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Role of Panel Analysis in Identifying Asymmetric Information with Optional Unit Provision in Federal Crop Insurance

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Abstract

This paper has a two-fold contribution, first we demonstrate the relationship of spatial, temporal and residual yield risk estimated from a two-way panel random effects model to asymmetric information with an optional unit provision in the federal crop insurance program. Second, the yield risk components are incorporated in a discrete choice model to examine the presence of asymmetric information due to potential yield switching with optional unit provisions. Empirical application to 1998 U.S. cotton crop insurance data reveals the presence of asymmetric information with optional unit provisions.

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I. Introduction

The crop insurance program in the U.S. administered by the U.S. Department of Agriculture, Risk Management Agency (RMA) for Federal Crop Insurance Corporation, provides an umbrella of protection for farmers against crop loss due to natural disasters, including drought, excessive moisture and unusually hot weather. Unlike other insurance policies, federal crop insurance is a unique public-private product sold and serviced by 17 private insurance companies with 1.14 million policies sold to agricultural producers in 2008. Currently the federal crop insurance program covers 271 million acres spread across 100 plus commodities with over $67.35 billion coverage under 22 existing crop insurance plans (for more details see http://www.rma.usda.gov).

Even though it is largely seen as an effective risk management tool for the producer, from the time of its inception this unique public-private[1] federal crop insurance program has been faced with higher then desired loss ratios (indemnities/premiums) and lower than desired participation. The higher than desired loss ratios have been attributed in part to adverse selection[2] as a result of information asymmetries, that is, a situation in which a producer has more information about his or her risk of loss than does the insurance provider.

With the introduction of the optional unit provision in the 1980s, farms that satisfy certain spatial requirements[3] are allowed to insure and collect indemnities separately on each unit. The optional unit provision is popular with producers due to its relatively low cost and ability to insure separate sections of land. However, since the current system relies heavily, although not totally, upon self-reported but verified yields, there is the potential for moral hazard. Producers can potentially manipulate their optional unit's yields by switching yields between units and increase claim payments. This kind of moral hazard with optional unit provisions is different from the traditional moral hazard (hidden action), defined as the ability of the producer to increase his or her expected indemnities by actions taken after buying insurance. Further, in the context of optional unit provisions, adverse selection (hidden temporal and spatial incentives) is a situation in which a producer has more temporal and spatial information about his or her risk of production (not loss) than does the insurance provider. Optional unit provisions, as will be demonstrated later in the paper, are prone to potential moral hazard and adverse selection leading to higher indemnity payments. Furthermore, higher than desired loss-cost ratios (indemnities/liabilities) and loss ratios due to potential moral hazard (see USDA, OIG reports in 1994 and 1999, and US, GAO report in 1999) and adverse selection were observed for farms insuring as optional units[4].

Issues of adverse selection (see Stilgtiz, 1977; Pierre-Andre Chiappori and Bernard Salanie, 2000; Bev Dahlby, 1983; and Georges Dionne and Neil A. Doherty, 1994) and traditional moral hazard (Mark V. Pauly, 1974; Michael D. Whinston, 1983; Marcel Boyer and Dionne, 1989; and Richard J. Arnott and Stiglitz, 1988) have been addressed in the literature. Recently there has been increased focus on the identification and empirical examination of insurance fraud (see the chapters by Pierre Picard; and Georges Dionne from the Handbook of Insurance, 2000; September issue of Journal of Risk & Insurance, 2002; and http://www.insurancefraud.org/downloads/Research_reports.pdf) in the literature. In crop insurance, potential fraudulent or exploitive activities like yield switching, changing the structure of the farm by reconstituting units; changing the types of insurance, coverage levels or unit types; and dropping in and out of the program over time has also received attention (see USDA, OIG reports in 1994 and 1999, and US, GAO report in 1999).

In this study focusing on optional unit provisions in the federal crop insurance program, first demonstrate the relation of orthogonal error decomposition of the two-way random effects panel model to potential moral hazard and adverse selection. Specifically, using cross-sectional unit[5] yields over time, farm yield variance decomposed into temporal, spatial, and residual variance provides information with respect to potential adverse selection and moral hazard (details below). Secondly, the decomposed components reflecting yield risk measures form the basis to examine the presence of potential moral hazard and adverse selection in the RMA insured pool while incorporating information with respect to the producer perceived risk of their farm as revealed by the number of units insured.

