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Adverse Selection in the Market for Crop Insurance

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Abstract

This paper examines the potential for adverse selection when farmers are offered a portfolio of insurance policies. We analyze the risk characteristics farmers who bought alternative insurance instruments in 1996-97. Inability to differentiate farmers according to risk types results in poor actuarial performance of insurance product.

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This paper examines the potential for adverse selection in crop insurance market when producers are offered a portfolio of insurance products. Since 1995 a rapid expansion has occurred in the number of new crop insurance products offered to farmers (GAO). In Iowa, for example, three types of revenue insurance, Crop Revenue Coverage (CRC), Income Protection (IP), and Revenue Assurance (RA), were offered in addition to the traditional Multiple Peril Crop Insurance (MPCI) during the past year. These new revenue insurance products represented more than one third of the acres insured for both corn and soybeans nationwide in 1997.

Adverse selection has long been recognized as a problem in insurance markets. Empirical studies in automobile and health insurance markets have found that adverse selection reduces the consumption of insurance by low risk individuals (Browne and Doerpinghaus 1993; Dionne and Doherty 1994; Puelz and Snow 1994). In a review of US crop insurance market, Knight and Coble (1997) showed the effects of adverse selection on the poor actuarial performance of MPCI. As the number of insurance products available to farmers increases, the adverse selection problem could potentially worsen and, therefore, increase the private and public cost of crop insurance program. To address these issues we develop a theoretical model of adverse selection which extends previous models by allowing for selection across multiple products. Empirically, we test for adverse selection by examining the risk characteristics of Iowa and Nebraska corn and soybean farmers who bought different insurance products in 1997.

Theoretical Framework

Consider the following simple model of a crop insurance market. For a farmer who incurs a loss X (equivalent to yield or revenue falling below a certain level) with probability p, an insurance contract with a coverage level θ yields an expected profit of zero for the insurer if the premium π for the policy is given by

(1) $$\pi = (1+k_0)\{k_1 + p(X + k_2)\}$$

where X is the amount of loss, p is the probability of loss, k_0 is a cost proportional to the net premium necessitated by commission payments to insurance agents and ceded reinsurance charges, k_1 is the fixed cost of book keeping, and k_2 is the cost of processing a claim.

With an applicant's risk type unobservable, insurers categorize them on the basis of traits that are observable and correlated with risk type such as farm type, farm practice, crops grown, past yield records, risk area, etc. Farmers who want to buy crop insurance are offered the opportunity to choose from a menu of premium-coverage level choices:

(2) $$\pi = g(\theta, z)$$

where z is a vector of observable characteristics indicative of the loss to be insured[1.]

Consider a farmer with an initial wealth w, who is exposed to a risk which can cause a loss X with a probability p. The farmer can pay a premium π to an insurance firm, which in return undertakes to pay a compensation or indemnity Υ if the loss occurs. The farmer chooses the coverage level that maximizes her/his expected utility:

(3) $$U(c) = (1-p)\,U(w - \pi) + p\,U(w - \pi - X + \Upsilon)$$

where U(c) is the von Neumann-Morgenstern utility function, assumed to be increasing, strictly concave (reflecting risk aversion), and differentiable. Υ is the indemnity payments from the insurance company to farmers when actual yield (y^a) falls below the guaranteed yield (y^g):

(4) $$\Upsilon = \max \{ (y^g - y^a) P^g , 0 \}$$

where P^g is the guaranteed price or the elected price. y^g and P^g are a certain fixed proportion of the expected yield and price, respectively, usually based on previous records on the same farm:

(5) $$y^g = \theta y^e$$

Using equations (2) (4) and (5), we can rewrite equation (3) as

(6) $$U(c) = (1-p) U\big(w - g(\theta, z) \big) + p U\big(w - g(\theta, z) - X + \Upsilon(\theta, y, P) \big)$$

where y and P are, respectively, the yield and price vectors given by $y = (y^g, y^a)$ and $P = (P^g, P^a)$. The chosen coverage level satisfies the following first order condition (w.r.t. θ):

