Asymmetric Information in the Market for Yield and Revenue Insurance Products. Shiva S. Makki and Agapi Somwaru. Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1892

Abstract

This report analyzes farmers' choice of crop insurance contracts and tests for the presence of asymmetric information in the market for multiple yield and revenue insurance products. Farmers' risk characteristics, their level of income, and the cost of insurance significantly affect their choices of yield and revenue insurance products as well as their selections of alternative coverage levels. Empirical analysis indicates that, in the presence of asymmetric information, high-risk farmers are more likely to select revenue insurance contracts and higher coverage levels. The results also indicate that premium rates do not accurately reflect the likelihood of losses, implying asymmetrical information in the crop insurance market.

Keywords: Asymmetric information, adverse selection, crop insurance, revenue insurance, risk management.

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Summary

This report examines the effects of asymmetric information on U.S. crop insurance markets when a portfolio of yield and revenue insurance products is offered to farmers. The asymmetric information modeling framework developed in health and automobile insurance markets is applied to the crop insurance market in Iowa, where several yield and revenue products were offered to farmers in 1997. The report indicates inaccurate assessment of individual risks and finds evidence of asymmetric information in the market for individualized crop insurance products.

Since the mid-1990's, a number of new crop insurance products have become available to farmers for managing yield and revenue risks. At the same time, several legislative changes have contributed toward increasing the level of farmers' participation and widening the use of crop insurance as a risk management tool. In some sense, these new insurance products might be very instrumental in increasing efficiency in the U.S. crop insurance market by meeting the needs of different producers. At issue is whether the introduction of the new products increases or decreases asymmetric information problems in crop insurance markets. This study, by analyzing the factors that influence the choice of alternative insurance products and coverage levels, attempts to understand the implications of asymmetric information for assessing risk and setting premium rates in the market for crop insurance.

A Generalized Polytomous Logit model is used to analyze producers' choices of insurance products, and a three-stage least-squares model is specified to analyze premium rates and the choice of coverage levels. Results indicate that high-risk farmers are more likely to choose revenue insurance and higher coverage levels. High-risk farmers are also more likely to choose an insurance product where the guarantee and indemnity are based on individual yields for the producer, rather than a product based on county yields. Results also suggest that high-income farmers are more likely to purchase revenue insurance products and higher coverage levels.

Non-parametric methods are used to test the presence of asymmetric information. The results suggest that individual risk types are not assessed accurately and that premium rates do not reflect the likelihood of losses. Results show that, for individual yield and revenue insurance products, low-risk farmers are overcharged and high-risk farmers are undercharged for comparable insurance contracts. In the presence of asymmetric information, premium rates charged to different risk types are likely to suffer from averaging.

A method of assessing an individual's risk, which includes not only average yield and revenue but also yield and revenue variability, might be the key to reducing rating inequities for individually based insurance products. Even though the analysis is limited to Iowa corn and soybeans, the findings provide useful insights into preferences of farmers of various risk types in choosing among alternative insurance contracts. Analysis of more years, crops, and regions would be useful in comparing results to ascertain the robustness of the findings.

Asymmetric Information in the Market for Yield and Revenue Insurance Products

Shiva S. Makki and Agapi Somwaru

Introduction

Rapid expansion has occurred since 1996 in the number of new federally backed crop insurance products offered to farmers. They include several new revenue insurance products that bring new challenges to evaluating the performance of the multiple-product crop insurance market. In some sense, these new insurance products might be very instrumental in increasing efficiency in the U.S. crop insurance market by meeting the needs of different producers. At issue is whether the introduction of the new products increases or decreases informational asymmetries in crop insurance markets. This study is the first attempt to examine the effects of asymmetric information on U.S. crop insurance markets when a portfolio of yield and revenue insurance products is offered to farmers. We analyze the crop insurance market in Iowa, where multiple yield and revenue insurance products were offered to corn and soybean farmers in 1997.

Farmers choose an insurance product based on expected benefits derived from the product. It is often argued that farmers, who produce under uncertainty, know more about their own expected losses (benefits) than can be discerned by the insurer, as farmers are better informed about their distribution of yields. Such asymmetry of information can give rise to the problem of adverse selection, with negative consequences for the efficient functioning of the crop insurance market. In the presence of adverse selection the insurance provider fails to accurately assess the risk of loss and, therefore, is unable to set premiums commensurate with risk. Ideally, crop insurance premiums should be set such that they reflect the likelihood of losses. However, such premiums are difficult to establish in the presence of asymmetric information, where insurance firms are unable to accurately distinguish among different risk types. Such asymmetries exist because of differences in inherent farm risks, arising from factors such as the farm's location characteristics and farmers' managerial abilities.

This report analyzes the characteristics of the crop insurance market under asymmetric information and investigates the presence of adverse selection. The specific issues addressed in this report include: (1) assessment of individual farm risk when limited information is available to the insurer on the farm and farmer, (2) analysis of factors that influence farmers' choices of alternative insurance products and coverage levels; (3) investigation of the presence of heterogeneous risk types in the insurance pool and the possibilities of risk type signaling through contract selection; and (4) testing for adverse selection.

Asymmetric Information in Insurance Markets

Asymmetric information manifests itself primarily in terms of adverse selection and moral hazard. Adverse selection is caused by the inability of the insurer to accurately rate the risk of loss, while moral hazard is caused by the hidden actions of the insured which increase the risk of loss. In this study, we assume that the insured individual cannot affect his/her distribution of losses, which limits the analysis of asymmetric information to adverse selection.

Theoretical and empirical studies in automobile and health insurance markets have shown that adverse selection reduces the consumption of insurance by low-risk individuals, and results in the transfer of income from low-risk to high-risk insureds. The theoretical works of Akerlof (1970), Rothschild and Stiglitz (1976), Miyazaki (1977), and Wilson (1977) describe the insurance market under asymmetric information. Miyazaki and Wilson demonstrate that when it is impossible or highly expensive to distinguish between high- and low-risk insurance applicants, the insurer prices insurance contracts at an average premium for all individuals. This results in undercharging high-risk customers and overcharging low-risk customers for similar contracts. Empirical evidence in automobile and health insurance markets generally supports the predictions of these theoretical models (Browne, 1992; Browne and Doerpinghaus, 1993; Puelz and Snow, 1994).

Several studies have documented the implications of the presence of adverse selection on the performance of crop insurance in the United States. Ray (1974) argues that adverse selection in crop insurance markets can make the industry less self-sustaining if only high-risk farmers buy insurance, as evidenced in the U.S. market for crop insurance. Skees and Reed (1986) show that the potential for adverse selection depends on a farmer's subjective assessment of expected yield and variability of yield. They argue that premium rates based only on mean crop yields can lead to adverse selection, particularly when the variance of yields fluctuates considerably among farms.

Goodwin (1993) illustrates the effects of adverse selection on the actuarial performance of the U.S. crop insurance program, stating that only farmers whose risk is above average are likely to buy insurance. He concludes that high-risk producers are less responsive to premium changes because of adverse selection. In a review of the crop insurance program in the United States, Goodwin and Smith (1995) indicate that there is considerable evidence of adverse selection, and that adverse selection is a direct consequence of insurers' inability to set premiums commensurate with the level of risk.

In a recent study, Just et al., (1999) examined the adverse selection problem in the crop insurance market using nationwide data on the U.S. insurance program. They argue that adverse selection occurs when actual premium rates fail to reflect farmers' expected indemnities. Their results suggest that participating farmers tend to be those with higher expected indemnities, as farmers with lower expected indemnities are priced out of the program. They conclude that when the insurance market is concentrated with high-risk farmers, the result can lead to market failure.

The studies cited above narrowly focus on adverse selection when a yield insurance product was offered to farmers when participation was quite low. In addition, none of the crop insurance studies explicitly test for adverse selection. This study tests for adverse selection when both the number of crop insurance products available and farmer participation are increasing. We apply the asymmetric information modeling framework developed in health and automobile insurance markets to crop yield and revenue insurance markets. Our empirical results indicate that farmers' decisions to buy yield or revenue insurance are significantly affected by the risk they face, their level of income, and the cost of insurance. Our analysis also indicates that inaccurate assessment of individual risks results in overcharging low-risk farmers and undercharging high-risk farmers for comparable contracts. We find evidence of asymmetric information in the market for individualized yield and revenue insurance products.

Theoretical Considerations

We begin by describing how the market attains equilibrium using the demand for and supply of insurance contracts in a well-functioning competitive environment. Consider an individual who purchases an insurance contract to smooth the flow of his/her income across different states of nature. For simplicity, we assume two states of nature, *no loss* and *loss*. We also assume that the insured individual maximizes his/her expected utility. In the absence of insurance, an individual's preference for income in these two states of nature is given by:

(1) $V(m, p) = (1\text{-}p)\, U(m) + p\, U(m - d)$

where m is income, p is the probability of loss, and d is the reduction in income or the amount of loss. U(•) represents the utility of money income, while (1-p) indicates the probability of not incurring a loss. When an individual purchases an insurance contract, the function describing his or her preference for income in the two states of nature is:

(2) $V(\alpha_1, \alpha_2; p) = (1\text{-}p)\, U(m\text{-}\alpha_1) + p\, U(m\text{-}d\text{-}\alpha_1\text{+}\alpha_2)$

where α_1 is the premium cost, α_2 is the payoff (indemnity) from the insurance contract in the case of loss, and V is the expected utility. An insurance contract may be viewed as a promise by the insured to pay an amount α_1 to the insurer, in return for a promise by the insurer to pay indemnities α_2 if a loss occurs. We assume that individuals are risk averse ($U' < 0$) and, thus, that V is quasi-concave. From all the contracts offered, the individual will choose the one that maximizes his/her expected utility, V.

Assuming that insurance companies are risk neutral (concerned only with expected profits) and that returns from insurance contracts are random, an insurance contract sold to an individual who has the probability of incurring a loss of p, is worth:

(3) $\pi(\alpha_1, \alpha_2; p) = (1\text{-}p)\alpha_1 - p(\alpha_2\text{-}\alpha_1)$.

If insurance contracts are sold in a full information-competitive market, then the expected profits are zero:

(4) $(1\text{-}p)\alpha_1 - p(\alpha_2\text{-}\alpha_1) = 0$.

Equation 4 ensures that the expected benefit, $(1\text{-}p)\alpha_1$, is equal to the expected cost, $p(\alpha_2\text{-}\alpha_1)$, of the firm, assuming no administrative costs.[1] In other words, equation 4 represents the set of contracts that have actuarially fair premium rates.

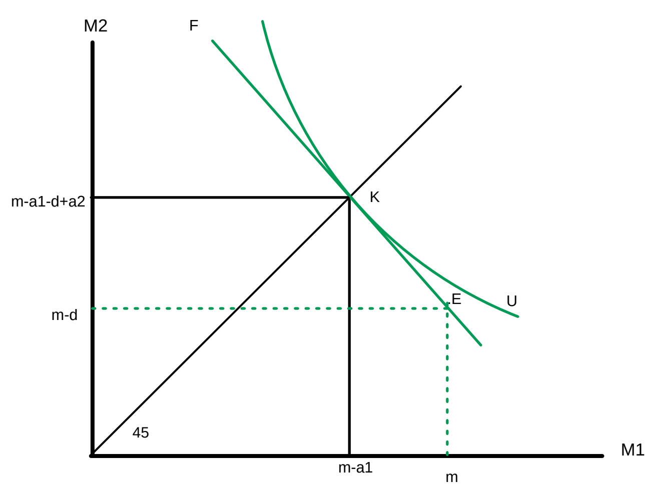
Market Equilibria in Insurance Markets

In insurance markets, unlike other markets, the state of information available to consumers and suppliers of insurance, as well as the nature of the insurance markets' equilibria, matters in understanding how the market functions. Next, we describe in detail the nature of market equilibria under different information conditions in insurance markets.

Market Equilibrium with Full Information

Figure 1A illustrates the equilibrium of a competitive insurance market with identical individuals and *full information* conditions. The horizontal (M_1) and vertical (M_2) axes represent income in the two states: *no loss* and *loss*, respectively. U is the indifference curve representing an individual's preference set. The 45^o line represents equal income in both states of nature. The line EF, which is referred to as the fair-odds line, represents the supply of insurance (see equation 4). Policies break even (zero profit for the insurance company, assuming no administrative costs) along the fair-odds line. The slope of the fair-odds line (the supply of insurance) is given by the ratio of the probability of not having a loss to the probability of having a loss, (1-p)/p, while the slope of the indifference curve (the demand for insurance) is given by the marginal rate of substitution of incomes in the two states of nature $\{U'(m_1)\}/\{U'(m_2)\}$. In equilibrium, the

Figure 1A
Market equilibrium with full information and identical risk types



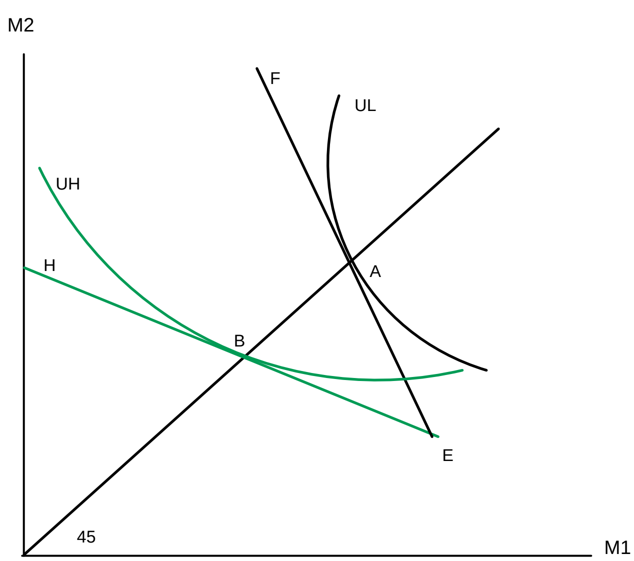
slope of the fair-odds line is equal to the slope of the indifference curve.

