Promoting Farm Safety with Economic and Managerial Incentives

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ABSTRACT

The ex ante marginal values of management strategies for farm producers facing significant exposures to accident risks is assessed. A probit model describing the factors influencing the probability of a farm accident is estimated jointly with an ordered probit model for the severity of the accident.

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The National Safety Council reports that farming and mining has consistently ranked among the nation's most hazardous occupations. Yet even as death rates in mining have decreased, comparative fatality and accident rates in agriculture remain high. Thu *et al*. (1997) noted that risk factors for agricultural injuries appear to differ significantly from those for other occupations and present a challenge for modelling and designing effective health and safety programs.

The objective of this paper is to apply valuation methods based on the expected utility model to assess the ex ante marginal value of management strategies for farm producers facing significant exposures to accident risks. The model exploits survey data on producer characteristics, farm organization, and work routines along with accident outcomes to estimate and evaluate factors that jointly influence the occurrence of accidents and the severity of observed accidents.

Individual responses to dealing with risk may involve interventions to reduce the probability of an accident or management decisions to limit the severity of an accident that occur. Ehrlich and Becker (1972) recognized that risk can be reduced by two main types of private or collection actions. Self-protection refers to managerial strategies or actions that reduce the probability of an event given the magnitudes of the prospective loss. Self-insurance is designed to reduce the size of the possible loss if an accident occurs, given the probability distribution of the hazardous event. Self-protection and self-insurance respond in different ways to risk attitudes and have different implications for the demand for preventive care and insurance.

Kisner and Pratt (1997) also distinguished between the probability and severity of injuries. They used data from the National Traumatic Occupational Fatalities surveillance system to show that older workers are more likely to experience injuries that result in death or permanent disability than are younger workers. Root (1981) suggested that although older workers experience fewer work-related injuries, the injuries that do occur are more severe.

Effective health and safety programs to reduce the adverse impact of farm injuries must address the issue of how to allocate resources to reduce the impact of accidents. One policy option is to target resources to reduce the probability that an accident occurs. A second approach focusses on allocating resources to reduce the severity of the accidents that do occur.

Specification of the Choice Model

The risk-averse producer's utility function is defined over goods X and an adverse work related event such as an accident A over which the producer has no direct control. The variable A measures the severity of the accident and takes the value A^* with probability p and the value 0 with the probability 1 - p.

The preference ordering for this state is represented by the indirect utility function denoted by V(M, P, A) where M and P represent income and prices which are assumed constant. Accidents have an adverse impact on the producer's utility so that the producer's utility is lower when the accident A^* occurs so that V(M, P, 0) > V(M, P, A^*).

Following Freeman (1991) producers maximize expected utility so that observed behavior is the solution to the following maximization problem:

$$Max:\quad E[U] = (1 - p)\,V^{na}[M] + p\,V^{a}[M - A^{*}] \qquad \textbf{(1)}$$

Consider managerial strategies and occupational health and safety policies that attempt to influence the probability of a farm accident. The *ex ante* marginal value for a change in the probability of an accident is derived from:

$$dEU = [(1 - p)V_M^{na} + pV_M^{a}]dM + [V^{a} - V^{na}]dp = 0 \quad . \qquad \textbf{(2)}$$

The *ex ante* marginal value for a change in the probability of an accident can be written as an elasticity

$$\eta_{Mp} = \frac{\partial M}{\partial p}\frac{p}{M} = \frac{V^{na} - V^{a}}{(1 - p)V_M^{na} + pV_M^{a}}\frac{p}{M} \quad . \qquad \textbf{(3)}$$

Producers also are concerned with the severity of accidents and welfare measures to limit this source of risk can be derived. The *ex ante* willingness to pay for a marginal change for reduced severity of an accident is presented in elasticity form as

$$\eta_{Ma} = \frac{\partial M}{\partial A}\frac{A}{M} = \frac{pV_M^{a}}{(1 - p)V_M^{na} + pV_M^{a}}\frac{A}{M} \qquad \textbf{(4)}$$

A key risk management issue is whether producers are more responsive to changes in the probability of accident or to changes in the severity of an accident. Examining the income elasticity terms defined in equations (3) and (4), we see that $\eta_{Mp} > \eta_{Ma}$ if

$$\frac{V^{na} - V^{a}}{A} > V_M^{a} \quad . \qquad \textbf{(5)}$$

If the producer is risk-averse or $V_{MM} < 0$, this condition cannot hold. The term V^{na} - V^{a} represents the chord connecting two points on the producer's expected utility indifference curve. The producer's utility when no accident occurs is V^{na}. When the producer is injured in an accident, utility is V^{a}.