(7) $$\frac{(1-p) U'\big(w - g(\theta, z) \big)}{p U'\big(w - g(\theta, z) - X - \Upsilon(\theta, y, P) \big)} = \frac{\Upsilon'(\theta, y, P) - g'(\theta, z)}{g'(\theta, z)}$$

where $U'(\cdot) > 0$ is the marginal utility of wealth. According to the relation in (7), an individual's choice of coverage level depends on the following factors: (i) *risk type* (τ) indicated through the odds ratio (1-p)/p; since risk type is unobservable, it is measured in terms of observable traits such as farm type, farm practice, crops grown, past yield records, risk area, etc. that are correlated with risk type; (ii) *degree of relative risk aversion* (ρ) indicated through marginal utility of wealth $\big(\rho = w U''(\cdot)/U'(\cdot) \big)$; and (iii) *marginal price of coverage* - through relative price ratio $\{ \Upsilon'(\theta, y, P) - g'(\theta, z) \}/ g'(\theta, z)$; marginal price of coverage is determined by coverage levels, premium rates, expected indemnity, and transaction costs.

We can write the demand for insurance implied by the set of equations 1 though 7, expressed as demand for the coverage level as

(8) $$\theta = f(\tau, \rho, m)$$

where τ is the risk type, ρ is the degree of risk aversion, and m(θ, Υ, y, P z) is the marginal price of coverage. The demand for alternative insurance products would involve a function similar to (8) with coverage level (θ) being replaced by the product:

(9) $$\Phi = \phi(\tau, \rho, m)$$

where Φ is the alternative insurance products available to farmers.

When risk type is *not observable* and insurance is *not costless*, equilibrium insurance contracts in the market depend on the manner in which insurers and customers engage in competition. The problem of adverse selection may occur if the differentiation of applicants according to risk types is impossible or prohibitively expensive and, as a result, it's not possible to set the appropriate premium rates. In other words, in the absence of perfect information, insurers fail to categorize applicants/farmers according to risk types and, therefore, are unable to charge appropriate premium rates.

Assume, for simplicity, that there are two types of farmers in the market: "low risk" and "high risk". Also, assume that low and high risk farmers have a similar underlying utility function but differ in their probability of suffering loss. Let the probability of loss for high and low risk farmers be $\mathbf{p^H}$ and $\mathbf{p^L}$, respectively, which implies that $\mathbf{p^H}$ is greater than $\mathbf{p^L}$. In the absence of perfect information, this market can have only two kinds of equilibria: *pooling equilibria* in which both groups buy the same contract, or *separating equilibria* in which different types purchase different contracts (Rothchild and Stiglitz 1976). The pooling equilibrium, however, is not sustainable because such a contract is not fair to low risk farmers, who soon leave the market. Pooling equilibrium, if it exists, may implicitly subsidize high risk farmers (Wilson 1977; Miyazaki 1977)[2]. Adverse selection is even more problematic when only high-risk farmers buy insurance as evidenced during the early years of crop insurance in the U.S. (Ray 1974).

Figure 1 illustrates the adverse selection problem in the case of two risk types (low and high), two states of nature (loss and no loss), and where there are no transaction costs. The low risk and high risk fair-odds lines are represented by EL and EH, respectively. When a farmers' probability of loss is hidden knowledge, the full-information equilibrium (L,H), in which both risk types are optimally insured, is unattainable because of the adverse selection of contract L by high risks. An equilibrium contract for low-risk types must not be more attractive to high-risk types than H* ; it must lie on the southeast side of U^h, the high-risk indifference curve through H. This establishes that the set (L*; H*) is the possible equilibrium for a market with low and high-risk farmers.

If categorization is imperfect, farmers of different risk types separate by their choice of coverage level, with higher risk types choosing higher coverage levels, or by their choice of alternative insurance products, with higher risk types choosing the product that gives higher protection. The equilibrium contractual configuration satisfies the incentive compatibility conditions/constraints that require that each risk type does not prefer the contract received by any other risk type.

Adverse selection occurs when insurance firms cannot distinguish low risk farmers from high risk farmers because of "hidden information". However, an individual farmer knows to which group he/she belongs. When the farmer makes his/her decision to buy one of the alternative insurance products or one of the alternative coverage levels, he/she reveals some information about himself/herself, or sends a "signal" to the insurer[3]. For example, if the farmer purchases only partial coverage (say 50%), he/she sends a "signal" which could mean that he/she represents lower risk than the one who opted for maximum coverage (say 75%). Since each contract specifies both the level of coverage and the unit price of coverage, individuals reveal their risk type through their contract choice.