An individual starts at an initial endowment E, where income is equal to m if no loss occurs or m-d if a loss occurs. Individuals may reduce their exposure to the risk of loss by trading insurance contracts along the fair-odds line, EF. The equilibrium contract, K, maximizes an individual's expected utility, and it represents *full insurance* coverage, equalizing income in both states of nature. That is, in equilibrium, individuals buy full insurance coverage at an actuarially fair rate resulting, in what is known as, a *full information equilibrium*. Since the contract, K, is on the fair-odds line, the insurer just breaks even.

Figure 1B illustrates the equilibrium of a competitive insurance market with *full information* but individuals representing different levels of risk. Consider a market structure similar to the one discussed above, except that there are low- and high-risk individuals whose probability of loss is known to the insurer. We assume, for simplicity, that there are only two types of individuals ("low-risk" and "high-risk") in the market who differ in their probability of suffering a loss. Let the probability of loss occurrence for high- and low-risk individuals be p^H and p^L, respectively, which implies that p^H is greater than p^L. The low-risk contracts are represented along the line EF, with a slope given by $(1-p^L)/p^L$, while the high-risk contracts are represented along the line EH, with a slope given by $(1-p^H)/p^H$. In this case, the slopes and shapes of indifference curves

Figure 1B

Market equilibrium with full information and different risk types



differ among risk types and depend on the individuals' risk attitudes. Let UL and UH represent indifference curves for low-risk and high-risk individuals, respectively. When the individuals' probability of loss is known, the insurer will offer different contracts commensurate with the various risk types. At equilibrium, both risk types are fully insured at actuarially fair rates at points A and B, where the marginal rate of substitution (the slope of the indifference curve) along the 45º line is just equal to the ratio of the probability of not having a loss to that of having a loss (the slope of the fair-odds line).

Market Equilibrium with Asymmetric Information

Akerlof (1970), in his pioneering work on asymmetric market information, demonstrates the problems that arise in health insurance markets when an applicant for insurance has full information about his/her health, while insurers have no such information. He uses the example of an insurer who is unable to distinguish between high- and low-risk insurance applicants, and values contracts at an average premium for all applicants. In this case, only those individuals whose risk is above average are likely to buy insurance. This will result in losses for the insurer and, thus, premiums would have to be raised for the insurer to break even. Of the group which purchased insurance in the first place, only the worse-than-average risks would purchase insurance again at the higher premium. Premiums would again need to be raised to cover losses and, eventually, only the very high-risk individuals would purchase insurance at extremely high premiums and the entire market for insurance would collapse.

In their seminal work, Rothschild and Stiglitz (1976) explain the existence of equilibrium in an insurance market in which asymmetric information exists between insurer and insurance applicant. In the absence of full information, this market can have two kinds of equilibria: *a pooling equilibrium* or a *separating equilibrium*. In a pooling equilibrium, high- and low-risk insurance applicants are not differentiated by the insurer and, therefore, contracts are priced at an average premium. Contracts are offered to both groups at the same premium, and hence, applicants buy *identical contracts*. This situation leads to the type of market described above in the Akerlof model. In a separating equilibrium, on the other hand, different risk types purchase different contracts that are associated with different premium rates and contract characteristics. In a separating equilibrium, individuals of different risk characteristics separate themselves by contract selection, with the insurer offering *different contracts* commensurate with different risk types.

Figure 1C illustrates an example of *pooling equilibrium* under asymmetric information. As in the previous example, we assume that there are two types of individuals in the market: “low-risk” and “high-risk,” who differ in their probability of suffering a loss. Let the probability of loss occurrence for high- and low-risk individuals be p^H and p^L , respectively, which implies that p^H is greater than p^L. The low-risk contracts are represented along the line EF, with a slope given by $(1-p^L)/p^L$, while the high-risk contracts are represented along the line EH, with a slope given by $(1-p^H)/p^H$. In this case, the slopes and shapes of indifference curves differ among risk types and depend on the individuals’ risk attitudes. Let UL and UH represent indifference curves for low-risk and high-risk individuals, respectively. When an individual’s probability of loss is hidden knowledge, the full-information equilibrium (A, B), in which both risk types are optimally insured, is *unattainable*. This is because insurers cannot prevent high-risk individuals from purchasing the contract A, which assures higher utility in each state.

Furthermore, the nature of asymmetric information implies that insurance companies are unable to distinguish among their customers and, therefore, charge an average premium (represented by line EG). In the resulting pooling equilibrium, the high-risk individual will buy contract B′ and the low-risk individual will buy contract A′. At these levels of coverage, high-risk individuals pay less and low-risk individuals pay more relative to their respective full insurance contracts. In this case, the high-risk individual is over-insured (undercharged), while the low-risk individual is under-insured (overcharged).

Figure 1D illustrates an example of a *separating equilibrium* under asymmetric information, as described by Rothschild and Stiglitz (1976). Consider a market structure similar to the one discussed in figure 1C, except that the insurer offers two contracts at two different prices. The low-price contracts are represented along the line EF, with a slope given by $(1-p^L)/p^L$, while the high-price contracts are represented along the line EH, with a slope given by $(1-p^H)/p^H$. Let UL and UH represent indifference curves for low- and high-risk individuals, respectively. As in the previous case, when an individual’s probability of loss is unknown, the full-information equilibrium (A, B), in which both risk types are optimally insured, is *unattainable*. The full information equilibrium (represented by contracts A and B in this example) is where the insureds’ expected utilities are maximized (UL and UH) and the insurer breaks even. This full information equilibrium is unattainable because high-risk individuals prefer the contract A over B, as A assures higher utility (consumption) in each state. In this case, however, the insurer can offer two contracts (represented

Figure 1C
Pool equilibrium under asymmetric information and different risk types

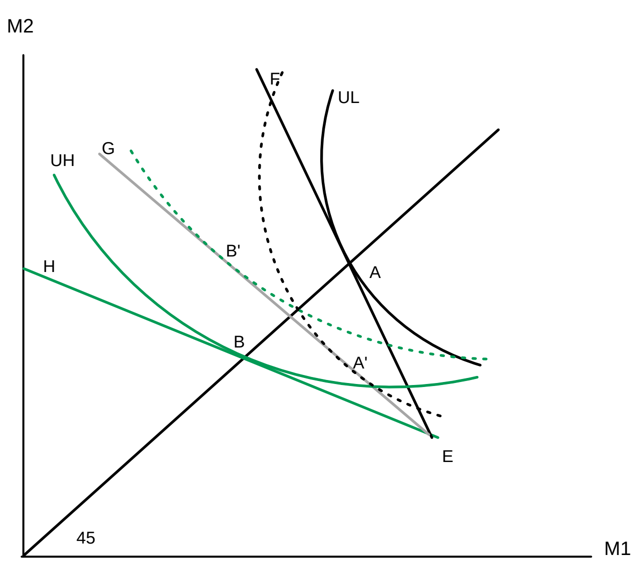
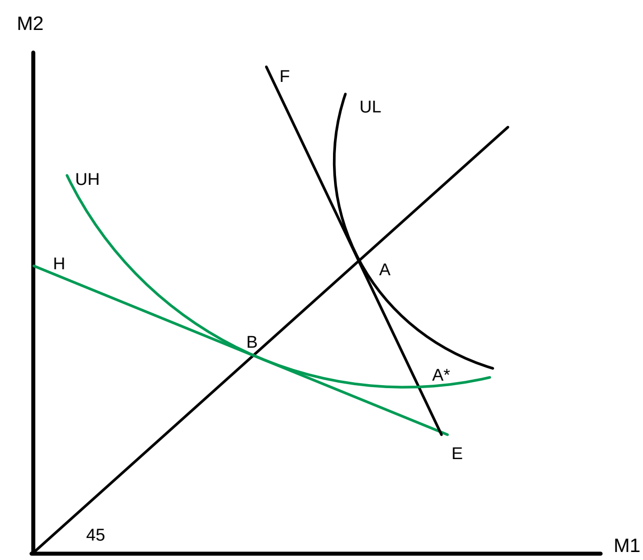


Figure 1D
Separating equilibrium under asymmetric information and different risk types



by fair-odds lines EF and EH) suitable for the two different risk types.

Since the insurer cannot separate low-risk applicants from high-risk applicants, the contract offered to low-risk types must not be more attractive to high-risk types than their best contract. In the resulting equilibrium, the high-risk individual will buy contract B and the low-risk individual will buy contract A*. Thus, for a separating equilibrium to exist, the low-risk contract must lie on the high-risk indifference curve, U^H, or lower. This establishes the contract set (A*, B) as the attainable equilibrium for a market with low- and high-risk individuals. At the equilibrium, high-risk individuals buy the full insurance contract, B (where the high-risk fair-odds line is tangent to the high-risk indifference curve), while low-risk individuals will buy the partial insurance contract, A* (where the low-risk fair-odds line intersects the high-risk indifference curve).

Since individuals may not have any incentive to divulge information on their level of risk, the insurer is better off by offering a menu of contracts such that high-risk and low-risk types purchase different contracts commensurate with their level of risk. Studies in automobile and health insurance demonstrate that offering a selection of contracts with different prices and coverage levels is more efficient than offering a single contract at an average price (Hoy, 1982).

Wilson (1977) and Miyazaki (1977) extended the Rothschild and Stiglitz model further to show the *transfer of income* from low-risk individuals to high-risk individuals under both pooling and separating equilibria. The Wilson model demonstrates the transfer of income from low-risk to high-risk individuals as both individuals purchase *identical contracts* for the same price. A low- to high-risk subsidization results as the high-risk individuals have a greater incidence of loss for the identical contracts than the low-risk individuals.

In the Miyazaki model, high-risk and low-risk individuals purchase *different contracts*. The contracts purchased by high-risk individuals generate losses for the insurer, while contracts purchased by the low-risk individuals generate profits. Therefore, the low-risk to high-risk subsidization in the Miyazaki model occurs across individuals buying different contracts. In the Wilson model, the subsidization is across individuals buying identical contracts.

Market signaling. The theory of market signaling suggests that in insurance markets with asymmetric information, agents signal their hidden knowledge through their choice of insurance contracts (Cho and Kreps, 1987; Spence, 1978). Studies in automobile and health insurance markets have shown that low-risk individuals have an incentive to signal their risk characteristics by selecting high deductibles in the presence of hidden knowledge and unobservable heterogeneity of risk types among the insurance applicants (Riley, 1985; Browne, 1992; Puelz and Snow, 1994).

Rothschild and Stiglitz (1976) and Spence (1978) have shown that when insurance firms offer a menu of contracts, high-risk individuals are more likely to purchase the high coverage contracts, while low-risk individuals are more likely to choose the low-coverage contracts. This is a self-revealing mechanism widely used in automobile and health insurance markets to identify risk types. When an individual chooses an insurance contract among the menu of contracts offered, the individual reveals some information about himself/herself, or sends a “signal” to the insurer. For example, if an individual purchases a health insurance contract with a high deductible, the individual sends a “signal” which could mean that he/she represents lower risk than the one who opted for a lower deductible contract.

It is possible that signaling could also be influenced by other characteristics such as the degree of risk aversion. When individuals vary in risk averseness as well as in their likelihood of expected loss, the choice of an insurance contract is no longer influenced by the probability of loss alone. For example, an individual may purchase an insurance contract with high coverage either because his/her probability of loss is high, or because he/she is highly risk-averse. However, if we assume independence of the distribution of probabilities of loss and the distribution of attitudes towards risk, individuals who buy insurance with higher coverage will tend, on average, to have larger expected losses than those with insurance with lower coverage (Pauly, 1974).

Adverse selection. Adverse selection has long been recognized as a problem in insurance markets, including crop insurance. Empirical studies in automobile and health insurance markets have found that adverse selection reduces the consumption of insurance by low-risk individuals and results in the transfer of income from low-risk to high-risk insureds (Browne and Doerpinghaus, 1993; Dionne and Doherty, 1994; Puelz and Snow, 1994).

Figures 1C and 1D illustrate the adverse selection problem in the case of two risk types, low-risk and high-risk. When an insured's probability of loss is unknown to the insurer, the full information equilibrium (A, B) is unattainable. Under asymmetric information, those with high risk are over-insured and under-priced (B′) and those with low risk are under-insured and over- priced (A′ or A*).

The Crop Insurance Market

To analyze the crop insurance market, where different products and coverage levels are offered to farmers, we apply the asymmetric information equilibrium framework developed in automobile and health insurance markets. Consider a farmer with an initial income, m, who is exposed to a risk, which can cause a loss, d, with a probability of insuring a loss, p, while (1-p) is the probability of not insuring a loss. The farmer can pay a premium, π, to an insurance firm, which in return pays some compensation or indemnity (I) if the loss occurs. The farmer chooses a contract that maximizes expected utility:

$$(5) \quad U(\bullet) = (1\text{-}p)\,U(m - \pi) + p\,U(m - \pi - d + I)$$

where U(•) is the von Neumann-Morgenstern utility function, assumed to be increasing, strictly concave (reflecting risk aversion), and differentiable. The indemnity paid by the insurance company to the farmer when the actual yield (revenue) falls below the guaranteed yield (revenue) depends on the insurance contract (α):

$$(6) \quad I = I(\alpha).$$

The insurance contract is defined as a yield or revenue insurance product with a coverage level that specifies the yield or revenue guarantee. To derive an equilibrium condition, we assume that α is a continuous choice variable. Assuming there are no transaction costs, the premium can be expressed as a function of α and other observable characteristics (z) indicative of risk type[2]:

$$(7) \quad \pi = \pi(\alpha, z).$$

When risk type is *not observable* and insurance is *not costless*, equations 6 and 7 imply that equilibrium insurance contracts depend on the manner in which insurers and insureds interact in the market.

Differentiating (5) with respect to α, we obtain the optimal choice of an insurance contract that satisfies the following first order condition:

$$(8) \quad \frac{U'(m - \pi)}{U'(m - \pi - d + I)} = \frac{p\,\{I'(\alpha) - \pi'(\alpha, z)\}}{(1\text{-}p)\,\pi'(\alpha, z)}$$

where $U'(\bullet) > 0$ is the marginal utility of income. The ratio p/(1-p), which gives the odds of incurring a loss, is a measure of risk associated with the insurance contract. $I'(\alpha)$ and $\pi'(\alpha, z)$ represent the indemnity and the premium at the margin, respectively. Equation 8 implies that, in equilibrium, the demand for insurance is equal to the supply of insurance.

