0.5l(1-j_d)^2 s_l^2.$$

Where; M is the potential income per CRD, $\bar{l} = PL$ is the stochastic loss per CRD, wn_d is the insurance premium paid irrespective of the state of nature (n_d is the expected coverage level per acre in a particular CRD and w is the premium set by competition in the insurance market), L is the value of loss with known probability P, $n_d L$ *is* the proportion of the loss reimbursed by insurance if there is a disaster, s_l^2 is variance of loss, and 0.5ë represents the equilibrium slope at the tangency between an iso-expected utility line and the MV set (Robinson and Barry). The first-order conditions for optimal coverage level for crop quality insurance is given by equation 2.

$$(2) \qquad \frac{\P U}{\P j_d} = -w + \bar{l} + l\, s_l^2 (1-j_d) = 0$$

$$-w + \bar{l} + l\, s_l^2 (1-j_d) = 0$$

Equation 2 represents the demand for crop quality insurance at premium w. It can be shown that the demand for crop quality insurance decreases as the premium increases, and increases with increases in expected loss, risk aversion, ë, and with variance of loss s_l^2. Equation 3 presents the model for the

supply of insurance. As in the case of the demand for insurance, risk averse insurance firms are assumed to have linear MV preferences and are risk averse with risk parameter 0.5È. The coefficient for risk aversion are different because insurance companies are assumed to be more diversified and larger than barley production from a CRD. Given the fact that an insurance companies are seeking to maximize end-of-period wealth, the supply model can be written as:

$$(3) \qquad MaxV = n j_s \left[(1-a)(w-\bar{l}-c) + d\bar{l} \right] - 0.5\Theta n j_s^2 s_l^2 (l-a-d)^2 \left[1+(n-1)r \right].$$

Where, s refers to the supply of insurance, n the number of policies, *1* -á the proportion of premium left after reinsurance (the insurance company gives up some proportion, $(0 \leq \prec 1)$, of its premium to a reinsurer, in return, the reinsurer accepts the responsibility to pay some proportion (á+ä) of indemnity with the value of ä satisfying $0 \leq d \prec 1-a$), c is the insurance costs per unit of coverage, and ñ is the correlation coefficients between CRD. Other assumptions for the supply of insurance are that the values of á and ä are set exogenously by government policy, and with no scab outbreak ñ = 0. The short-run supply of optimum insurance coverage for scab is given by equation 4.

$$(4) \qquad (l-a)(w-\bar{l}-c) + d\bar{l} - \Theta j_s s_l^2 (1-a-d)^2 \left[1+9n-1)r \right] = 0$$

The margin between premium received from a CRD and cost of insurance is (w – c) and there is no subsidy from the reinsurer when *ä* = 0. It can be shown that the short-run supply for insurance increases with increasing *w*, decreases with increasing expected loss, $\bar{l}$, ñ, and variance of loss, s_l^2. The second-order condition for a maximum is satisfied because the third term on the right-hand side is

strictly positive. By solving for w in equation 2 and substituting its value into equation 4, we obtain the competitive Equilibrium solution given in equation 5.

$$(5) \quad j^* = \frac{(1-a)(l s_l^2 - c) + d\bar{l}}{(1-a) l s_l^2 + \Theta s_l^2 (1-a-d)^2 \left[1 + (n-1) r\right]}.$$

For any given n, the above equation gives the equilibrium coverage level that equates the demand and short-run supply for insurance. In this paper we use equation 5 to empirically derive the effects of quality risk from vomitoxin on the optimum coverage n^*. These empirical results are then compared with the theoretical findings of Duncan and Myers. As mentioned earlier, the major empirical challenge however is to characterize quality risk in a framework that accounts for the correlation between yields and price. In the proceding section, we adopt the approach of Johnson et al. to characterize quality risks due to scab to scab for malten barley.

Characterization of Yield and Revenue Risks and Data

Figures 1 and 2 provide a graphical representation of yield, price, and their correlation impacts due to scab. To estimate production losses due to scab in a given CRD, it is first necessary to estimate the value of production under 'normal' conditions (q_n), i.e. production in the absence of scab outbreak. Precipitation and temperature data are used to estimate 'normal' production, the loss production is then calculated as the difference between actual and normal production and then adjusted for acreage abandoned as a result of scab[5].

In Figure 1, the net price effect is positive (A + 0.5B), while the yield effect is negative [-(0.5B + D)][6]. In Figure 2, the net price effect is negative [-(E + 0.5F)] and the yield effect is negative [-(0.5F + H)].