The role of spatial, temporal and residual components of the two-way random effects panel model and their relationship to potential adverse selection and moral hazard is presented in section II, followed by the expected utility model of asymmetric information in section III. Discrete choice procedures to examine the presence and importance of potential moral hazard and adverse selection using RMA 1998 cotton yield data are detailed in section IV. We conclude with results and conclusions in sections V and VI.

II. Two-way random effects error decomposition and potential moral hazard/adverse selection

Role of temporal moments of yield, price and loss distributions has been the basis in the development of earlier and new insurance policies, estimation of demand for insurance policies, examining the presence of asymmetric information, and in the establishment of premium rates for different insurance policies for crops and livestock. For example, expected returns to insurance (or more specifically temporal yield risk measures) form the basis for examining the demand for crop yield insurance. Similarly, measures of temporal yield and price risk and their interaction risk form the basis in estimating the demand for revenue insurance relative to yield or no insurance and examining the presence of adverse selection. To estimate the demand for coverage levels, apart from temporal yield risk measures, the subsidy provided by RMA could play a role. Similarly in the development of new insurance products and establishment of actuarially sound premium rates, the focus has been on the temporal moments and accounting for spatial variation in an ad hoc fashion. Seldom was there a need for the explicit use of spatial risk measures in addition to temporal risk measures in the federal crop insurance program.

However, the introduction of optional unit provisions provides panel data, i.e. cross sectional unit level yields over time for each farm or policy. This allows the use of spatial along with temporal moments of yield, price, and loss distributions in the development of new insurance policies, estimation of demand, premium rates, and more importantly potential moral hazard and adverse selection. Panel data rather than just cross-sectional or just time-series data would form the basis for estimating the demand for optional unit insurance, and examining the presence of potential moral hazard and adverse selection[6]. Chiappori and Salanie (2000b) suggested, "*In practice, the distinction between adverse selection and moral hazard may be crucial, especially from a normative viewpoint. But it is also very difficult to implement empirically, especially with cross sectional data*". Hence, panel data allows the differentiation of overall farm yield risk into measures of spatial, temporal, and the residual yield risk components that can be identified with potential moral hazard and adverse selection due to optional units. For single-unit farms, the overall farm yield risk is identified with temporal risk, while the overall farm risk could be identified with spatial, temporal, and residual risk components for multiple-unit farms.

To help us understand this relationship let us define the panel yield for farm f with optional units in vector form as:

(1) $$Y = \alpha + \beta^{\gamma}\ \tau^{\gamma} + \varepsilon$$

where Y represents a $1{\times}S\,T$ matrix; τ represents a $k{\times}ST$ matrix of k exogenous time trend variable (τ^1, τ^2 and τ^3) with S and T representing the spatial (cross-section) and temporal (time series) dimension; α', β' are the associated parameters to be estimated with γ representing the degree of polynomial for each of f = 1, 2, ... ,F farms.

Here the focus is on the additive errors of the two-way error components structure as it allows the estimation, testing the degree of polynomial trend and decomposition of overall risk into spatial, temporal and residual risk components. This can be represented in vector form as:

(2) $$\varepsilon = Z_u u + Z_v v + Z_w w$$

where

$$Z_u = (I_S \otimes \iota_T); \qquad u' = (u_1, u_2, \ldots\ldots, u_S)$$
$$Z_v = (I_T \otimes \iota_S); \qquad v' = (v_1, v_2, \ldots\ldots, v_T) \quad \text{, and}$$
$$Z_w = (I_S \otimes I_T); \qquad w' = (w_1, w_2, \ldots\ldots, w_{ST})$$

I_S and I_T (ι_S and ι_T) represent an identity matrix (vector of ones) of dimensions S and T, respectively; and represents the random error components with zero means and covariance matrix:

(3) $$E\begin{pmatrix} u \\ v \\ w \end{pmatrix}(u'\ v'\ w') = \begin{pmatrix} \sigma_u^2 & 0 & 0 \\ 0 & \sigma_v^2 & 0 \\ 0 & 0 & \sigma_w^2 \end{pmatrix}$$