If the price of insurance is actuarially fair, individuals would buy full insurance resulting in equalization of incomes in the two states of nature.[3] This is *full-insurance* in the sense that the individual would be indifferent between the two states of nature such that:

$$(9) \quad U'(m - \pi) = U'(m - \pi - d + I(\alpha)).$$

Individuals would trade income from one state of nature to another through a payment of premium (π) to the insurer, in return for a promise by the insurer to pay indemnities (I) if a loss occurs. Such trading will continue until the incomes are equalized. The ratio of marginal utilities of expected incomes explains why risk-averse individuals are willing to purchase insurance (Ehrlich and Becker, 1972).[4] Substituting 9 in 8 yields the optimal condition for the supply of insurance:

$$(10) \quad (1\text{-}p)\,\pi'(\alpha, z) = p\,\{I'(\alpha) - \pi'(\alpha, z)\}$$

which indicates that expected benefits are equal to expected costs for the insurer. Solving equation 10 for premium rate yields:

$$(11) \quad \pi'(\alpha, z) = p\,I'(\alpha)$$

which means that the fair premium is equal to the expected indemnity payment.

We derive the reduced-form solutions by applying the implicit function theorem to equation 8 (see Puelz and Snow). That is, the choice of α is expressed as a function of risk type (τ), willingness to pay for insurance (ρ), and cost of insurance or premium (π):

$$(12) \quad \alpha = \alpha(\tau, \rho, \pi).$$

An empirical finding that risk type is statistically significant ($\alpha_\tau \neq 0$) supports the presence of a *separating equilibrium* in the crop insurance market. Conversely, if risk type is not significant ($\alpha_\tau = 0$), the evidence is consistent with a *pooling equilibrium*.

When it is impossible or prohibitively expensive for the insurer to differentiate applicants according to risk types, insurance premiums may not accurately reflect the risk of loss (Borch, 1990; Browne, 1992; Puelz and Snow, 1994). Under such circumstances, the insurer sets premiums based on the average risk of the insured pool. As argued by Rothschild and Stiglitz, average premium rates are more attractive to high-risk individuals, potentially leading to adverse selection in the insurance markets.

Crop Yield and Revenue Insurance Contracts

In this study, we examine several crop yield and revenue insurance plans—Actual Production History (APH) insurance, Group Risk Plan (GRP), Crop Revenue Coverage (CRC), Income Protection (IP), and Revenue Assurance (RA)—and their discrete coverage levels of 50 percent through 75 percent. The exception to this coverage range is GRP, which is offered at up to the 90-percent coverage level. Three revenue insurance products, CRC, RA, and IP, were offered on a large scale in 1997, in addition to the traditional yield insurance products, APH and the GRP. In terms of geographic coverage, the revenue insurance products represented nearly a third of insured corn and soybean acres in Iowa in 1997 (Makki and Somwaru, 1999b).

The APH contract is an individual yield insurance plan that protects farmers against yield shortfalls if the actual yield falls below the guaranteed level. APH insurance includes catastrophic coverage (CAT) and optional (buy-up) levels of coverage above CAT. For a flat fee of $60 per crop per farm, CAT provides a 50-percent yield guarantee and pays an indemnity based on 55 percent of the projected price. In this analysis, we separate CAT and APH buy-up coverage and will hereafter refer to APH buy-up simply as APH insurance. APH insurance provides yield protection of up to 75 percent of the farmer's average historical yield, with a premium based on the chosen coverage level. The APH contract pays an indemnity if the farmer's yield falls below the guaranteed level but offers no price protection. The indemnity payment from a typical APH insurance is given by:

$$(13)\quad I = \max \{0, (y^g - y^a)\, P^g \}$$

where y^g is the guaranteed yield, y^a is the actual yield, and P^g is the guaranteed price (or elected price). The guaranteed price, P^g, is a certain fixed proportion of the expected price, which is usually USDA's projected farm-level price for the crop year. The guaranteed yield, y^g, is a certain fixed proportion of the expected yield (y^e), usually based on the average historical yield (y^{AHY}) of each given farm, and the chosen coverage level:

$$(14)\quad y^g = \theta\, y^e = \theta\, y^{AHY}, \qquad 0.50 \le \theta \le 0.75$$

where θ is the chosen coverage level. CAT and APH contracts allow for basic units, which combine each of the fields of a crop under a single type of ownership arrangement, and optional units, which allow insurance by section line and practice (dry land versus irrigated crops).

GRP is a yield insurance product, but is tied to the county average yield rather than the individual farm yield. GRP contracts provide indemnity payments when the county average yield (y^c) drops below a critical or guaranteed level, regardless of the yield of the individual farmer:

$$(15)\quad I = \max \{0, (y^g - y^c)\, P^g \}.$$

This indemnity function is similar to equation (13), except that the individual farm yield is replaced by the county yield and the critical yield is estimated based on past county yield histories. GRP buyers can insure up to 90 percent of the expected county yield at up to 150 percent of the expected price (Skees et al., 1997).

CRC, RA, and IP are revenue insurance plans that protect the farmer from lost revenue caused by low yields, low prices, or a combination of both. They are all based on the farmer's historical average yield and futures prices, but differ somewhat in their specific design and operation. CRC provides replacement-cost protection to producers in addition to a revenue guarantee. Indemnities are paid if the producer's calculated revenue (based on his or her actual yield in that year, multiplied by the harvest-time quote on the harvest-time futures contract) falls below the predetermined guarantee level (based on the coverage level chosen by the producer, the farmer's average historical yield, and the higher of the planting-time quote or the harvest-time quote on the harvest-time futures contract). In other words, under a typical CRC contract, the indemnity payment is defined by:

$$(16)\quad I = \mathrm{MAX} \{0, (y^g \max(P^g, P^m) - y^a P^m) \}$$

where P^m is the harvest futures market quote on the harvest-time futures contract, P^g is the planting-time quote on the harvest-time futures contract, y^g is the guaranteed yield, and y^a is the actual yield.[5] Since CRC uses the higher of the planting-time price for the harvest-futures contract or the actual-futures contract quote at harvest in setting the guarantee, the producer's revenue guarantee may actually increase over the season. This is because CRC allows producers to purchase "replacement bushels" if yields are low and prices increase during the season (Harwood et al., 1999). CRC, which allows for enterprise units, basic unit, and optional unit coverage, has rapidly expanded to all major crops in major growing areas (GAO, 1998).

RA and IP also protect farmers against reductions in gross income when either prices or yields decrease during the crop year from early-season expectations. Indemnity amounts are determined by individual farm yields and harvest-time futures prices:

$$(17) \quad I = MAX\,\{0, (y^g P^g - y^a P^m)\}$$

where P^m is the harvest futures market quote on the harvest-time futures contract, P^g is the planting-time quote on the harvest-time futures contract, y^g is the guaranteed yield, and y^a is the actual yield.

There are, however, key differences between RA and IP contracts. RA provides the option of enterprise-level farm insurance (where the guarantee is based on expected revenue from all the farmer's acreage in a given crop in the county) as well as whole farm insurance (where the guarantee is based on the expected revenue from multiple crops grown by the farmer in a given county). RA also allows both basic unit coverage (where the insurance contract is based on ownership and county) and optional unit coverage (where the insurance contract is based on ownership, farming practice, county, and section line). Beginning in 1999, RA also offers a harvest price option (RA-HP). If a farmer purchases the RA-HP contract, then his or her coverage is similar to CRC but with no price liability limit in a rising-price market (Risk Management Agency, 1999).

IP is offered only on the basis of enterprise units, meaning that all fields of a crop which a farmer owns or has a share of the commodity in the county are combined into one unit. IP and RA (without the HP option) offer exactly the same coverage if the farmer chooses enterprise units. IP and RA also differ in the way price guarantees are set. The IP revenue guarantee is based on the futures price with no basis adjustment (using an average of Chicago Board of Trade (CBOT) February price quotes for the December contract), while the RA guarantee is based on an approximate local price (the December price adjusted for a county factor). In both cases, indemnities are paid if the producer's gross income falls below the predetermined guarantee (Harwood et al., 1999). Even though both IP and RA were introduced in 1996, they are available only in selected counties and for selected crops (Risk Management Agency, 1999).

Description of the Data

Data used in this study are from USDA's Risk Management Agency (RMA), which maintains records of all individual farmers who buy federally backed crop-yield or revenue insurance. The data pertain to corn farmers in Iowa for the 1997 crop year. We selected a sample of about 60,000 unit-level insurance records for which 10 years of yield records were available.[6] For each unit, we have several variables that describe the characteristics of the contract, such as choice of coverage level and price, premium rate, and indemnity payments. We also have variables that assess the risk of an individual unit—past yield records, yield span, farm practice, ownership share, loss frequency, and liability.

Tables 1 and 2 summarize descriptive statistics for the various insurance products based on the 1997 individual insurance records for Iowa corn and soybeans, respectively. In tables 1 and 2, we separate CAT and APH buy-up coverage contracts. The sample includes three yield insurance plans—CAT, APH, and GRP—and two revenue insurance plans—CRC and RA. IP is dropped from the analysis for lack of sufficient data. Only 50 IP contracts were sold for corn and soybeans combined in Iowa in 1997.

We calculated the mean and the coefficient of variation (CV) for each insured farm unit based on 10 years of yield data. The mean yields for corn ranged between 120 and 130 bushels/acre (table 1), while mean yields for soybeans ranged between 40 and 45 bushels/acre (table 2). The estimated CV of yield was around 30 percent for both corn and soybeans. We also estimated the CV of revenue for each farmer based on the 10 years of yield records and the marketing year average prices for the corresponding years. The CV of revenue follows the CV of yield closely across all products, even though one would have expected a lower CV for revenue because of the possibility of negative correlation between price and yield.

Results presented in table 1 indicate that CRC is the most expensive product on both a per-acre and per-dollar-of-liability basis. For example, corn CRC contracts cost an average of $12 per acre or $6 per $100 of liability for a 65-percent coverage-level contract. The higher cost of CRC is due in part to higher expected indemnities, including provision for replacement coverage when the harvest-time price is greater than the projected planting-time price.

The loss frequency, calculated as the percentage of policies indemnified, for APH, CRC, and RA was, respectively, 1.4 percent, 2.1 percent, and 1.6 percent for the 65 percent coverage contract for corn in Iowa (table 1). The loss ratio, defined as indemnity paid out per dollar of premium, was 0.0543, 0.0514, and 0.0774 for APH, CRC, and RA for corn in Iowa, respectively. The loss-cost ratio, defined as indemnity paid out per dollar of liability, was also low for all insurance prod-

Table 1—Summary statistics for Iowa crop insurance contracts based on sample data: Corn, 1997[1]

	APH			CRC			RA			GRP	CAT
Characteristics	65	70	75	65	70	75	65	70	75	All	50
Number of units insured	24,676	2,381	8,628	16,022	8,850	4,442	3,232	779	1,353	808	4,316
Average area insured (acres)	54.45	59.00	50.00	57.25	56.60	58.43	59.30	63.64	60.70	158.40	76.22
Mean yield (bu/ac)[2]	126.02	127.34	123.52	125.80	127.20	124.90	128.00	130.33	128.76	123.00	129.40
CV of yield[3]	0.31	0.31	0.32	0.31	0.31	0.32	0.30	0.30	0.30	0.21	0.33
CV of income	0.33	0.33	0.34	0.32	0.33	0.34	0.32	0.32	0.32		0.35
Loss frequency (%)[4]	1.4	2.2	4.2	2.1	3.0	5.4	1.6	1.8	3.1	0.37	0.1
Premium rate ($ per acre)	8.25	10.56	14.07	11.90	15.05	20.14	5.86	7.64	10.62	6.70	2.85
Rate (premium per $ of liability)	0.0430	0.0501	0.0650	0.0581	0.0678	0.0864	0.0310	0.0361	0.0481	0.2000	0.0317
Loss ratio[5]	0.0543	0.0544	0.1300	0.0514	0.0857	0.1397	0.0774	0.0660	0.1321	0.1290	0.0049
Loss-cost ratio[6]	0.0030	0.0037	0.0091	0.0035	0.0091	0.0133	0.0034	0.0030	0.0066	0.0062	0.0007
Ownership share (%)	70	73	70	72	73	74	72	75	70	78	66
Average price elect ($ per bu)	2.45	2.45	2.45	2.59	2.59	2.59	2.42	2.42	2.42	2.45	1.47

[1] Sample data consist of individual farm-unit level insurance records.
[2] For APH, CRC, RA, and CAT, mean yield is calculated for each unit based on 10 years of yield records, while for GRP the mean yield is calculated using county-level yield records.
[3] CV is coefficient of variation (standard deviation/mean).
[4] Loss frequency is the percentage of total policies indemnified.
[5] Loss ratio is the indemnity paid out per dollar of premium collected (indemnity/premium).
[6] Loss-cost ratio represents indemnity per dollar of liability (indemnity/liability).

ucts in 1997 (tables 1 and 2). The loss cost and loss ratios are low because insurance contracts in Iowa experienced lower claims in 1997 than in many other years largely due to favorable weather conditions and relatively high commodity prices. One should note that these numbers reveal little regarding the long-term actuarial soundness of insurance products. The descriptive statistics for soybeans are similar to those for corn in 1997 (table 2).