The term V_M^a represents the marginal utility of income when an accident occurs and is the slope of the indifference curve. When the utility function is concave or producers are risk-averse the tangent represented by V_M must be steeper than the chord represented by V^{na} - V^{a}. Robison and Barry (1987) demonstrate this effect graphically and survey the methods available to risk-averse competitive agricultural producers for managing uncertainty. The risk-averse producer is more sensitive to changes in the severity of an accident than to changes in the probability of an accident.

A second implication compares the elasticity of the willingness to pay measure for risk-averse producers with the welfare measure for risk-neutral producers. Risk-averse producers prefer policies that reduce the severity of an accident while risk-neutral farmers place equal value on policies that enhance self-protection and self-insurance.

Modelling the Probability of a Farm Accident

The economic model highlights the importance of identifying critical factors that influence both the probability and severity of farm accidents. Risk-averse producers place higher value on information that assists them in reducing the severity of farm accidents. A probit model describing the factors influencing the probability of a farm accident is estimated jointly with an ordered probit model for the severity of the accident.

The Georgia Healthy Farmers Project (GHFP) is designed to address the high injury rates in farming using information and expertise provide by occupational health nurses. The GHFP, funded by the National Institute for Occupation Safety and Health, covers six south Georgia farming counties and is one of ten state-based Occupational Health Nurses in Agricultural Communities (OHNAC) Projects (Hartley, 1994).

Model Specification and Analysis

Using information from the GHFP a farm accident (FA) is identified when as incidents that occurred when the victim was directly engaged in farm work. The FA variable is positive when the accident is incurred in farming activities and is zero to record an accident that was unrelated to farm work activity. The probability that a farm accident occurred is specified as a linear function of demographic variables and information on producer organizational and work habit variables.

The farm injury surveillance report gathered information on the severity of the farm accident. The severity of the accident was identified by a certified health professional, an emergency medical service attendant, or a police officer. Information on accident severity was collected after identifying detailed information on the type of injury, contributing to the accuracy of the severity measure.

The explanatory variables and distribution of the accident severity measure are shown in Table 1 for accidents identified as farm-related work accidents (229 incidents) and for accidents that were not work related (91 incidents).

The severity of the farm accident is a measured as a discrete ordered continuous variable. The ordered probit model defined in Greene (1993) is used to analyze the factors influencing severity of is based on the latent regression

$$SEV_i^* = \beta' X_i + \varepsilon_i, \tag{6}$$

where SEV^* is the true but unobserved injury severity, X represents the explanatory variables, and ε_i is the person-specific error term. The parameter β is a vector of coefficients that measure the average impact of the explanatory variables on the level of injury severity. The true level of injury severity is not observed but is measured by the categories defined by the accident information survey. The observed variable SEV represents the classes of injuries but not the actual level of harm associated with the injury. Maximum likelihood estimates of the parameters of the ordered probit model obtained using LIMDEP (Greene, 1993) are asymptotically efficient and asymptotically normal.

The Probability and Severity of Farm Accidents

Maximum likelihood estimates for the probit model of farm accidents are presented in Table 2. The impacts of key explanatory variables on the probability that a farm accident occurred are presented in Table 2 along with standard errors for these measures. Marginal effects for dichotomous explanatory variables are calculated as the difference between the accident probability when the condition occurs and when the condition does not occur.

Estrella's R^2 measure for models based on dichotomous dependent variables evaluates the fit of the estimated probit model. The probit model incorrectly predicted accidents for 19 percent of the cases. These incorrect predictions were allocated between incorrect predictions of an accident that did not occur (6 percent) and incorrect predictions of no accident when one did take place (13 percent).

Table 3 reports the coefficients, standard errors, and marginal effects from the ordered probit model for accident severity. The goodness of fit measure proposed by Veall and

Zimmermann (1992) assesses the fit of the model. The marginal effects measure the impact of a change in the explanatory variable on the probability of accident severity across each of the three levels.

The probit model identifies five factors that have a significant impacts on the probability that a farm accident occurred. Significant variables that influence the severity of accidents are more difficult to identify from the ordered probit model as the ordered probit model reveals only three statistically significant variables. Only two variables are significant in both the probability of accident and severity of accident model.

The probit model indicates that older farmers and hired farmworkers are more likely to be involved in farm accidents. Workers who live alone have a lower probability of an accident, indicating that farmers may take extra care or alter work habits when immediate assistance will be unavailable. The severity of accident is not impacted by the fact that a farmer lives alone. Farmers who arrange work schedules so that other adult workers are present also have a lower probability of farm accident but this factor plays no role in the severity of accidents. The value of heightened self-protection is highlighted by the medical conditions variable which records whether previously existing medical conditions contributed to the injury. This measure has a negative coefficient on the probability of a farm accident.