To obtain the spatial, temporal and residual components, using an unbalanced panel data for each farm with a maximum of nine years of data, equation (1) is estimated and tested for the presence of linear or no trend. For a no trend fit, the two-way random effects panel model as defined in equation (1) allows the orthogonal decomposition of error into three *iid* components – one component associated with time, another associated with the cross-sectional units, and the third varying in both dimensions. With optional unit provisions, producer's risk reflected by overall farm yield risk can be decomposed into: 1) temporal risk, identified with potential adverse selection, 2) spatial risk, identified with potential adverse selection and moral hazard, and 3) residual risk, identified with potential moral hazard and adverse selection due to possible potential fraudulent yield switching. The decomposed variances estimated from equation (1) can also be computed for a no trend farm as:

$$\frac{1}{ST}\sum_s\sum_t (y_{st}-\bar{y})^2 = \frac{1}{S}\sum_s(\bar{y}_s-\bar{y})^2 + \frac{1}{T}\sum_t(\bar{y}_t-\bar{y})^2 + \frac{1}{ST}\sum_s\sum_t(y_{st}-\bar{y}_s-\bar{y}_t+\bar{y})^2$$

$$\sigma_y \quad = \quad \sigma_y^S \quad + \quad \sigma_y^T \quad + \quad \sigma_y^R$$

Total Farm Variance	=	Spatial Variance	+	Temporal Variance	+	Residual Variance

(4)

where T is time and S is the number of optional units within a farm, $y_{s,t}$ is the yield for optional unit s at time t, $\bar{y}_s$ is the mean of unit s, $\bar{y}_t$ is the mean of period t, and $\bar{y}$ is the overall mean.

To illustrate the relationship between potential moral hazard with optional unit provision and residual risk, we assume a nine-unit farm. Table 1 presents yield information for a nine-unit farm over time that represents a farm that is committing potential fraudulent yield switching. Under the assumption that a producer is committing fraudulent yield switching, the optimal behavior would be to report 1000 pounds of cotton yield on any three of the nine units (for example the first, fourth, and seventh units) and zero on the remaining six units in a year. Continue this behavior next year by reporting 1000 pounds of cotton yield on the second, fifth, and eight units, and zero yields on the remaining six units, and so on. This would allow the producer to maintain his or her average yield and premium rates on each unit, but at the same time trigger maximum indemnity payments on individual units sequentially each year. The cross-section unit-level yields over time are used to estimate the temporal, spatial, and residual variance from equation (1) or constructed from equation (4) with no trend. Under optimal yield switching, results from Table 1 show that 100% of farm variance is explained by the residual, as the variation across units and within each unit over time is zero. For any kind of multivariate normally distributed unit yields over time, we would expect the overall farm variance to be shared across temporal, spatial, and residual components. Hence, when optimal yield switching behavior occurs we would expect 100% of yield variation to be explained by the residual.

Next, redistributed yields presented in Table 2, illustrates the relationship of potential moral hazard and adverse selection to spatial, temporal, and residual risk. The overall production on the farm is no different from Table 1, but the yields are redistributed not only to reflect moral hazard but also the presence of adverse selection, i.e., the producer has more information compared to the insurance provider about the heterogeneous risks (varying standard deviation) across units within a farm due to optional unit provision. The panel structure of the yield data is used to estimate the temporal, spatial, and residual variance as defined in equation (1) or constructed from equation (4). Results from Table 2 show that 98% of overall farm variance is explained by residual variance and 1% each by temporal and spatial variance. The difference of 2% reflected in the temporal and spatial variance share is due to adverse selection and/or moral hazard.

Table 3 presents the shares of temporal, spatial, and residual risk components computed from panel data for a single-unit farm up to nine-unit farms. Furthermore, the temporal, spatial, and residual shares for farm with four years up to nine years of panel data is also presented in Table 3. Shares instead of variance are presented and utilized in the analysis to provide unitless measures of temporal, spatial, and residual risk.