Table 2—Summary statistics for Iowa crop insurance contracts based on sample data: Soybeans, 1997[1]

	APH			CRC			RA			GRP	CAT
Characteristics	**65**	**70**	**75**	**65**	**70**	**75**	**65**	**70**	**75**	**All**	**50**
Number of units insured	18,263	1,269	7,359	10,484	4,840	3,451	2,143	408	811	782	4,198
Average area insured (acres)	48.80	53.30	46.33	52.17	52.08	55.40	53.82	57.70	50.32	118.13	69.50
Mean yield (bu/ac)[2]	39.44	40.80	39.76	39.90	40.66	40.50	40.50	41.75	40.13	41.44	39.10
CV of yield[3]	0.28	0.26	0.27	0.28	0.27	0.27	0.28	0.26	0.28	0.17	0.31
CV of income	0.29	0.27	0.28	0.29	0.28	0.29	0.29	0.27	0.28		0.31
Loss frequency (%)[4]	1.4	1.4	2.6	1.8	2.4	4.3	2.0	1.0	1.0	0.0	0.1
Premium rate ($ per acre)	5.04	6.25	8.30	7.06	8.92	12.20	5.30	7.40	10.00	3.00	1.73
Rate (premium per $ of liability)	0.0314	0.0351	0.0451	0.0403	0.0468	0.0596	0.0297	0.0371	0.0496	0.0108 0	.0230
Loss ratio[5]	0.0406	0.0502	0.0987	0.3152	0.5554	0.8514	0.0637	0.0178	0.0420	0.0000	0.0062
Loss-cost ratio[6]	0.0015	0.0022	0.0050	0.0174	0.0358	0.0541	0.0025	0.0008	0.0020	0.0000	0.0006
Ownership share (%)	0.68	0.71	0.68	0.70	0.71	0.72	0.70	0.71	0.66	0.75	0.66
Average price elect ($ per bu)	6.15	6.15	6.15	6.62	6.62	6.62	6.64	6.64	6.64	6.15	3.69

[1] Sample data consist of individual farm unit-level insurance records.
[2] For APH, CRC, RA, and CAT, mean yield is calculated for each unit based on 10 years of yield records, while for GRP the mean yield is calculated using county-level yield records.
[3] CV is coefficient of variation (standard deviation/mean).
[4] Loss frequency is the percentage of total policies indemnified.
[5] Loss ratio is the indemnity paid out per dollar of premium collected (indemnity/premium).
[6] Loss-cost ratio represents indemnity per dollar of liability (indemnity/liability).

Empirical Model and Hypotheses Testing

The econometric analysis is carried out in two stages. First, equation 12 is estimated as a Generalized Polytomous Logit (GPL) function to handle the discrete choice of insurance products, measured on a nominal scale (Greene, 1990; Kennedy, 1992; Long, 1997; Stokes et al., 1998) and second, a three-stage least-squares model is specified to analyze premium rates and the choice of coverage levels.

Generalized Polytomous Logit Model

The probability that a farmer will choose one of the *m* alternative insurance products, Φ_i, from a set of choices, Φ, is given by:

$$(18)\quad prob\left(\Phi_i \middle| \Phi\right) = \frac{\exp\left[U\left(\Phi_i\right)\right]}{\sum_{j=1}^{m} \exp\left[U\left(\Phi_j\right)\right]} = \frac{\exp\left(x_i\beta\right)}{\sum_{j=1}^{m} \exp\left(x_j\beta\right)}$$

where $U(\Phi_i)$ is the utility for alternative Φ_i, x_i is a vector of variables that affect the choice of the insurance product, and β is a vector of parameters. The probability that a farmer will choose a particular product is given by the probability that the utility of that product is greater than the utility from any other available alternative (utility maximization approach). Insurance products available to farmers include CAT, APH, GRP, CRC, and RA.[7] The explanatory variables are risk type, willingness to pay for insurance, and cost of insurance (see table 3).

Since the response variable, choice of insurance product, has no inherent ordering, we estimate equation 18 as a generalized polytomous logit function. The logit of the response variable is formed as a ratio of the probability of choosing a product over the probability of choosing the reference product:

$$(19)\quad logit_{hijk} = log[\frac{\eta_{hijk}}{\eta_{hijr}}]$$

where k = 1, 2, ..., (r-1) indexes the choice of insurance products, r is the reference choice or the choice used as the basis for comparison, h, i, and j reference the explanatory variables, and η_{hijk}, which represents equation 9, is the probability of the k^{th} choice. Specifically, hijk is given by:

$$(20)\quad \eta_{hijk} = \frac{e^{\alpha_k + x_{hji}\beta}}{1 + e^{\alpha_k + x_{hji}\beta}}.$$

A logit of the response variables under consideration is formed for the probability of each product over the reference product. For example, the generalized logits for a four-level nominal response (where the producer chooses among four different insurance products) can be specified as follows:

$$logit_{hij1} = log[\frac{\eta_{hijk1}}{\eta_{hij4}}]$$

$$(21)\quad logit_{hij2} = log[\frac{\eta_{hijk2}}{\eta_{hij4}}]$$

$$logit_{hij3} = log[\frac{\eta_{hijk3}}{\eta_{hij4}}]$$

where product 4 is the reference choice. The model that applies to all logits *simultaneously*, for every combination of the explanatory variables, in a matrix form, is:

$$(22)\quad \mathrm{logit}_{hijk} = \alpha_k + x_{hij}\,\beta_k$$

where k indexes the choice of the product. The matrix x_{hij} is the set of explanatory variable values for the hij^{th} group. This model accounts for each response by estimating separate intercept parameters (α_k) and different sets of regression parameters (β_k) for all explanatory variables. That is, in the GPL model specification, we estimate simultaneously as a panel multiple sets of parameters for both the intercept and the explanatory variables.[8]

We estimate two GPL models using equation 22. Model 1 is a GPL specification with product choices GRP, CRC, and RA with APH as the reference choice. Model 2 is also a GPL specification with product choices APH, GRP, CRC, or RA with CAT are the reference choice. The reason for estimating model 2 is to use the completely subsidized contract as the reference choice.[9] In both models, however, farmers make a choice from a portfolio of yield and revenue insurance products.

Interpretation of the GPL parameter estimates is not very straightforward because the dependent variable has no inherent ordering. To facilitate interpretation of the model parameters, we estimate probabilities and odds ratios. The predicted probability that a particular product is chosen is a function of the estimated model parameters given in equation (22). Odds ratios are obtained from the predicted probabilities (Stokes et al., 1998). For example, to obtain the odds of choosing product k by a high-risk farmer relative to a low-risk farmer, we compute:

$$(23)\quad Odds\ Ratio \;=\; \frac{e^{(\alpha_k \,+\, x_{hij}\,\beta)}}{e^{(\alpha_k \,+\, x_{lij}\,\beta)}}, \qquad h \neq l\,,$$

where *h* and *l* are reference risk types. The odds ratio is a multiplicative coefficient, which means that positive effects are greater than 1, while negative effects are between 0 and 1. Determining the effect of the odds of the event not occurring involves taking the inverse of the effect of the odds of the event occurring (Long, 1997).

Explanatory variables used in the GPL regression model are: (i) probability of yield or revenue falling below the guaranteed level to represent risk type, (ii) level of income or size of operation to represent the willingness to pay for insurance, and (iii) premium per dollar of liability to represent the cost of insurance. Risk type of a farm (RISK) is measured in terms of the probability of yield or revenue falling below the guaranteed level. For yield insurance products, CAT, APH, and GRP, RISK is the probability of *yield* falling below the guaranteed level (Y^p), while for revenue insurance products, CRC and RA, RISK is the probability of *revenue* falling below the guaranteed level (R^p).

The probability of yield falling below the guaranteed level is estimated for *each farm* based on 10 years of yield records, the chosen guaranteed level, and assuming a normal distribution of yield.[10] The probability of revenue falling below the guaranteed level is estimated for *each farm* based on 10 years of yield records and the marketing year average prices, the chosen guaranteed level, and assuming revenues are normally distributed. This measure of risk accounts for both the mean and variance of yield or revenue (Skees and Reed, 1986; Just et al., 1999).

In this study, we use predicted probability of yield or revenue falling below the guaranteed level to measure risk. This measure of risk (Y^p or R^p) is a function of observable variables, including past yield or revenue histories and chosen guaranteed level, and thus provides a robust measure of an individual's risk.[11]

Since neither farm income nor net worth data were available, the level of income that represents willingness to pay is proxied by accumulated savings. Conceptually, income indicates the liquidity position of the farmer, which is an important determinant of the willingness to pay for an insurance contract (Makki and Miranda, 1999). The farmer's level of income, which is proportional to the size of the operation, also indicates the amount of income at risk, along with the operators' ability to pay for insurance or to self-insure against the risk of loss. In our analysis, income is estimated for each farmer as $M = \lambda \Sigma A_t Y_t P_t,\ \forall\ t = 1, 2, \ldots, 10$, where M is the income level, A_t is the number of acres insured in time t, Y_t is the yield per acre in time t, P_t is the marketing-year average price in time t, and λ is the proportion of gross revenue saved in each year. The parameter, λ, is assumed to be equal to 0.10 or 10 percent of gross revenue (Holbrook and Stafford, 1971).[12]

The cost of insurance, captured by premium per dollar of liability, is calculated as total premium (including subsidy) divided by total liability (RATE). Liability represents the maximum potential indemnity or value of the insurance contract if a producer loses the entire crop. This measure of insurance cost facilitates comparison across different insurance contracts. Premiums are subsidized by the Federal Crop Insurance Corporation up to 42 percent (Makki and Somwaru, 1999), but we use total premium in this study.

We adopt the CATMOD procedure in SAS to estimate the GPL model. This procedure is recommended when the dependent variable has several nominal responses without any inherent ordering (Stokes et al., 1998). The CATMOD procedure forms a separate group for each distinct combination of the explanatory variable values. For continuous explanatory variables with many distinct values, the procedure would create a larger number of combinations, rendering the results impossible to interpret. To overcome this limitation, we group each of the explanatory variables into three categories, low, medium, and high.

We group the explanatory variables using their mean and standard deviation. For example, the estimated mean and standard deviation for Y^p were 0.17 and 0.11, respectively, for Iowa corn producers. Farmers with Y^p near the mean (± 1 standard deviation or 0.06

$< Y^p \leq 0.28$) are categorized as medium-risk. Farmers with $Y^p \leq 0.06$ (mean minus one standard deviation) are categorized as low-risk, while those farmers with $Y^p > 0.28$ (mean plus one standard deviation) are categorized as high-risk. Similarly, the estimated mean and standard deviation for R^p were 0.24 and 0.12, respectively. Farmers are categorized as low-risk if $R^p \leq 0.12$, while $0.12 < R^p \leq 0.36$ indicates medium-risk and $R^p > 0.36$ is high-risk. Other variables, income level, and premium rate, are categorized into the three classes using similar procedures.

Three-Stage Least-Squares Model

We specify a simultaneous equation system to analyze premium rates and choice of coverage level:

(24) $\pi_i = x_i \beta + e_i$

(25) $\theta_i = x_i \beta + u_i$

where π_i is premium per dollar of liability (including the subsidy), θ_i is the coverage level chosen by the farmer, x_i is a matrix of explanatory variables, β is a vector of parameters, while e_i and u_i are error terms. The set of explanatory variables included in equation 24 include risk type, coverage level, practice, ownership share, and yield span, while explanatory variables in equation 25 include risk type, level of income, premium rate, practice, ownership share, and yield span (see table 3).

Variables representing risk type, income level, and premium rate are as defined earlier in equation 22, except that they are not grouped. Farm practice—i.e., whether or not a farm is irrigated—is included because irrigation has the potential to reduce yield risks and may provide the incentive to buy higher coverage levels. For the econometric analysis, practice is set equal to 1 for irrigated farms and to 0 for non-irrigated farms.

Ownership share, which is the percentage share of the crop owned by the insured, could potentially influence the choice of an insurance contract. However, the direction of the effect on the level of coverage purchased is indeterminate. A positive effect implies that as the share of ownership increases, farmers are more likely to purchase higher coverage contracts. This is plausible because full ownership could mean greater dependence on farm income for livelihood. On the other hand, a negative effect is also possible, as tenant farmers are usually more leveraged and thus may be subjected to insurance requirements from lenders (Gardner and Kramer, 1986; Goodwin, 1993; Wu, 1999). Given these conflicting effects, the issue of whether ownership share is positively or negatively associated with the insurance purchase decision must be resolved empirically.

USDA's Risk Management Agency (RMA) uses the "yield span" concept to categorize farms into different *classes* (table 3). The yield spanning approach classifies farmers' yields into nine discrete risk categories (R01 through R09) based on the ratio of a farmer's yield to the average county yield. According to the yield span concept, category R01 includes the lowest average yields while category R09 includes the highest average yields. Yield span category R05 includes all those farms whose yields are expected to be equal to the county's expected yield. Yield span ranges are derived from historical county loss experience and are calibrated to the expected county yield reported by the National Agricultural Statistical Service (NASS).

Equations 24 and 25 are estimated simultaneously using the three-stage least-squares procedure. Because error terms are correlated, the farmer's decision choice of coverage levels and the premium rates require a simultaneous equation system approach.[13] The procedure is applied to each insurance product separately.

The purpose of estimating the coverage level and premium rate as a system is to analyze, *ex-post*, the relationship between the producers' choice of coverage levels and the premium rates at which they are offered. Past studies of crop insurance participation have often treated premium rates as exogenous (Coble et al., 1996; Goodwin, 1993). Although the premium rates for different coverage levels are known *ex-ante*, in this analysis we treat them simultaneously as an endogenous choice to gain insight into farmers' decision making processes and the factors affecting those decisions. This is particularly important for an analysis of markets affected by asymmetric information problems. As past yield histories and other farm and farmer risk characteristics are not easily available, the best way to address farmers' attitudes is by observing the choice(s) made by the farmers themselves. Thus, analysis of premium rates and coverage levels can enhance our understanding of farmers' behavior in the crop insurance market. Furthermore, if farmers effectively signal their risk type, through the choice of premium-coverage level, then such information is useful in assessing potential losses and setting premium rates commensurate with risk.