Data

Data used in this study are from the USDA's Risk Management Agency which maintains records of individual farmers who buy federally-backed crop yield or revenue insurance. The data pertain to Iowa and Nebraska where three revenue insurance products (CRC, RA, and IP) were offered on a large scale in 1997 in addition to traditional MPCI. We analyzed the risk characteristics of corn and soybean farmers who bought crop or revenue insurance in 1997. Data gathered for this study provides the first opportunity to test the potential for adverse selection when a portfolio of insurance products are offered. Since the data still coming in, we have limited our analysis to comparing MPCI and CRC in the next section.

Empirical Analysis of Crop Insurance Markets

Tables 1 and 2 summarize descriptive statistics that characterize MPCI and CRC in Iowa and Nebraska, respectively. MPCI protects farmers from yield shortfall if the yield falls below the guaranteed level. While CRC protects the farmer from lost revenue caused by low yields, low prices, or a combination of both. Since CRC provides greater protection (amount of liability per acre), producers pay a higher premium rate for coverage. Farmers in Iowa, for example, paid two times more premium per acre to obtain the greater protection of CRC. The loss frequency for MPCI and CRC, calculated as the percentage of indemnified policies, were, respectively, 2.3% and 5.1% for corn and 1.7% and 3.8% for soybeans in Iowa. Preliminary analysis also indicates that, in Iowa, 40% of farmers who bought CRC chose more than 65 percent coverage, while less than 20% who bought MPCI chose more than 65% coverage. The loss ratio, defined as indemnity paid out per dollar of premium collected, was 0.11 for CRC and 0.09 for MPCI for corn crop in Iowa[4]. One should note, however, because of differing indemnity functions this reveals little regarding the relative actuarial soundness of the two products.

Econometric Model

A binomial LOGIT model is used to test for the presence of adverse selection problems among Iowa and Nebraska farmers in choosing alternative insurance products offered to them in 1997[5]. Explanatory variables used are acreage covered, farm practice, FCIC relative expected yield-span category, coverage type, and premium rates. Equation (9) is estimated by specifying the following equation to represent the market for alternative insurance products:

(10) $$\mathbf{Y} = \mathbf{X}\,\boldsymbol{\beta} + \mathbf{e},$$

Where Y = the alternative crop/revenue insurance products (MPCI and CRC) offered in Iowa and Nebraska for corn and soybeans; X = a vector of explanatory variables; these variables include *acreage* which is defined as the reported area insured under each policy; *farm practice* is a dummy variable with irrigated farms represented by 1 and non-irrigated by 0; FCIC recognized 9 categories of farms based on *expected farm yield* relative to expected county yield[6] ; there are three *type of coverage,* viz., CAT, limited and additional; and *premium rates* are expressed as amount of premium paid per dollar of liability; β = a vector of regression coefficients; and e = the random error term.

Results

Table 3 presents the estimated coefficients along with the marginal effects of explanatory variables on the probability of choosing alternative insurance products. Four separate functions are estimated for corn and soybeans in Iowa and Nebraska. Variables acreage, crop practice, and relative yield are farm-specific variables that reflect the extent of risk each farm represents; while other variables including coverage type and premium rate are insurance related. All variables except crop practice are significant at the 5% level. The marginal effect of a change in an explanatory variable on the probability of choosing one of the alternative insurance products is given by $\partial y/\partial x_i = \partial\Phi(\beta' x)/\partial x_i$, where $\Phi(\beta' x)$ is the standard normal CDF computed at the means of all explanatory variables (see Greene, 1990).

The estimated relationship between reported acres and the choice of insurance product is positive and significant implying the preference for CRC by larger farms. Marginal effect indicates that one acre increase in size would increase the probability of preferring CRC over MPCI by 0.09 percent. The positive coefficient for crop practice indicates that irrigated farmers prefer CRC over MPCI. The marginal effect implies that if a farm shifts its practice from non-irrigated to irrigated status, its preference for CRC would increase by 26%. The parameter estimate for the relative crop yield is positive and significant, indicating that those farms with higher expected yield compared to the county average are more likely to buy CRC, while farms with lower expected yields relative to the county average are more likely to prefer MPCI. Results in general indicate the preference for CRC by larger irrigated farms with higher average yields relative to the county average.