Based on the trends in the spatial, temporal, and residual shares, it is expected the temporal (spatial and residual) risk component to decrease (increase) with an increase in the number of units from one to nine. In contrast, the temporal (spatial and residual) risk component will increase (decrease) with an increase in the number of years of data from four to nine. However, these trends might actually reflect the true yield variation across units within a farm. To identify the presence of potential moral hazard and adverse selection due to optional unit provision, the influence of true yield variation and the number of units within a farm needs to be accounted. One approach would be to normalize the individual farm risk components by dividing them by the average of Monte Carlo simulated risk components computed from a representative or normal farm’s yield distribution. With the use of normalized risk components i.e., risk components over and above the representative or normal farm’s yield distribution, the positive and significant coefficients of spatial, temporal, and residual shares indicate the presence of potential moral hazard and adverse selection due to optional unit provision in the federal crop insurance program.

Table 1. Decomposition of Risk for an Ideal Case of Optimal Yield Switching without Adverse Selection

	Temporal, Spatial and Residual Variance										
Year	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	**mean**	**Std**
1990	1000	0	0	1000	0	0	1000	0	0	333.33	500.00
1991	0	1000	0	0	1000	0	0	1000	0	333.33	500.00
1992	0	0	1000	0	0	1000	0	0	1000	333.33	500.00
1993	1000	0	0	1000	0	0	1000	0	0	333.33	500.00
1994	0	1000	0	0	1000	0	0	1000	0	333.33	500.00
1995	0	0	1000	0	0	1000	0	0	1000	333.33	500.00
1996	1000	0	0	1000	0	0	1000	0	0	333.33	500.00
1997	0	1000	0	0	1000	0	0	1000	0	333.33	500.00
1998	0	0	1000	0	0	1000	0	0	1000	333.33	500.00
mean	333.33	333.33	333.33	333.33	333.33	333.33	333.33	333.33	333.33		
std	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00		

Risk	**Spatial**	**Temporal**	**Residual**
Variance	0	0	222,222
Share	0	0	1

Table 2. Decomposition of Risk for an Ideal Case of Optimal Yield Switching with Adverse Selection

	Temporal and Spatial Variance										
Year	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	**mean**	**Std**
1990	1000	0	0	1500	0	0	500	0	0	333.33	559.02
1991	0	1000	0	0	1500	0	0	500	0	333.33	559.02
1992	0	0	1500	0	0	1000	0	0	500	333.33	559.02
1993	1500	0	0	1000	0	0	1500	0	0	444.44	682.11
1994	0	1500	0	0	1500	0	0	1000	0	444.44	682.11
1995	0	0	1000	0	0	1000	0	0	1000	333.33	500.00
1996	500	0	0	1500	0	0	500	0	0	277.78	506.90
1997	0	500	0	0	1000	0	0	500	0	222.22	363.24
1998	0	0	500	0	0	1000	0	0	1000	277.78	440.96
mean	333.33	333.33	333.33	444.44	444.44	333.33	277.78	222.22	277.78		
std	559.02	559.02	559.02	682.11	682.11	500.00	506.90	363.24	440.96		

Risk	**Spatial**	**Temporal**	**Residual**
Variance	4,801	4,801	567,901
Share	0.008	0.008	0.983

Table 3. Shares of Temporal, Spatial and Residual Variance (or Risk)

Number of Units	Effect of Number of Units			Effect of Number of Years		
	Temporal	**Spatial**	**Residual**	**Temporal**	**Spatial**	**Residual**
1	1	0	0			
2	0.632	0.137	0.231			
3	0.547	0.182	0.271			
4	0.502	0.210	0.288	0.6472	0.1614	0.1914
5	0.482	0.217	0.301	0.7379	0.1127	0.1494
6	0.454	0.250	0.296	0.7183	0.1138	0.1679
7	0.437	0.257	0.307	0.8010	0.0740	0.1250
8	0.416	0.274	0.310	0.8045	0.0697	0.1258
9	0.396	0.285	0.319	0.7358	0.0891	0.1751

II a. Monte Carlo analysis to address the effects of number of units on yield variation