Table 3—Variable description

Variable name	Variable definition
Insurance plans	Alternative insurance plans or products that include Catastrophic Coverage (CAT), Actual Production History Insurance (APH), Group Risk Plan (GRP), Crop Revenue Coverage (CRC), Revenue Assurance (RA), and Income Protection (IP).
Coverage level	Alternative coverage levels that range from 50% to 85% in an interval of 5%.
Premium	Per-acre premium paid in dollars to purchase insurance (includes subsidy).
Rate	Rate is the premium per dollar of liability (premium/liability).
Loss ratio	Loss ratio = Indemnity/Premium.
Loss-cost ratio	Loss-cost ratio = Indemnity/liability.
Risk type	Probability of yield or revenue falling below the guaranteed level, estimated for each farm based on 10 years of yield records and using the corresponding year market average price.
Loss frequency	Ex post observation of whether a farmer filed a claim, also known as loss frequency; set equal to one for those who filed a claim and set equal to zero otherwise.
Yield span	A yield-spanning process creates nine discrete categories (R01 through R09) of yields. Category R01 is associated with the lowest average yields, while category R09 is associated with the highest average. The yield-span ranges are derived from historical county loss experience and are calibrated to the expected NASS county yield. 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 premiums than the base county rate.
Farm income	Income is estimated for each farmer as follows: $M = \lambda \sum A_t Y_t P_t, \ \forall t = 1, 2, ..., 10$, where M is the income level, A_t is the number of acres, Y_t is the yield per acre, P_t is the State average price, and is the proportion of income saved, which is assumed to be 0.10.
Expected indemnity	Expected indemnity, E(I), is estimated for each farmer as follows: E(I) (per acre) from a typical yield insurance contract: $E(I) = MAX(0, Y^g - Y)P^g$, E(I) (per acre) from a typical revenue insurance contract: $E(I) = MAX(0, Y^g P^g - Y P^m)$, where Y^g is the guaranteed yield, Y is the actual farm yield, P^g is the guaranteed price, P^m is the market price at harvest time.
Farm practice	Farm practice, which indicates whether a farm is irrigated, is set equal to one for irrigated farms and zero for non-irrigated farms.
Ownership share	Ownership share is the percentage share of the crop owned by the insured.

Hypotheses Testing

Testing for separating equilibrium. The model is tested for the existence of a separating equilibrium by assessing the signs and the statistical significance of the variable RISK in equations 22 and 25. Significant coefficients for RISK in equations 22 and 25 would indicate a separating equilibrium, implying that low-risk and high-risk farmers purchase different contracts. For example, a significant positive coefficient for RISK in equation 25 would indicate that low-risk types purchase contracts with lower coverage, while high-risk types purchase higher coverage contracts. On the other hand, a non-significant coefficient would indicate a pooling equilibrium, implying that all risk types purchase the same contract.

Testing for the effects of farm income. We expect the choice of insurance contracts to be related to income in a manner consistent with the decreasing risk-aversion hypothesis. This is equivalent to asserting that farmers with higher income retain the risk of some losses. One expects that high-income farmers would be more likely to choose the lower coverage contracts, as they are able to self-insure and manage variations in income within their operations better than would farmers with lower income.

Testing for the effects of cost of insurance. Premium rates are conditioned on insurance product, coverage level, irrigated versus non-irrigated production, and RMA's yield span classification. Assuming low-risk types buy lower coverage levels, a positive correlation between coverage level and the premium rate in equation 24 implies that insurers compensate low-risk types accordingly. The statistical significance of the premium rate in equations 22 and 25 has implications for public subsidization of the risk insurance programs.

Testing for market signaling. A nonlinear relationship in the coverage-premium schedule indicates the presence of signaling in the insurance market.[14] The nonlinearity of the coverage- premium schedule is tested by introducing three dummy variables into the system representing three coverage levels, 55 percent, 65 percent, and 75 percent. Over the range of coverage levels in our sample, nonlinearity would be present if the marginal premiums at the various coverage levels are significantly different. Assuming that farmers make informed decisions, a farmer's selection of an insurance contract reveals information, although imperfectly, about the riskiness of his or her operations. This information could potentially be used to decrease the adverse effects of asymmetric information in the insurance market.

Testing for adverse selection. We test for adverse selection using a two step procedure. First, we test for the independence of the choice of insurance contract and the risk using non-parametric methods. If the choices are correlated with risk, then agents indeed have a better knowledge of their risk (Chiappori and Salanie, 2000). Rejection of independence would suggest that there is evidence of adverse selection in the crop insurance market.

Parametric methods used by Puelz and Snow (1994) or Dionne, Gourieroux, and Vanasse (1998), for instance, rely on a fairly large number of exogenous variables and restrictive functional forms. Hence, the results from parametric methods would be biased. Non-parametric methods are, on the other hand, less restrictive and account for more complicated non-linear relationships between variables (Chiappori and Salanie, 2000). The two non-parametric tests performed are the Kruskal-Wallis χ^2 test and the Kolmogorov-Smirnov test. The Kruskal-Wallis test statistic is given by:

$$(26)\quad H = \frac{12}{N(N+1)}\sum_{i=1}^{k}\frac{T_i^2}{n_i} - 3(N+1)$$

(where N is the sample size, T_i is the rank assigned to the ith group, and n_i is the number of groups in the sample. The test statistic H approximately follows a chi-squared distribution with k-1 degrees of freedom. See Milton and Arnold (1990) for more details on the Kruskal-Wallis test. The Kolmogorov-Smirnov test statistic is given by:

$$(27)\quad K = \sqrt{M}\,\sup_x \left|F_M(x) - F(x)\right|$$

where $F_M(x)$ is the empirical cdf and F(x) is the cdf of a $\chi^2(1)$. Under conditional independence, the test statistic K converges to a distribution that is tabulated in statistics textbooks (Chiappori and Salanie, 2000).

The second step involves comparing the actual and competitive premiums across different risk types. In an efficient market, the competitive premium is equal to the expected indemnity (Puelz and Snow, 1994; Rothschild and Stiglitz, 1976). The expected indemnity E(I) is calculated for each insurance contract separately. For example, E(I) for a typical CRC contract is:

$$(28)\quad E(I) = \frac{1}{n}\sum_{t=1}^{n} MAX[0,\ (\theta Y^e\ \max(P^g,\ P^m)\ -\ Y^t P^m)]\ ,$$

where n is the number of periods for which yield records are available, θ is the coverage level, y^e is the expended yield, y^t is the actual yield in year t, Pg is the guaranteed price (or elected price), and P^m is the market price. We use 10 years (1987-96) of actual yield history for each farm and corresponding annual market prices. Coverage level θ and guaranteed price P^g were chosen by farmers in 1997. We adjust the guaranteed yield for the growth rate in yield to make it comparable with yield in period t. The market price, however, did not exhibit any trend during the 1987-96 period. The calculated E(I) captures farm risk characteristics by accounting for alternative yield and price possibilities.[15]

Under a full-information equilibrium, the difference between actual and competitive premium rates should be zero for all risk types. Under asymmetric information, however, one would expect differences to exist between actual and competitive premium rates, as the accurate determination of individual farmers' risk is either not possible or prohibitively expensive. We use non-parametric tests and graphical illustrations to demonstrate the differences, if any, between the actual and competitive premium rates. The two non-parametric tests performed are the Kruskal-Wallis χ^2 test and the Kolmogorov-Smirnov test as described above.

Empirical Results

In this section we present the empirical results from the Generalized Polytomous Logit (GPL) and the three-stage least-squares (TSLS) models. The GPL model analyzes the discrete choice of insurance product as a function of risk type, income level, and insurance cost, while the TSLS model analyzes the choice of coverage levels and premium rates in a simultaneous equation system. We present the results of our analysis for both corn and soybeans, but limit the discussion to corn.

Choice of Insurance Products

The maximum likelihood analysis of variance results are presented in table 4, which summarizes the main effects of models 1 and 2. The likelihood ratio statistic indicates goodness of fit of the model, while chi-square values indicate the significance of the explanatory variables. The likelihood ratio statistic for model 1 has a value of 253 with 60 degrees of freedom, which is indicative of a good fit. Model 2 is also a good fit, with a likelihood ratio of 367 with 80 degrees of freedom. A likelihood ratio test is performed to test whether the two specifications are statistically different. Test results indicate that the two models are indeed different. Since models 1 and 2 represent choices with respect to APH, which is a partially subsidized product, and CAT, which is a completely subsidized product, we infer that premium subsidies are likely to influence farmers' decisions in choosing an insurance product.

The hypothesis to be tested is that the insurance market entails low-risk types selecting products that provide lower protection, while high-risk types select products that provide higher protection. Results presented in table 4 reveal a strong relationship between risk type and the choice of insurance products. The risk type variable has Wald Chi-Square values of 1,712 with 6 degrees of freedom in model 1, and 1,920 with 8 degrees of freedom in model 2. We reject the hypothesis that risk type has no influence on the choice of insurance products at less than the 1-percent level of significance.[16] These results are consistent with the presence of a *separating equilibrium* in crop insurance markets, where low- and high-risk farmers choose different products depending on their risk types.

Our results also indicate that income has a significant influence on the choice of insurance products (table 4). The Wald Chi-Square values for income are 630 with 6 degrees of freedom in model 1, and 744 with 8 degrees of freedom in model 2. The cost of insurance, captured by the premium per dollar of liability (RATE), is also a critical factor in choosing a product. RATE is statistically significant, with Wald Chi-Square

Table 4—Maximum likelihood analysis of model fit and variable significance[1]

	Model 1			Model 2		
Variable	**df**	**Chi-square[2]**	**Probability**	**df**	**Chi-square**	**Probability**
Corn						
Risk type (RISK)	6	1712.58	0.00	8	1920.40	0.00
Level of income (M)	6	629.95	0.00	8	743.65	0.00
Cost of insurance (RATE)	6	6225.10	0.00	8	9553.60	0.00
Likelihood ratio	60	253.13	0.00	80	367.27	0.00
Likelihood ratio test[3]			228.28			
Variable	**df**	**Chi-square**	**Probability**	**df**	**Chi-square**	**Probability**
Soybeans						
Risk type (RISK)	6	619.86	0.00	8	1167.25	0.00
Level of income (M)	6	532.64	0.00	8	843.28	0.00
Cost of insurance (RATE)	6	1099.30	0.00	8	1932.89	0.00
Likelihood ratio	60	411.85	0.00	80	550.74	0.00
Likelihood ratio test[3]			277.78			

[1] Model 1 is a GPL specification with product choices GRP, CRC, and RA with APH as the reference choice, while model 2 is a GPL specification with product choices APH, GRP, CRC, and RA with CAT as the reference choice.
[2] The table Chi-square values at 1% level of significance are 16.81 and 20.1 for 6 and 8 degrees of freedom, respectively.
[3] The likelihood ratio test statistic is given by $-2\log\lambda$, where λ is the ratio of two likelihood ratios from models 1 and 2 (Kennedy 1992).

The statistic is distributed asymptotically as Chi-square with degrees of freedom equal to the number of restrictions imposed.

values of 6,225 with 6 degrees of freedom in model 1, and 9,554 with 8 degrees of freedom in model 2.

Table 5 presents the parameter estimates for models 1 and 2, along with the standard errors that indicate the statistical significance of the estimated parameters (table 6 presents the parameter estimates for soybeans). Parameter estimates are arranged according to the logits they reference. In what follows, we limit our discussion to model 1.

Odds ratios facilitate interpretation of the estimated parameters (Long, 1997). We compare the odds of choosing CRC, RA, and GRP over APH for different risk types and for different income levels. The odds ratio measures the likelihood of choosing an insurance

Table 5—Generalized multinomial logit model, corn

Model 1	**logit(GRP/APH)**			**logit(CRC/APH)**			**logit(RA/APH)**		
Variable		Coefficient	Std. error		Coefficient	Std. error		Coefficient	Std. error
Intercept	α_1	-4.7946*	0.3358	α_2	-1.9052*	0.1186	α_3	-1.7419*	0.0318
High-risk	β_1	-0.5190*	0.1087	β_2	0.1808*	0.0164	β_3	0.1790*	0.0380
Med risk	β_4	0.1562**	0.0644	β_5	0.2985*	0.0115	β_6	0.2965*	0.0240
High income	β_7	0.7740*	0.0531	β_8	0.1635*	0.0152	β_9	0.1742*	0.0278
Med income	β_{10}	-0.6460*	0.0568	β_{11}	0.0687*	0.0118	β_{12}	-0.0722*	0.0226
High rate	β_{13}	-2.8672*	0.6689	β_{14}	2.3900*	0.1199	β_{15}	-0.7536*	0.0563
Med rate	β_{16}	-0.5619^{n}	0.3385	β_{17}	1.7001*	0.1186	β_{18}	-0.8095*	0.0314

Model 2	**logit(APH/CAT)**		**logit(GRP/CAT)**		**logit(CRC/CAT)**		**logit(RA/CAT)**	
Variable	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Intercept	2.9172*	0.1284	-1.8759*	0.3579	1.0082*	0.1741	1.1727*	0.1312
High-risk	2.4752*	0.2534	2.9882*	0.2740	2.6570*	0.2534	2.6460*	0.2554
Med risk	-1.2144*	0.1277	-1.0885*	0.1414	-0.9123*	0.1279	-0.9319*	0.1290
High income	-0.4167*	0.0287	0.3260*	0.0540	-0.2497*	0.0305	-0.2609*	0.0332
Med income	0.2176*	0.0253	-0.4227*	0.0582	0.2853*	0.0266	0.1494*	0.0289
High rate	0.1798*	0.0618	-2.6828*	0.6688	2.5760*	0.1325	-0.5664*	0.0794
Med rate	1.4135*	0.0367	0.8632*	0.3389	3.1174*	0.1232	0.6097*	0.0459

* Significant at 1% level; ** Significant at 5% level; n is non-significance.