In estimating the impact of scab on the net price received by producers, two factors are considered: first, the impact of production shortfall on market prices; and second, the quality of the crop (quality discounts). Flexibility coefficients or elasticities were estimated for barley using total U.S. barley supply and the loan rate. The flexibility coefficients were adjusted for imports from Canada and used to estimate supply in the absence of scab. The impact on market prices and quality discounts were then estimated. The combined yield and price effects are presented in Figures 3. A comparison yield and price risks used for conventional MPCI and IP instrument versus quality risk due to scab is presented . The price impact on barley due to quality shortfalls is greater than the IP revenue risk for most CRDs in North Dakota and Minnesota.

Data from all barley producing CRDs for North Dakota (six CRDs) and Minnesota (three CRDs) from 1998-2000 were used for the analysis. Production and price data are obtained from USDA-NASS web sites. The quality data on scab and vomitoxin levels for the CRDs were provided by Schwarz, Cereal Science Department, North Dakota State University[7].

Results and Discussion

We applied the analytical framework described, to an empirical analysis of the equilibrium optimal coverage levels of MPCI and IP with scab risk. To do this, simulations were conducted for the two insurance programs under two scenarios, with reinsurance and without reinsurance. Our analysis

incorporated the correlation coefficient (ñ) to assess the degree of importance of scab on the catastrophic nature of the combined effect of price and yield risk, and its impact on the MPCI and IP programs. The simulated optimal coverage levels for the two insurance programs are used to compute the optimal premium with or without scab risks.

The main findings of our analysis are summarized in Table 1. One is that, the explicit incorporation of scab risks increases the catastrophic nature of the risk environment for both the MPCI and IP programs as evident by the increase in the correlation coefficient of losses across CRDs. This supports our analysis of scab risk with a model that captures catastrophic risk as presented by Duncan and Myers. With the MPCI program that incorporates scab risk only at the level of yields, the catastrophic nature of scab risk is far lower (0.1462) than with the IP program that incorporates both the yield and price effects of scab risk (0.9119). Second, there is a drop in the simulated optimal coverage level for both programs, with or without reinsurance, when scab risk is incorporated. However, with reinsurance, the optimal coverage level that can be borne by insurers increases significantly. The incorporation of scab risk increases the estimated optimal premium per acre for both programs, with a significantly higher amount ($71.649) with the IP program which considers the yield and price effects of scab. This represents a higher amount compared to the revenue per acre, meaning that farmers would be concerned if they are to shoulder all the cost to insure against scab. This raises the question of subsidized reinsurance as opposed to federal disaster payments.

The third empirical result is that high levels of scab risk effectively reduces coverage levels, and increases premiums. For instance, as ñ increases for the IP from 0.34 to 0.91, the coverage level with reinsurance decreases from 0.55 to 0.42. Furthermore, the cathastrophic nature of scab almost leads

to a breakdown of the insurance market in the absence of reinsurance (equilibrium coverage levels were 0.04 and 0.18 for IP and MPCI respectively). Finally, subsidized reinsurance can help facilitate an equilibrium that incorporates scab risk by expanding the set of available equilibria, and increases coverage levels (18.6% to 43.9% for MPCI and 4.4% to 41.9% for IP).

Conclusion and Policy Implication

Unexpected changes in crop quality are known to have important impact on producer income and risks. This study develops a framework that incorporates quality-related risk in crop insurance programs. Specifically the paper analyses the impact of quality on yield and price discounts in the case of vomitoxin in malting barley. The analysis provides important and timely implications for the design and management of crop insurance for quality shortfalls. Business risks of crop quality losses are important and in many cases, such as with vomitoxin in barley, these risks exceed traditional sources of risk-price level and yield.

An analysis of the yield and revenue shortfalls in barley as traditionally covered by the MPCI and IP versus yield and revenue shortfalls due to scab and vomitoxin indicates that these two programs have not been effective mechanisms to manage quality risk. The risk posed by scab and vomitoxin are shown to be greater in most barley Crop Reporting Districts (CRDs) of North Dakota and Minnesota. The analysis revealed that scab risks increases the catastrophic nature of the risk environment for crop insurance. With the MPCI program that incorporates scab risk only at the level of yields, the catastrophic nature of scab risk is far lower than with the IP program that incorporates both the yield and price effects of scab risk.