The parameter estimate for coverage type is positive and significant implying that if farmers were to buy additional coverage over and above CAT coverage, they are more likely to prefer CRC over MPCI.

Policy Implications

This study is the first attempt to address the potential for adverse selection in a new agricultural policy environment which allows for multiple products to be offered to producers. Our analytical framework shows that unless care is given to the management of these alternatives, government risk management resources may be mis-allocated. By examining risk and other characteristics associated with farmers who buy different policies, it may be possible to structure insurance policies to appropriately reflect farmers' profiles. Our findings are useful in understanding the preferences of low risk and high risk farmers among alternative policies and substitutability among policies.

End notes.

1. From the theoretical point of view, offering alternative coverage levels is similar to offering alternative insurance products. For ease of exposition, we develop the theoretical model of demand for insurance using alternative coverage levels. The empirical model tests both the demand for alternative coverage levels and alternative products.

2. The Rothchild and Stiglitz model entails a separating equilibrium with low risks and high risks buying different insurance products both of which break even individually. The Wilson and Miyazaki models differ from Rothchild and Stiglitz model in that there is an across risk class subsidization in both models. In the Wilson model both high and low risks purchase the same policy for the same price. A low to high risk subsidization results as the high risks have a greater incidence of loss. In the Miyazaki model high risks and low risks purchase different policies. The policies purchased by high risks generate losses for the insurer while policies purchased by the low risks generate profits. Therefore, the high risk to low risk subsidization in the Miyazaki model is across policies.

3. Market signaling theory predict that equilibria in insurance markets with adverse selection in which signaling of hidden knowledge is possible through the choice of insurance products and levels of coverage. Riley (1985) argues on the similar lines for the levels of deductible.

4. In 1997, the crop insurance program in general experienced much lower claims largely due to favorable weather conditions and relatively high prices.

5. A multinomial logit model is also estimated to test the presence of adverse selection across alternative coverage levels within each product. However, we have not presented those results in this paper to save space. Some of the key variables including yield records are expected to arrived only in the second week of June limiting our analysis before the deadline of May 15. We hope to finish the analysis before the end of July.

6. The relative expected yield for a farm is a key factor in the FCIC rating design. A base county rate derived from historical county loss experience is calibrated to the expected NASS county yield. A yield spanning process creates nine discrete categories of yields relative to the county expected yields . Rates for each category are inversely proportional to the farm's expected yield. Thus, farms in relative expected yield categories 1-4 are charged premium rates which are higher than the base county rate. Conversely, farms in relative expected yield categories 6-9 are charged lower premium than the base county rate. Underlying this process are assumptions regarding the relationship between the individuals expected yield and the expected insurance losses. The standard FCIC assumptions imply that expected losses increase as expected yield decreases.

Table 1. Risk Characteristics of Different Insurance Products: Iowa, 1997

CHARACTERISTICS	CORN		SOYBEANS	
	MPCI[a]	CRC	MPCI[b]	CRC
Number of policies sold in 1997 (percentage of the total)	55,004 (62%)	26,548 (30%)	55,681 (67.3%)	21,407 (26.0%)
Proportion of acres covered	57.6%	33.1%	63.1%	29.0%
Number of policies indemnified (Loss frequency)	1,265 (2.3%)	1,358 (5.1%)	926 (1.7%)	810 (3.8%)
Price of Insurance				
Premium Rate ($ per acre)	7.25	14.00	4.10	8.50
Premium Rate per $ liability	0.04	0.06	0.03	0.05
Liability (coverage) per acre	164.35	217.57	129.50	187.00
Liability per $ premium paid	22.70	15.54	31.60	21.90
Indemnity paid out (per acre)	0.52	1.55	0.35	1.05
Indemnity paid out per $ premium collected (Loss Ratio)	0.07	0.11	0.09	0.12
Premium subsidy $ per acre (percent of per acre premium)	3.25 (45%)	3.50 (25%)	1.96 (48%)	2.14 (25%)
Practice			c	c
Irrigated (%)	0.3	0.3		
Non-irrigated (%)	99.7	99.7		
Relative yield				
Lower relative to county (%)	34.1	24.7	29.6	22.6
Equal to county (%)	26.8	25.7	27.8	30.0
Higher relative to county (%)	39.1	49.6	42.6	47.4
Coverage type				
Cat coverage (%)	24.6	-	32.5	-
Limited coverage (%)	2.9	3.0	3.6	3.5
Additional coverage (%)	72.6	97.0	63.9	96.5
Coverage level				
Less than 65 % (%)	27.1	3.0	37.5	3.5
65% (%)	53.7	56.6	47.6	57.3
More than 65 % (%)	19.2	40.4	15.8	39.2

a. 22,801policies (41 %) had only CAT coverage; b. 30421 policies (55 %) had only CAT coverage; c. no information available. d. number of policies indemnified divided by the total number policies issued.