Table 6—Generalized multinomial logit model, soybeans

Model 1	**logit(GRP/APH)**			**logit(CRC/APH)**			**logit(RA/APH)**		
Variable		Coefficient	Std. error		Coefficient	Std. error		Coefficient	Std. error
Intercept	α_1	-4.3203*	0.0824	α_2	-0.2932*	0.0126	α_3	-2.0431*	0.0240
High-risk	β_1	-0.8553*	0.1373	β_2	0.0751*	0.0159	β_3	0.2764*	0.0294
Med risk	β_4	0.2492*	0.0867	β_5	0.2178*	0.0130	β_6	0.0958*	0.0252
High income	β_7	1.0597*	0.0749	β_8	0.1984*	0.0185	β_9	0.2738*	0.0347
Med income	β_{10}	-0.5302*	0.0757	β_{11}	0.0839*	0.0135	β_{12}	0.0735*	0.0261
High rate	β_{13}	0.0738^{n}	0.1065	β_{14}	0.3661*	0.0169	β_{15}	0.1514*	0.0326
Med rate	β_{16}	-0.2270*	0.0725	β_{17}	-0.3988*	0.0130	β_{18}	-0.3505*	0.0253

Model 2	**logit(APH/CAT)**		**logit(GRP/CAT)**		**logit(CRC/CAT)**		**logit(RA/CAT)**	
Variable	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Intercept	3.7447*	0.822	-0.5747*	0.1157	3.4517*	0.0823	1.7022*	0.0848
High-risk	2.5763*	0.1367	1.7202*	0.1931	2.6512*	0.1370	2.8521*	0.1392
Med risk	-1.1394*	0.0704	-0.8933*	0.1110	-0.9203*	0.0707	-1.0436*	0.0739
High income	-0.5630*	0.0287	0.4989*	0.0784	-0.3634*	0.0301	-0.2890*	0.0422
Med income	0.1983*	0.0240	-0.3321*	0.0785	0.2828*	0.0250	0.2725*	0.0337
High rate	-0.8010*	0.0571	-0.7235*	0.1192	-0.4309*	0.0570	-0.6455*	0.0636
Med rate	-1.1916*	0.0487	-1.4202*	0.0863	-1.5924*	0.0490	-1.5441*	0.0536

* Significant at 1% level; ** Significant at 5% level; n is non-significance.

product over any other choice. For example, the odds of choosing CRC over APH by high- vs. low-risk types are computed using equation 23 and the model 1 parameters in table 5 as:

$$\frac{e^{\alpha_2+\beta_2+\beta_8+\beta_{14}}}{e^{\alpha_2-\beta_2-\beta_5+\beta_8+\beta_{14}}} = \frac{2.30}{1.18} = 1.95.$$

Thus, the odds ratio indicates that high-risk farmers are 1.95 times more likely to choose CRC over APH than low-risk farmers. Our analysis also indicates that the expected indemnity payoffs (expressed as percent of liability) from the revenue insurance products, CRC and RA, are about 12 percent for high-risk farmers relative to about 2 percent for low-risk farmers (table 7).

Since GRP indemnities are based on county-level losses, high-risk farmers would find it less attractive relative to APH. The expected indemnity payoffs for high-risk farmers were 4 and 9 percent for GRP and APH products (table 7). In general, the results indicate a preference for revenue insurance by high-risk farmers and yield insurance by low-risk farmers.

Results presented in table 5 suggest that high-income farmers prefer CRC and RA over APH, within the same risk class. The odds of choosing CRC over APH by high-income farmers relative to low-income farmers is given by:

$$\frac{e^{\alpha_2+\beta_2+\beta_8+\beta_{14}}}{e^{\alpha_2+\beta_2-\beta_8-\beta_{11}+\beta_{14}}} = \frac{2.30}{1.54} = 1.5.$$

This odds ratio indicates that high-income farmers are 1.5 times more likely to choose CRC over APH relative to low-income farmers within the same risk category. One possible explanation for high-income farmers' greater willingness to buy revenue insurance products is that they attempt to maximize payoffs from these crop insurance contracts that are subsidized by the Federal Government. Another possible explanation is that the accumulated savings used as a proxy for income is more a measure of liquidity constraint rather than a measure of risk aversion.[17]

The cost of insurance is also a critical factor that influences farmers' choice of insurance product. This finding is consistent with Just et al. (1999), who found that farmers' participation in crop insurance is primarily driven by the cost of insurance and the premium subsidy.

Using the estimated model, we explore further the relationship between risk type and choice of insurance product by calculating the probability of choosing an insurance product given the farmer's risk type. The probabilities presented in table 8 are estimated from the GPL model 2. The results indicate that high-risk farmers are more likely to choose revenue insurance contracts CRC or RA, over CAT or GRP, while low-risk farmers are more likely to choose GRP or CAT (table 8). This is because high-risk farmers have a greater incentive than low-risk farmers to select contracts that provide greater protection in the absence of full information.

Choice of Coverage Levels

The system of equations 23 and 24 is estimated by the three-stage least-squares method because coverage level and premium rates are determined simultaneously. We estimate the system for each insurance product separately. Tables 9 and 10 present the estimated coefficients of the empirical model for corn and soybeans. We limit our discussion to corn.

The estimated functions reveal a strong relationship between risk type and choice of coverage level (table 9). The positive and significant coefficients for risk type indicate that those farms that have a higher probability of yield or revenue falling below the guaranteed level are more likely to choose higher coverage contracts. Results are consistent across all products. This

Table 7—Expected indemnity payoffs from alternative contracts for different risk types

	Corn			**Soybeans**		
	Risk type			Risk type		
	Low-risk	Medium-risk	High-risk	Low-risk	Medium-risk	High-risk
APH (65% coverage)	0.81	4.50	9.30	0.83	3.82	7.31
CRC (65% coverage)	2.10	5.10	11.60	0.97	5.22	10.13
RA (all coverage)[1]	1.80	5.20	11.50	0.80	4.05	9.06
GRP (all coverage)[1]	0.76	1.70	3.74	0.41	1.20	2.14

[1] All coverage levels are combined for RA and GRP for lack of sufficient number of contracts under different risk types.

Table 8—Probability of choosing an insurance product, by risk type

	Corn			Soybeans		
	Low-risk	Medium-risk	High-risk	Low-risk	Medium-risk	High-risk
Prob{INSPLAN = CAT}[1]	0.32	0.16	0.003	0.26	0.22	0.01
Prob{INSPLAN = APH}	0.19	0.20	0.29	0.18	0.19	0.28
Prob{INSPLAN = GRP}	0.22	0.20	0.15	0.29	0.17	0.08
Prob{INSPLAN = CRC}	0.09	0.24	0.36	0.13	0.22	0.29
Prob{INSPLAN = RA}	0.17	0.21	0.20	0.13	0.20	0.35

[1] INSPLAN is the insurance plan or product.

Table 9—Three-stage least-squares model, corn

Insurance Plan	Dependent Variable	Explanatory variables[1]							
		Coverage level	Premium rate	Risk type	Income	Yield span	Practice	Ownership share	R-square
APH	**Coverage level**	*	0.0607	0.1579	0.0015	0.0660	-0.0250	-0.0256	
			(159.65)	(26.24)	(11.20)	(229.57)	(-1.91)	(-11.57)	
									0.9791
	Premium rate[1]	2.2340	*	6.7994	*	-0.8345	0.3781	0.1275	
		(135.79)	(72.91)			(96.82)	(1.87)	(3.82)	
CRC	**Coverage level**	*	0.0521	0.1482	0.0012	0.0565	0.0182	-0.0309	
			(129.66)	(22.58)	(9.70)	(151.15)	(1.30)	(-11.80)	
									0.9810
	Premium rate	14.5456	*	6.6021	*	-0.9050	-0.1624	0.3108	
		(110.05)		(54.40)		(-73.53)	(-0.62)	(6.64)	
RA	**Coverage level**	*	0.1460	0.1070	0.0020	0.0350	-0.1836	-0.0678	
			(24.70)	(2.72)	(3.82)	(9.92)	(-1.85)	(-4.16)	
									0.9325
	Premium rate	4.5621	*	7.4577	*	-0.2212	1.0500	0.1874	
		(17.48)		(28.95)		(-7.34)	(1.63)	(1.88)	
GRP	**Coverage level**	*	0.4022	0.8100	-0.0034			-0.1512	
			(11.58)	(3.77)	(-1.51)			(-2.04)	
									0.9436
	Premium rate	0.1970	*	11.40	*			0.1470	
		(1.70)		(33.13)				(1.50)	
CAT	**Premium rate[2]**			11.9283		0.1034	1.1431	1.9680	0.7142
				(25.52)		(8.44)	(2.34)	(18.93)	

[1] Numbers in parentheses indicate t-statistics.
[2] Premium rate for CAT is the fee per dollar of liability.

again indicates a separating equilibrium in crop insurance markets, where farmers choose coverage levels depending on their risk type.

The estimated relationship between income and choice of coverage level is positive and significant for APH, CRC, and RA (table 9). The positive coefficient implies a preference for greater coverage by high-income farmers, and does *not* support the hypothesis that high-income farmers prefer lower coverage levels and retain the risk of some losses. Possible explanations for this behavior can be that income is uncorrelated with risk and that farmers maximize the premium subsidy they receive from the Government.

The coefficients for ownership share show a negative association with coverage level (table 9). This implies that as the ownership share decreases, farmers are more likely to choose higher coverage levels. One explanation for this result is that farmers who lease land (lower ownership share) are often required to purchase insurance, particularly when external financing is involved. This result is consistent with the findings of Wu (1999). A negative coefficient for farm practice indicates that farmers who irrigate their land prefer lower coverage compared with non-irrigated farms. This is likely because irrigation generally reduces risk.

Table 10—Three-stage least-squares model, soybeans

Insurance Plan	Dependent Variable	Explanatory variables[1]						
		Coverage level	Premium rate	Risk type	Income	Yield span	Ownership	R-square share
APH	**Coverage level**	*	0.0850	0.1300	0.0048	0.0660	-0.0180	
			(156.33)	(20.06)	(25.77)	(183.87)	(-7.24)	0.9789
	Premium rate	10.2456	*	3.3477	*	-0.6415	0.1062	
		(145.60)		(43.64)		(-97.05)	(3.76)	
CRC	**Coverage level**	*	0.0740	0.1170	0.0030	0.0563	-0.0277	
			(126.13)	(17.36)	(14.10)	(131.24)	(-9.41)	0.9818
	Premium rate	11.7445	*	3.1164	*	-0.7251	0.3204	
		(116.96)		(34.91)		(-73.32)	(7.96)	
RA	**Coverage level**	*	0.1405	0.0982	0.0017	0.0275	-0.0225	
			(27.04)	(2.93)	(3.73)	(8.06)	(1.50)	0.9498
	Premium rate	5.5934	*	4.0430	*	-0.1878	-0.2495	
		(22.21)		(17.35)		(-6.40)	(-2.36)	
GRP	**Coverage level**	*	0.6812	0.8147	-0.0069	*	-0.0701	
			(10.30)	(2.82)	(-1.40)		(-0.87)	0.9745
	Premium rate	0.4952	*	7.80	*	*	-0.0209	
		(9.88)		(46.88)			(-0.50)	
CAT	**Premium rate[2]**	*	*	4.4344	*	0.1.475	1.3700	0.6994
				(11.888)		(15.13)	(17.16)	

[1] Numbers in parentheses indicate t-statistics.
[2] Premium rate for CAT is the fee per dollar of liability.

Results show that the yield-span—the ratio of actual yield to the county-level average—is a significant variable (table 9). The positive relationship between coverage level and yield-span implies that farmers with high expected yields are more likely to buy higher coverage levels, while farmers with low expected yields are more likely to buy lower coverage levels. Yield-span is a key factor in the RMA rating design. A standard RMA assumption is that expected loss decreases as expected yield increases, which implies that farmers with high expected yields represent low risks. If this were true, then the results would imply that low-risk farmers purchase higher coverage levels and vice versa.

Empirical Evidence on Market Signaling

Although evidence that low-risk farmers tend to choose lower coverage levels and high-risk farmers tend to choose higher coverage levels is consistent with the theory that predicts separation by risk type, this finding alone is not sufficient to demonstrate that individuals effectively signal their risk type. We compared the estimated premium rates by introducing three dummy variables to represent three coverage levels: 55 percent, 65 percent, and 75 percent. The results presented in table 11 indicate that the premium rates, evaluated at their mean values, are significantly different from one another, suggesting a *nonlinear relationship between premium rates and coverage levels*. The premium rates per $100 of liability for APH are estimated to be 0.78, 1.65, and 3.80, respectively, for 55 percent, 65 percent, and 75 percent coverage levels (table 11). For CRC, the estimated premium rates per $100 of liability are 1.17, 2.61, and 5.35 for 55 percent, 65 percent, and 75 percent coverage levels (table 11).

The nonlinear relationship between premium rates and coverage levels is also captured in figures 2A and 2B. A visual examination of figures 2A and 2B suggests that the premium-coverage schedule is non-linear for both APH and CRC. The premium rates across coverage levels provide evidence of the hypothesized relationships in our model of the crop insurance market. The nonlinear coverage-premium schedule implies that farmers do signal their risk types through their choice of coverage levels to the insurance company.

Table 11—Marginal premium rates for APH and CRC, corn, Iowa

Insurance Plan	Explanatory variables[1]							R-square
	Risk type	Yield span	Practice	Ownership share	Coverage level			
					55%	65%	75%	
APH	0.0436 (37.35)	-0.0091 (-115.55)	0.0058 (4.59)	0.0021 (6.29)	0.0855 (37.79)	0.0857 (143.02)	0.1025 158.22)	0.4362
	Marginal premium rates (per 100 dollars of liability):				0.78	1.65	3.80	
CRC	0.0367 (22.20)	-0.0095 (-83.50)	-0.0024 (-0.47)	0.0039 (23.55)	0.0940 (23.55)	0.1017 (109.83)	0.1247 (106.34)	0.3459
	Marginal premium rates (per 100 dollar of liability):				1.17	2.61	5.35	

[1] Numbers in parentheses indicate t-statistics.

Evidence of a nonlinear premium-coverage schedule, taken together with the finding that different risk types choose different contracts supports the hypothesis that equilibrium in the market for multiple crop insurance products entails *market signaling and a separating equilibrium*.

Empirical Evidence on Adverse Selection

We present a two-step procedure to test adverse selection in the market for multiple yield and revenue insurance products. First, we test for independence of the choice of insurance contract and the risk type using non-parametric methods. Failure to reject independence would suggest that there is no evidence of adverse selection in the crop insurance market. Second, we test for the difference between the actual and the competitive premium rates for different risk types using non-parametric methods as well as graphical illustrations. If the two rates are not different across risk types, then there is no evidence suggesting the presence of adverse selection in the crop insurance market.