Scab risk like a typical catastrophic risk, is shown to lead to a drop in the optimal coverage level that insurance programs can borne. This coverage level is significantly increased with reinsurance. The estimated optimal premium per acre for both MPCI and IP programs with the incorporation of scab is significantly high, especially with the IP program which considers the yield and price effects of scab. These results emphasize the fact that for scab to be effectively incorporated in the present insurance scheme, part of the risk should of necessity be borne by reinsurance while the need for federal programs to subsidize the rate for premium payments should be reemphasized.

The methodology used illustrates how quality impacts could be incorporated into crop insurance types of contracts. Heretofore, mechanisms to deal with these risks have been ex post and not necessarily effective in terms of third-party risk transfer. Though applied here in the case of malting barley, the methodology could be applied similarly in many regions and crops.

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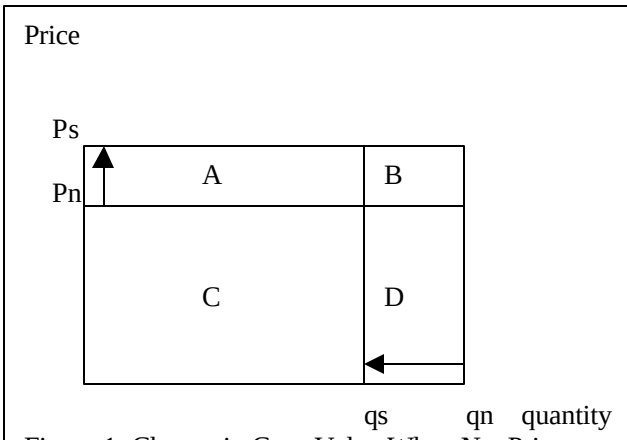


Figure 1: Change in Crop Value When Net Price Impact is Positive

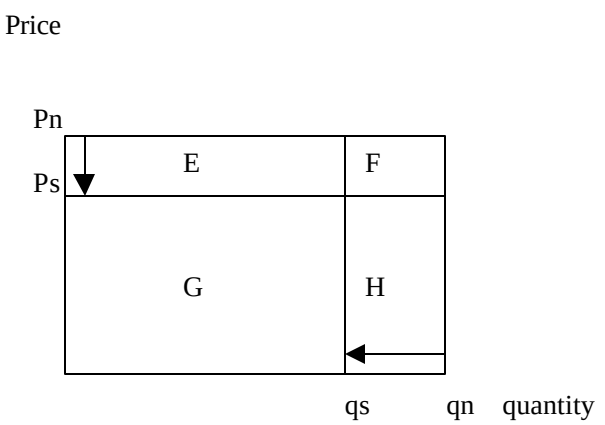
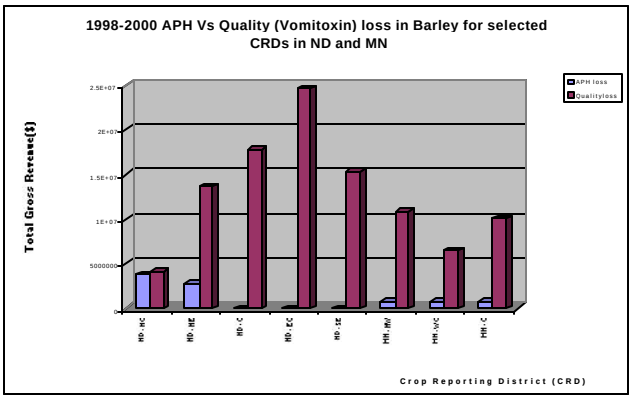
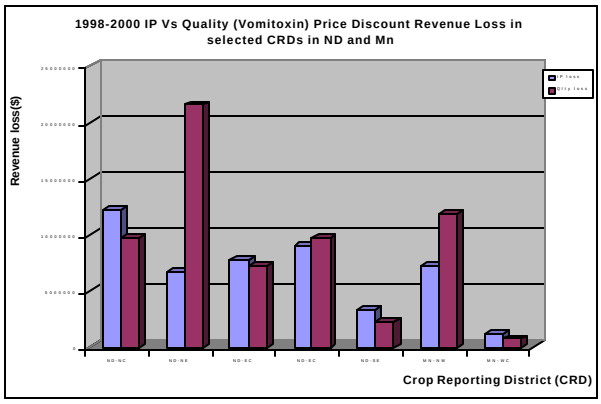
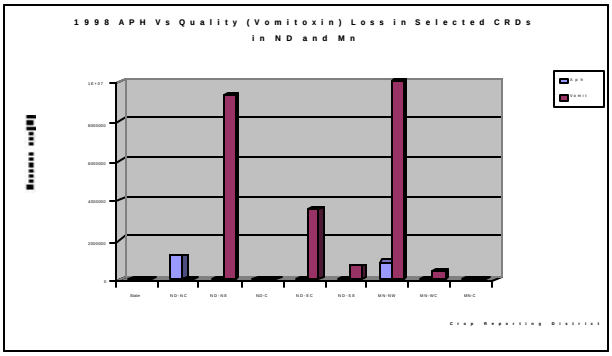
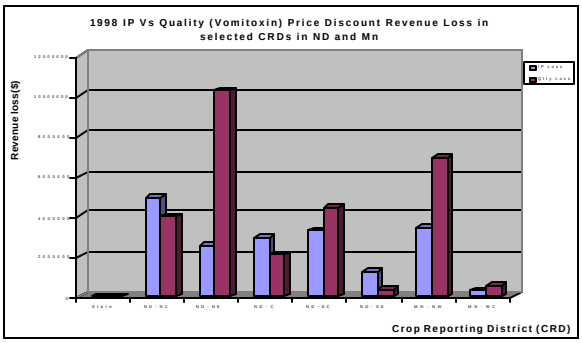