The location of the accident was identified as a private area if the work activity was located near the home, work structure, or private farm property. Reis and Elkind (1997) suggested that habitual and routine farm operations may contribute to a higher probability of accidents. Familiar work locations and routine tasks that are frequently are organized to take place in the private areas identified in this variable may contribute to lower levels of safety practice. Results from the probit and ordered probit model show that both the probability of an accident and the severity of accident were significantly effected by the area of work location.

The overall results confirm that information valued by risk-averse producers to assist in reducing the probability of farm accidents can be extracted from surveys such as the Georgia Healthy Farmers Project. The goodness of fit measures suggest that models designed to identify observable factors that lower the probability of farm accidents outperform those models aimed at reducing the severity of accidents. The marginal effects from the probit model demonstrate that changes in an explanatory variable has a greater impact on the probability of a farm accident than on the severity of observed accidents.

The policy implications from defining a set of observable factors that influence farm safety should be addressed. Von Essen *et al*. (1997) highlight the need for incentives to convince farmers to take advantage of new technology and work strategies to reduce work hazards and health risks. They suggest linking health insurance products and pricing strategies to farm inspection and safety promotion practices. Identifying observable factors that are related to farm safety may guide in the development of incentives to reward and sustain safe farming practices.

Table 1. Variable Description and Summary Statistics[a]

Variable	Description	Entire Sample	Reported Accident
SEV	Severity of farm-related accident		
	Mild injury	46.9	45.4
	Moderate injury	40.9	44.5
	Severe injury	8.8	8.3
	Fatal injury	3.4	1.8
LIVEALONE	Injured party lives alone	48.8	11.1
AGE	Age of injured party	33.6	37.2
FLTMFRMR	Accident occurred to fulltime farmer	23.4	27.1
HDFRMWKR	Accident occurred to hired farmworker	26.9	32.8
ALONEAGE	LIVALONE * AGE	11.23	10.8
PRIVAREA	Accident occurred in private area on the farm	61.9	68.1
MEDCOND	Medical condition contributed to injury	4.7	4.8
FRMMACH	Accident involved farm machinery	44.4	48.5
ADLTWKR	Accident occurred while working with an adult worker	33.1	27.1
SELFPAY	Self payment	47.5	42.8
N	Sample size	320	229

[a] Percentage of respondents for AGE shown in years.

Table 2.Estimates for Probability and Severity of Farm Accidents

Variable	Coefficient	Marginal Effect
LIVEALONE	-0.873*	-0.270
	(-1.934)	(-1.430)
AGE	0.017*	0.008*
	(2.059)	(2.062)
FLTMFRMR	0.182	0.055
	(0.781)	(0.827)
HDFRMWKR	0.862*	0.228*
	(3.886)	(2.837)
PRIVAREA	0.668*	0.217*
	(3.894)	(3.164)
ALONEAGE	0.019	0.006
	(1.373)	(1.115)
MEDCOND	-0.628	-0.143
	(-1.552)	(-1.486)
ADLTWKR	-0.427*	-0.143
	(2.031)	(-1.486)
CONSTANT	-0.213	
	(-0.553)	
R-squared	0.27	
N	320	

[a]Asymptotic t-values in parentheses with significance at 0.05 level.

Table 3.Likelihood of accident severity: Ordered probit analysis

		Marginal effect on probability			
Variable	Coefficient	Mild	Moderate	Severe	Fatal
LIVEALONE	0.043 (0.078)	-0.017	0.012	0.005	0.0009
AGE	0.013* (1.969)	-0.005	0.003	0.001	0.0003
FLTMFRMR	0.054 (0.265)	-0.021	0.014	0.006	0.001
HDFRMWKR	0.252 (0.942)	-0.100	0.068	0.027	0.005
PRIVAREA	0.394* (2.041)	-0.157	0.106	0.043	0.008
ALONEAGE	-0.007 (0.459)	0.003	-0.002	-0.0008	-0.0001
MEDCOND	0.195 (0.405)	-0.078	0.052	0.021	0.004
ADLTWKR	0.334 (1.267)	-0.133	0.089	0.036	0.007
FRMMACH	0.416* (2.355)	-0.166	0.112	0.045	0.009
SELFPAY	0.178 (1.094)	-0.071	0.048	0.019	0.004
CONSTANT	1.183* (2.798)				
MU(1)	1.434* (6.980)				
MU (2)	2.356* (6.752)				
R-squared	0.13				

[a]Asymptotic t-values in parentheses with significance at 0.05 level.

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