Figure 2A

Premium rates (% of liability), APH-buy-up and CRC, Corn

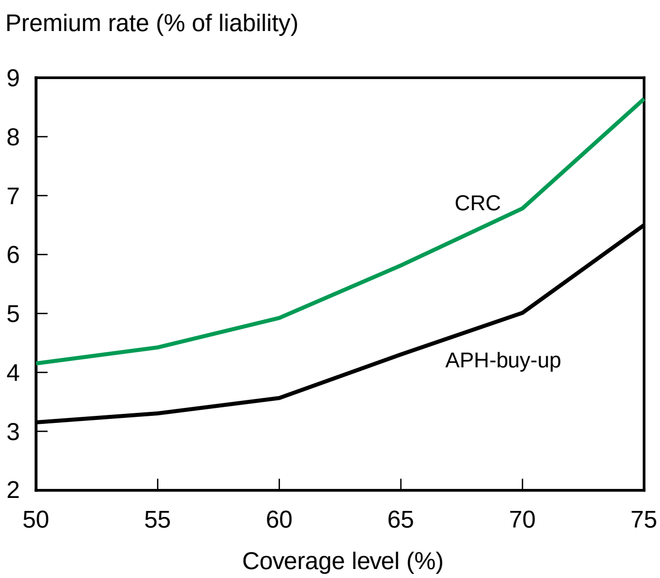
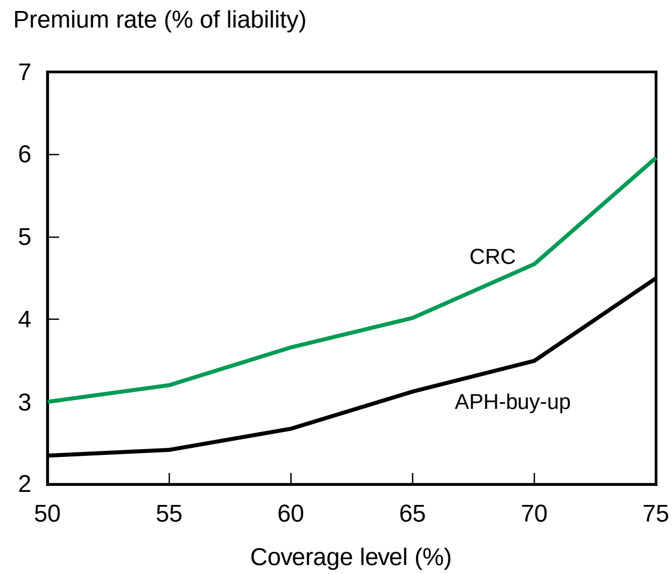


Figure 2B

Premium rates (% of liability), APH-buy-up and CRC, Soybeans



1. Testing for independence of insurance contract choice and risk type. Both the Kruskal-Wallis and the Kolmogorov-Smirnov tests reject the hypothesis of independence between the choice of insurance product and the level of risk at the 1 percent significance level (table 12). The computed value of χ^2 = 1251.5 for the Kruskal-Wallis test is much larger than the 1 percent critical value, which is 9.21 at 2 degrees of freedom. The computed value of K = 18.98 for the Kolmogorov-Smirnov test is much larger than the 1 percent critical value, which is 1.36. These results imply that farmers have better knowledge of their risk than insurance companies when choosing their crop insurance contracts. The non-parametric tests also reject the independence of the choice of coverage and the risk type for each insurance product at the 1-percent significance level. Thus, non-parametric tests suggest that adverse selection may not be a negligible phenomenon in the market for multiple yield and revenue insurance products.

2. Testing for the difference between actual and competitive premium rates. We test for the difference between actual and competitive premium rates for various risk types using non-parametric tests followed by a graphical illustration of the difference. The two non-parametric tests, Kruskal-Wallis and the Kolmogorov-Smirnov, reject the hypothesis that the actual and competitive rates are not different for different risk types at the 1-percent significance level for all products except GRP (table 12). The computed values of Kruskal-Wallis χ^2 for APH, CRC, RA, and GRP are 13668, 10397, 2738, and 1.96 compared with the critical value of 9.21 at 2 degrees of freedom. For GRP, non-parametric tests indicate that the actual and competitive rates are not statistically different from each other at different risk levels. This finding is consistent with Mahul (1999), who argues that an area yield insurance program mitigates adverse selection problems because information about area yields is more easily available and is more accurate than information about individual farm yields.

Table 12—Non-parametric test results

	Kruskal-Wallis Test	Kolmogorov-Smirnov Test
Independence of products and risk type	1,251.50	18.98
Independence of coverage and risk type		
APH	2,272.60	20.37
CRC	3,136.70	25.36
RA	363.83	8.73
GRP	671.60	11.98
Testing for the difference between actual and competitive premium rates across different risk types		
APH	13,668.00	55.33
CRC	10,397.00	46.02
RA	2,737.50	24.53
GRP	1.96	1.09
Critical Values	9.21	1.36

Figures 3 (A through D) and 4 (A through D) illustrate the differences between the actual and competitive premium rates (calculated as percent of liability) across different risk types and insurance products.[18] Actual premium rates are obtained by dividing premium by liability, while competitive rates are calculated by dividing expected indemnity by liability. The horizontal axis indicates the level of risk, measured by the probability of yield or revenue falling below the guaranteed level, while the vertical axis indicates actual and competitive premium rates as a percentage of liability.

Figure 3A compares the actual and competitive premium rates at the 65 percent coverage level across different risk types for APH contract. The figure shows that low-risk farmers are overcharged (pay more than their competitive rates) and high-risk farmers are undercharged (pay less than their competitive rates) for their respective insurance contracts. For example, a farmer with a risk level of 0.25 (slightly more than average) pays a premium of $5.06 for a 65-percent coverage level contract, while his/her competitive rate is $8.63. In other words, the actual premium rates fail to accurately reflect individual farmers' likelihood of losses. Figure 3A also indicates that the disparity between the actual and competitive rates is greater at lower and higher risk levels, implying the underlying difficulty in assessing individual farmers' risks accurately. The results are similar in the case of CRC (figure 3B) and RA (figure 3C), and different in the case of GRP (figure 3D). Figure 3D indicates that actual and competitive premium rates for GRP are similar across all risk types.

In sum, we find a significant relationship between the contract choice and risk type. When farmers choose their crop insurance contract, they behave as though they have better knowledge of their risk than insurers. Our analysis indicates that individual risk types are not assessed accurately and that premium rates do not reflect the likelihood of losses. We find evidence of adverse selection in the individualized crop insurance market for Iowa corn in 1997.

Figure 3A

Actual and competitive premium rates, Corn APH, 65%

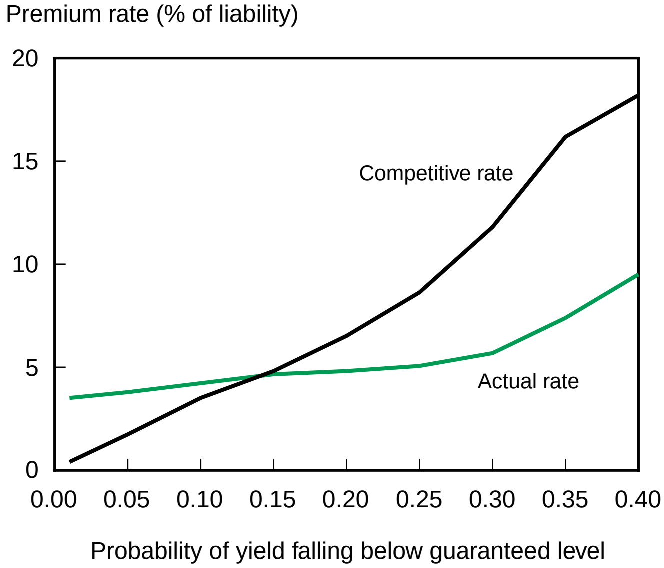


Figure 3B

Actual and competitive premium rates, Corn CRC, 65%

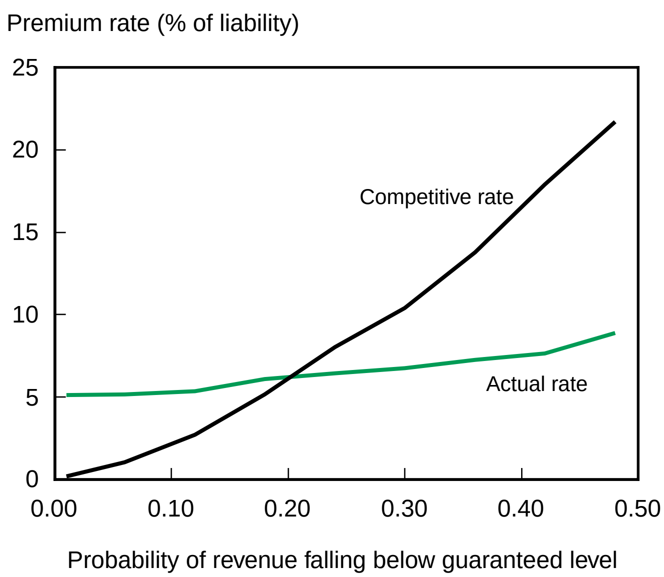


Figure 3C

Actual and competitive premium rates, Corn RA

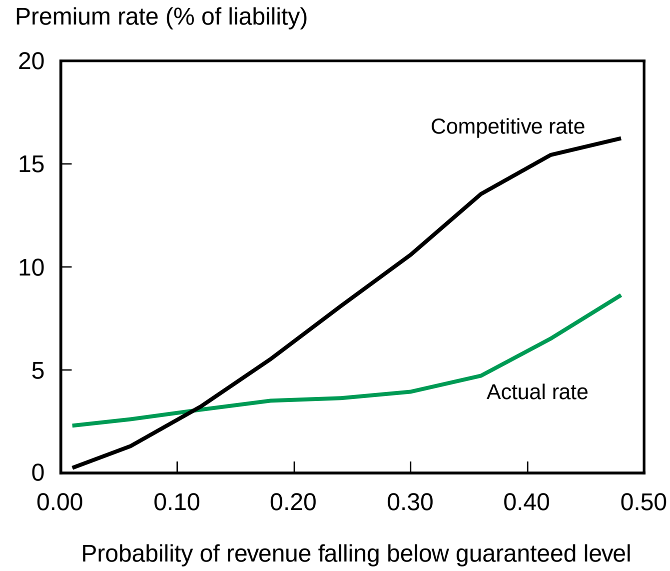


Figure 3D

Actual and competitive premium rates, Corn GRP

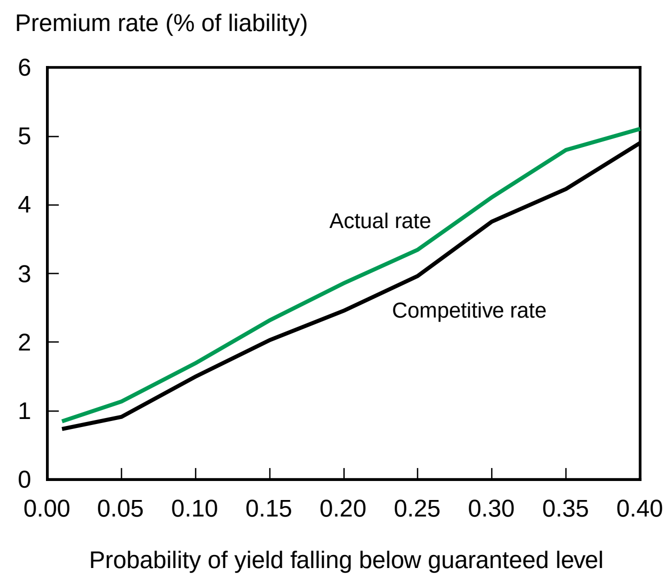


Figure 4A

Actual and competitive premium rates, Soybeans APH, 65%

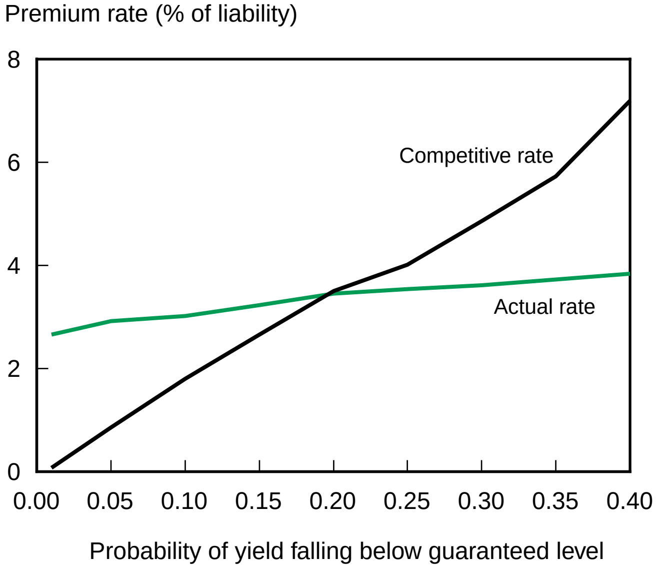


Figure 4C

Actual and competitive premium rates, Soybeans RA

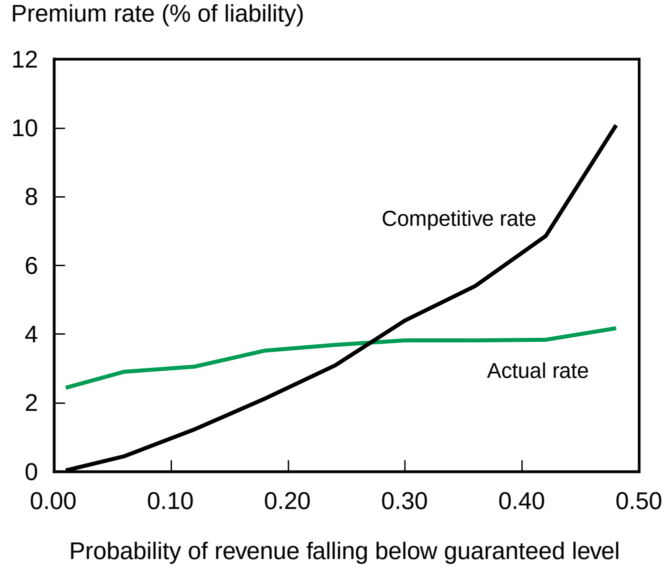


Figure 4B

Actual and competitive premium rates, Soybeans CRS, 65%

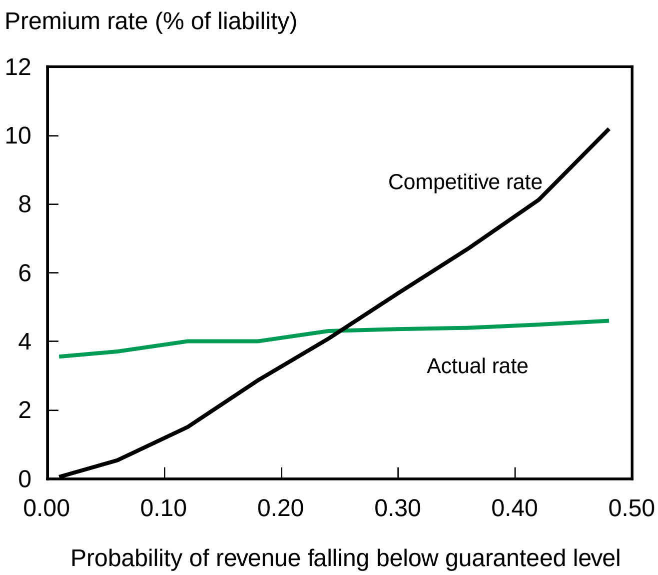
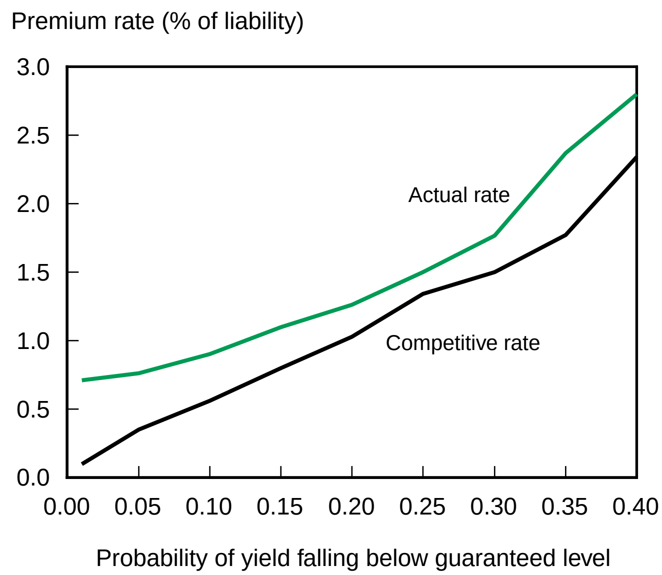