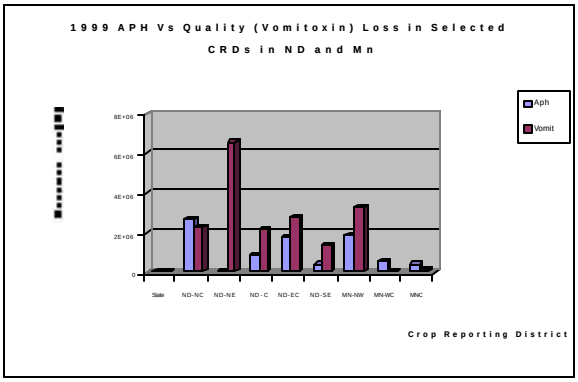
Figure 2: Change in Crop Value When Net Price Impact is Negative

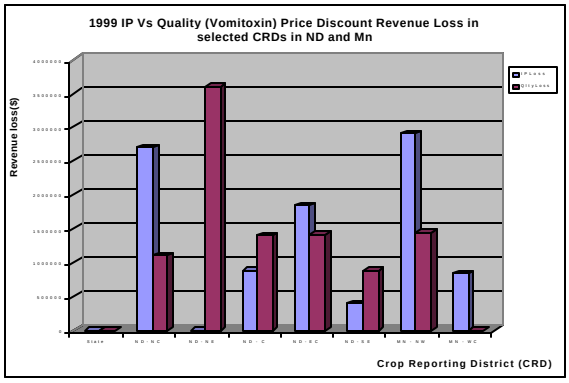

1998-2000 APH Vs Quality (Vomitoxin) loss in Barley for selected CRDs in ND and MN
Total Gross Revenue($)
2.5E+07
2E+07
1.5E+07
1E+07
5000000
0
APH loss
Qualityloss
ND-NC
ND-NE
ND-C
ND-EC
ND-SE
MN-NW
MN-WC
MN-C
Crop Reporting District (CRD)


1998-2000 IP Vs Quality (Vomitoxin) Price Discount Revenue Loss in selected CRDs in ND and Mn
Revenue loss($)
ND-NC
ND-NE
ND-EC
ND-EC
ND-SE
MN-NW
MN-WC
Crop Reporting District (CRD)


1998 APH Vs Quality (Vomitoxin) Loss in Selected CRDs in ND and Mn
1E+07
8000000
6000000
4000000
2000000
0
State
ND-NC
ND-NE
ND-C
ND-EC
ND-SE
MN-NW
MN-WC
MN-C
Crop Reporting District


1998 IP Vs Quality (Vomitoxin) Price Discount Revenue Loss in selected CRDs in ND and Mn
Revenue loss($)
State
ND-NC
ND-NE
ND-C
ND-EC
ND-SE
MN-NW
MN-WC
Crop Reporting District (CRD)


1999 APH Vs Quality (Vomitoxin) Loss in Selected CRDs in ND and Mn
8E+06
6E+06
4E+06
2E+06
0
Aph
Vomit
State
ND-NC
ND-NE
ND-C
ND-EC
ND-SE
MN-NW
MN-WC
MNC
Crop Reporting District


1999 IP Vs Quality (Vomitoxin) Price Discount Revenue Loss in selected CRDs in ND and Mn
Revenue loss($)
State
ND-NC
ND-NE
ND-C
ND-EC
ND-SE
MN-NW
MN-WC
Crop Reporting District (CRD)