Table 2. Risk characteristics of Different Insurance Products: Nebraska, 1997

CHARACTERISTICS	Corn		Soybeans	
	MPCI[a]	CRC	MPCI[b]	CRC
Number of policies sold in 1997 (percentage of the total)	33,134 (65.50)	17,447 (34.50)	26,681 (64.50)	14,704 (35.50)
Proportion of acres covered	61.54	38.46	57.35	42.65
Number of policies indemnified (Loss frequency)	2,082 (6.3)	1,913 (11.00)	1,210 (4.50)	1,224 (8.32)
Price of Insurance				
Premium Rate ($ per acre)	7.06	12.64	5.30	8.94
Premium Rate per $ liability	0.04	0.06	0.04	0.05
Liability (coverage) per acre	159.20	205.00	122.60	162.95
Liability per $ premium paid	22.54	16.20	23.20	18.23
Indemnity paid out (per acre)	2.00	3.86	1.70	3.40
Indemnity paid out per $ premium collected (Loss Ratio)	0.28	0.31	0.32	0.38
Premium subsidy per acre (percent of per acre premium)	3.50 (0.50)	3.64 (0.30)	2.45 (0.46)	2.60 (0.29)
Practice				
Irrigated (%)	48.8	41.7	29.4	24.7
Non-irrigated (%)	51.2	58.3	70.6	75.3
Relative yield				
Lower relative to county (%)	34.8	29.7	36.1	24.0
Equal to county (%)	22.6	21.8	27.7	25.2
Higher relative to county (%)	42.6	48.5	36.2	50.8
Coverage type				
Cat coverage (%)	22.2	-	22.7	-
Limited coverage (%)	6.8	3.0	2.7	1.2
Additional coverage (%)	71.0	97.0	74.5	98.8
Coverage level				
Less than 65 % (%)	29.0	3.0	25.2	1.2
65% (%)	67.6	87.3	66.9	83.3
More than 65 % (%)	3.4	9.7	7.9	15.5

a. number of CAT policies are 16,680 for corn and 9,819 for soybeans; b. number of policies indemnified divided by the total number policies issued.

Table 3. Results from LOGIT Analysis, dependent variable insurance products.

	Iowa				Nebraska			
	Corn		Soybeans		Corn		Soybeans	
Variable	**Parameters**[a]	**Marginal Effects**	**Parameters**	**Marginal Effects**	**Parameters**	**Marginal Effects**	**Parameters**	**Marginal Effects**
Acreage	0.0036 (5.40)	0.0009	0.0015 (2.02)	0.0004	0.0018 (4.28)	0.0004	0.0025 (3.01)	0.0006
Crop Practice	1.0634 (1.87)	0.2617	b	b	b	b	- 0.0926 (- 0.98)	- 0.0231
Coverage Type	0.8675 (4.70)	0.2135	0.9699 (4.24)	0.2424	b	b	2.1568 (6.23)	0.5390
Relative yield	0.2573 (9.77)	0.0633	0.2491 (6.49)	0.0623	b	b	0.3594 (12.87)	0.0898
Premium Rate	7.1408 (9.73)	0.0175	13.2886 (8.07)	3.3211	3.8684 (9.81)	0.9658	9.7772 (9.21)	2.4434
Intercept	- 3.75 (- 9.29)	- 0.9228	- 4.1629 (- 7.61)	- 1.0404	- 0.6119 (- 9.87)	- 0.1528	- 6.9264 (- 9.60)	- 1.7310
χ^2 value (d.f.)[c]	281.25 (5)		115.62 (4)		116.00 (2)		349.60 (5)	

a. Asymptotic t-ratios in the parentheses;
b. Information not available at this time;
c. d.f. is degrees of freedom.

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Figure 1