Figure 4D

Actual and competitive premium rates, Soybeans GRP



Summary and Conclusions

In this study, we analyze farmers' choice of crop insurance contracts and offer evidence of adverse selection in crop insurance markets. We develop an analytical framework that captures the essence of the current crop insurance market, which is characterized by multiple yield and revenue insurance products and alternative coverage levels. We analyze the impact of farmers' risk characteristics and level of income, as well as the cost of insurance, on their choice of yield and revenue insurance products and alternative coverage levels.

The data pertain to Iowa corn and soybean producers and five different insurance products that were offered in 1997. We include three yield insurance products (CAT, APH, and GRP) and two revenue insurance products (CRC and RA). Among these products, only GRP is a group-based plan with payments made based on county-level losses; the rest are individual plans where payments are made based on individual losses. The data gathered for the study provide the first opportunity to test for adverse selection when a portfolio of insurance products is offered to U.S. producers. The issues we examined and the major findings include:

Choice of insurance product. A Generalized Polytomous Logit model is used to analyze the nominal choice of alternative insurance products. Our results indicate that high-risk farmers are more likely to choose revenue insurance (CRC and RA) over yield insurance (APH). High-risk farmers are also more likely to choose an individual plan (APH) over a group-based plan (GRP). Results also suggest that high-income farmers are more likely to buy revenue insurance than yield insurance.

Choice of coverage level. A three-stage-least-square model is used to analyze the choice of coverage levels and premium rates. The results show that high-risk farmers are more likely to choose higher coverage levels. The evidence is consistent across all insurance products analyzed in the study. We also find that high-income farmers are more likely to purchase higher coverage levels.

Separating equilibrium. Our results indicate that a farmer's selection of insurance contract is significantly influenced by his/her risk type. That is, farmers' selections of insurance contracts are influenced by the extent of risk they face, measured in terms of the probability of yield or revenue falling below the guaranteed level. The data support the presence of a separating equilibrium in the crop insurance market, where low-risk and high-risk farmers are likely to purchase different contracts.

Market signaling. Farmers signal to insurers about the inherent or unobservable risk associated with their farm through their choice of insurance contract. Our analysis reveals that higher risk farmers signal their risk type by choosing contracts involving revenue products and higher coverage levels, while lower risk farmers signal their risk level by choosing yield insurance products and lower coverage levels. Thus, the finding supports the presence of a separating equilibrium and market signaling in the crop insurance market.

Adverse selection. The empirical evidence on adverse selection, assessed by testing independence of the choice of insurance contract and the risk type, using non-parametric methods and by comparing actual and competitive premium rates across risk types, suggests that the premiums fail to accurately reflect individuals' probability of loss and their expected size of indemnity benefits. Premium rates charged to different risk types are likely to suffer from averaging. The area-yield insurance product, GRP, seems to suffer less from adverse selection compared with individualized yield and revenue insurance products, APH, CRC, or RA.

This study is the first attempt to address the potential for adverse selection in a new agricultural policy environment that allows for multiple products to be offered to producers. By examining risk and other characteristics associated with farmers who buy different contracts, it may be possible to structure insurance rates to more closely reflect farmers' risk profiles. A prudent method of risk assessment that is tied to yield and revenue variability might be the key to avoiding adverse selection in the market for multiple yield and revenue insurance products. Even though our analysis is limited to Iowa corn producers, the findings provide useful insights into preferences of farmers of various risk types in choosing among alternative insurance contracts.

Limitations of the Study and Scope for Further Research

This study is an attempt to analyze the market for multiple crop insurance products and to investigate the potential for adverse selection. We apply the techniques developed in the health and automobile insurance literature to the crop insurance market. The results of our study provide new insights into the manner in which farmers choose alternative insurance contracts. The study, however, is limited by the lack of data for those farmers who did not buy crop insurance. Including non-participants in future studies would greatly enhance our understanding of the crop insurance market.

This study is limited to corn and soybeans in Iowa. An extension of the study to include other crops and States would be useful. Furthermore, the data used in this study represent only a single year, 1997, which is not a representative crop year by any means. An extension of this analysis to include more years would provide a more robust set of results.

We estimated yield and revenue distributions using only 10 years of data, which may not represent the full range of loss possibilities. The availability of more data, both at the individual farm and county level, would greatly improve the robustness of the results. Lack of data on farmers' wealth and other demographic characteristics, including the education levels of farmers and off-farm income, limited our estimation of the risk-aversion behavior of farmers.

A major issue which this study could not accurately address is the impact of Federal premium subsidies on the choice of alternative insurance contracts. It is possible that the level of Federal subsidy would distort the efficient functioning of the crop insurance market. On the other hand, given the nature of risks in agricultural production, it is possible to argue that the crop insurance market may not function efficiently without a Federal subsidy. An empirical investigation of this issue would be useful. A study to analyze the demand for multiple crop insurance products focusing on design, delivery, and premium discounts would be useful and would complement the results of this study.

Another critical issue which we did not directly address in this report is the impact of multiple insurance products on the efficiency of the crop insurance market. As in the case of automobile and health insurance markets, the availability of a large number of insurance products offers a wider range of choices for producers. That, in turn, allows producers to purchase insurance contracts that match their risk profiles more appropriately, which might improve program efficiency. An analysis of market efficiency over time can provide insights into the benefits from making available a large number of insurance products in the market.

End Notes

1. In reality, however, insurance premiums include a loading factor to cover the insurance company's administrative expenses and return on invested capital (Borch, 1989, p. 13). See Goodwin and Smith (1995) for a more detailed discussion of loading factor.

2. If risk type is *observable* (perfect/full information) and insurance is *not costless*, then the insurance would be fairly priced, so that $\pi = (1+k_0)\{k_1 + p(d + k_2)\}$, where 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 bookkeeping, k_2 is the cost of processing a claim, d is the amount of loss, and p is the probability of loss (Puelz and Snow, 1994).

3. Although the model is developed for two states of nature, the analysis applies equally well to more than two states. See Ehrlich and Becker (1972) for proof.

4. In economic theory, marginal utility of income or wealth is often used to measure the degree of risk aversion, which determines the willingness to pay for insurance protection (Varian, 1992, p. 189). However, this measure is not without ambiguities. As Ehrlich and Becker (1972) note, inferences about attitudes towards risk cannot be made independently of existing market opportunities.

5. One of the reviewers indicated that CRC specifies upper and lower bounds on the price guarantees, which is known as the Price Liability Limit (PLL). With PLL, the indemnity function is given by:
$I = MAX\{0, (y^g \max(P^g, \min(P^m, P^g + PLL)) - y^a \min(P^m, P^m + PLL))\}$. Since we did not have data on PLL, we used the simplified version of the indemnity function given in equation 12. The reviewer also agrees that the simplified version used in our study may not affect results for Iowa corn and soybeans.

6. Each parcel of land that is insured independently of other parcels is called a "unit." One farmer may have several insured units. Premium and indemnity payments are based on the insured unit-level risks and losses.

7. We implicitly assume that producers have equal knowledge of all products considered for analysis. However, that assumption may be weak because of differences in release dates and implementation strategies. For example, RA was released late in the 1997 season, while CRC may have been misrepresented in terms of the coverage truly offered under the CRC contract. Since it is difficult to control for such qualitative differences, it may be useful to test the 1998 and 1999 data as a follow-up to this study. In addition, lenders and insurance firms may also have a significant affect on the demand for crop insurance, which is not addressed in this report.

8. Instead of estimating one set of parameters for one logit function, as in a logistic regression for a dichotomous response variable, GPL models estimate sets of parameters for multiple logit functions. The CATMOD procedure in SAS is a convenient way to perform the generalized logistic regression when the model contains qualitative variables (Stokes et al., 1998).

9. Because CAT provides only minimal protection, it may be the best representation of self-insurance as a choice. Since data for non-participants are not available, Iowa farmers with CAT coverage alone may be the best representation of farmers who did not buy any crop insurance.

10. Just and Weninger (1999) fail to reject normality tests for yield distribution of Kansas farm-level wheat, corn, and sorghum yield data. In a recent study, Just et al. (1999) assume a normal distribution for corn yield histories. We recognize that several studies, including Buccola (1986), Moss and Shonkwiler (1993), Nelson and Preckel (1989), and Taylor (1990), reject the normality assumption. However, there seems to be no consensus among these studies regarding skewness of the distributions. If, indeed, the underlying yield and revenue distributions are non-normal, the quality of our results are unlikely to change.

11. Y^p and R^p are similar to variables measuring the probability of accidents used in Dionne, Gourieroux, and Vanasse (1998). Chiappori and Salanie (2000) criticize Puelz and Snow (1994) for their choice of variable to represent risk type. Puelz and Snow use a dummy variable, RT_i, that equals 1 if an individual had an accident and 0 otherwise. Chiappori and Salanie argue that this procedure to measure risk introduces a measurement error because the estimates are biased toward zero. Chiappori and Salanie also criticize Puelz and Snow for failing to account for missing variables and possible heterogeneity in the insurance pool. The data used in this study are for Iowa corn, which represents fairly homogeneous growing conditions.

12. Halbrook and Stafford (1971) indicate that the average weighted marginal propensity to consume for the general population is between 0.87 and 0.90. Consequently, the estimated marginal propensity to save would range from 0.10 to 0.13.

13. In earlier drafts, we experimented and estimated simultaneously equations 18, 20, and 21, treating the demand for insurance products as a continuous variable. Treating discrete choice of insurance products as a continuous variable is not desirable because the ensuing parameter estimates would be inefficient, and standard errors would be biased (Greene, p. 873, 1997; Long, p. 38, 1997). In addition, it imposes hierarchy among the products, when in fact there is none. This study treats the demand for insurance product as a discrete choice. The two-step procedure adopted in this report assumes that the decision on the choice of insurance product is made first, and on the coverage level later. Furthermore, we observe that the estimated parameters of the "fully" simultaneous system are in agreement regarding the statistical significance and the sign of parameters present in this report, although numerical differences exist among the two sets. Since our main objectives are an inquiry into the crop insurance market's functionality under asymmetric information and an investigation of the presence of separating equilibrium, market signaling and adverse selection, the two-stage estimation procedure seems more appropriate.

14. Note that a linear premium-coverage schedule does not necessarily constitute signaling since all farmers pay the same rate at the margin (indicated by constant slope). While low-risk producers select lower coverage, they are not compensated for doing so by paying a lower average premium for their insurance coverage (Rothschild and Stiglitz, 1976; Schmalensee, 1984).

15. The competitive premium rates and the measure of risk types developed in this study are based on individual insurance records for 1997 and 10-year farm yield records. Since we primarily aim to identify individual farmers' risk types, the short span of yield records might be sufficient, even though it excludes the full range of weather effects. Although weather variations are important determinants of yields, they provide little insights for assessing individual farmers' risk types within a given geographical area. In general, the impact of extreme weather events, such as droughts, extreme temperatures, or floods, are not specific to individual farms but to geographically extensive areas (Miranda and Glauber 1997).

16. A Wald test is a statistic that takes the form of a squared ratio of one estimate to its standard error; it follows an approximate chi-square distribution when the sample size is sufficiently large (Long, 1997; Stokes et al., 1998). The advantage of the Wald test over the Likelihood Ratio test is that the Wald test only requires estimating a single model. Thus, it is easier to apply when there are many variables to test. The practical weakness of the Likelihood Ratio test is that the full model must be estimated and then k-restricted models estimated corresponding to excluding each of the x_ks'.

17. This does not support the conventional argument that risk aversion decreases with wealth, and therefore high-income individuals self-insure and buy limited market insurance (Chiappori and Salanie, 2000; Makki and Miranda, 1999). In crop insurance, however, that assumption could be challenged, given that the program is highly subsidized by the Government.

18. RMA calculates the premium rates for each crop in each county for farmers who buy 65 percent coverage and whose normal production level is about equal to the average production in the county. Rates are subsequently adjusted to the loss-experience in that area, farmer's average crop yields (relative to county average yield), and for different coverage levels (GAO, 1999). The actual premium rates charged to farmers do not include any administrative or underwriting costs. Since we assume zero transactions costs, the estimated competitive rates reflect "pure premiums," and may, therefore, underestimate the actuarially fair-premiums.

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