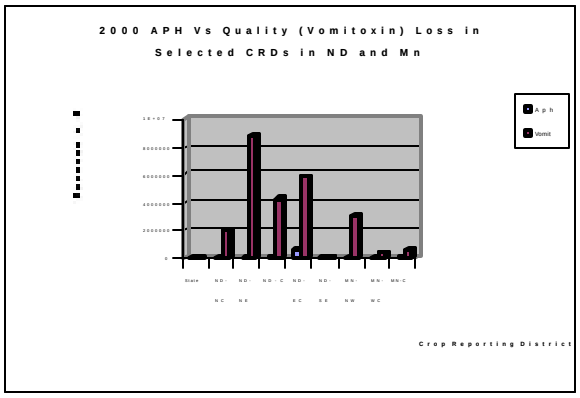
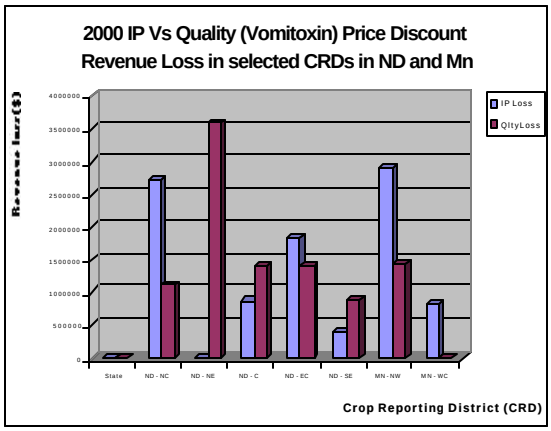

2000 APH Vs Quality (Vomitoxin) Loss in Selected CRDs in ND and Mn
Aph
Vomit
Crop Reporting District

Table 1. Stochastic Simulation Results: Optimum Coverage of MPCI and IP with Scab Risk

	Coverage Level		Average Loss	Premium(w) Per	Correlation
	No Reinsurance	Reinsurance	Per Acre ($)	Acre ($)	(ñ)
• MPCI	0.248	0.578	9.559	12.446	0.0877
• MPCI & Scab Risk	0.186	0.439	18.358	26.016	0.1462
• IP	0.0435	0.553	12.065	28.140	0.3483
• IP & Scab Risk	0.0435	0.419	28.432	71.649	0.9119



1. The guarantee is estimated by multiplying a four years APH by the selected coverage level and the market price. Growers with less than four years of APH are penalized, by receiving less insurance protection per premium dollar. In the case of barley, the four years of historic APH fall within scab infested years (barley growers have experienced scab outbreak since 1993). Estimating yield shortfalls due to scab requires sound economic methods other than APH.

2. Piloted in the spring of 1996 the CRC became the first privately developed policy in the insurance industry to be approved for government reinsurance as an alternative to MPCI. Starting off with two crops in 2 states, the CRC is presently available in 45 states and is available for 6 crops (corn, cotton, grain sorghum, rice, soybeans, and wheat).

3. The GAO report pointed out that the high losses ($8.9 billion) covered by the CRC, IP, and RA have been attributed to adverse selection and moral hazard issues. Adverse selection occurs when producers have more information about their risk than do insurers, such that premium rates are inaccurate. Moral hazard occurs when insuring producers, alter their behavior in order to increase the likelihood of collecting indemnities (Goodwin, Roberts, and Coble). Using data from CRD eliminates these concerns because the laboratory tests on scab and vomitoxin levels are performed by third parties like universities and private laboratories rather than farmers. The CRD data on vomitoxin levels used in this study were collected by the Cereal Department at the North Dakota State University. They collect and maintain annual vomitoxin levels for the Nothern Plains States.

4. Although the M-V framework has some limitations, it is adequate to demonstrate the main results of this study. Our study explicitly estimates the net impact due to scab (See Figures 1and 2).

5. Extension experts from all crop reporting districts were surveyed to obtain data on the difference between normal and actual production that was due to scab. See Demcey et al; GAO; and Nganje et al. for the detail procedures on scab yield and price impacts. Their approaches explicitly incorporate the correlation between yield and price.

6. See Johnson et al. for detail description of this approach.

7. Paul Schwarz of the Department of Cereal Sciences at the North Dakota Stae University, collects samples for barley producing CRDs for ND and MN, regions with greatest scab infestation from 1993-2000. His initiative is supported by the U.S. Wheat and Barley Scab Initiative.