Monte Carlo analysis is used to examine the effect of number of units on the share of spatial, temporal, and residual risk components. Nine years of yield data are generated for a single-unit up to nine-unit farm based on the mean yield and variance-covariance yield matrix of a representative farm. For a single farm f , with multiple units the vector of mean and variance-covariance matrix can be represented as:

$$\mu = \left(\mu_1', \ldots, \mu_N'\right)$$

(6)

$$\Omega \equiv E\begin{pmatrix} y_1 \\ . \\ y_N \end{pmatrix}\left(y_1', \ldots, y_N'\right) = \begin{pmatrix} y_{11} & \cdots & y_{1N} \\ \vdots & \ddots & \vdots \\ y_{N1} & \cdots & y_{NN} \end{pmatrix}$$

where μ is the vector of unit level mean yields based on unit 1 yields, y_1 to unit N yields, y_N time with N representing the total number of units within each farm, f ; and Ω is the corresponding variance-covariance matrix of mean μ for each farm, f . The variance-covariance matrix and mean yield for each farm is computed from the RMA yield history file based on actual yields reported by the producer for single-unit farm to a maximum of nine-unit farm.

The representative farm's mean, μ^f and variance-covariance matrix, Ω^f is computed as the average of all the farms for a single-unit to nine-unit farm. This can be represented as:

$$\mu^f = \frac{1}{F}\sum_{f=1}^{F}\mu$$

(7)

$$\Omega^f = \frac{1}{F}\sum_{f=1}^{F}\Omega$$

where f = 1, 2, ..., F number of farms in each of the single-unit to nine-unit farm.

This representative farm mean and variance-covariance matrix is used to generate the 20,000 samples with nine years of yield data for a single-unit farm, two-unit farm and so forth up to nine-unit farm based on multivariate normal distribution with replacement. The multivariate normal yield data is generated using the Cholesky root of the variance-covariance matrix. The panel structure of the generated data is used to estimate the temporal, spatial, and residual variance as defined in equation (1) or equation (4) for 20,000 samples. These variances are used in the computation of average Monte Carlo temporal, spatial, and residual shares.

II b. Steps involved in the Monte Carlo Analysis

Step 1 Each farm's mean and variance-covariance matrix are estimated.

Step 2 Representative farm's mean and variance-covariance matrix is computed as the average of all the farms by state and practice for a single-unit up to nine-unit farm and within each farm 2-years up to 9-years of data.

Step 3 This representative farm's mean and variance-covariance matrix is used to generate the 20,000 samples for a single-unit, two-unit, and so forth up to nine-unit farm based on multivariate normal distribution.

Step 4 Similarly, representative farm's mean and variance-covariance matrix is used to generate the 20,000 samples for a farm with four years of data, five years of data, and so forth up to nine-years of farm data based on multivariate normal distribution.

Step 5 The MC simulated data is used to estimate the temporal, spatial, and residual variance as defined in equation (1) for 20,000 samples.

Step 6 The variances are then used in the computation of average Monte Carlo temporal, spatial, and residual shares for single-unit to nine-unit farm and four-year to nine-year panel data.

These components form the basis for examining the presence of potential moral hazard and adverse selection (identified with spatial, temporal, and residual risk components) by the producer decision to insure as a single or multiple-unit farm due to optional unit provisions in federal crop insurance program. Two discrete choice models are estimated, model 1 used the spatial, temporal, and residual risk components while model 2 used the normalized spatial, temporal, and residual risk component shares. The signs on the spatial, temporal, and residual risk components in model 2 are expected to be positive and significant indicating the presence of potential moral hazard and adverse selection due to optional unit provisions. While negative (positive) is expected on the temporal (spatial and residual) risk components in model 1.

III. Ordered probit model to examine asymmetric information

In this section, an asymmetric information model incorporating the spatial, temporal, and residual risk components to examine the presence of moral hazard and adverse selection due to optional unit provisions is developed. A multinomial discrete choice model of number of optional units insured by a farm or policy is developed.

Following Greene, 1997 (pp 927), the ordered probit model can be represented as:

$$
\begin{aligned}
y_i^* &= \beta' x_i + \varepsilon_i \\
y_i &= 0 \ if \ y_i^* \le 0 \\
y_i &= 1 \ if \ 0 \le y_i^* \le \mu_1 \\
y_i &= 2 \ if \ \mu_1 \le y_i^* \le \mu_2 \\
&.... \\
y_i &= j \ if \ y_i^* \ge \mu_{j-1}
\end{aligned} \tag{9}
$$

where the choice, j is equal to zero for farms with one optional unit, 1 for farms with two optional unit and 8 for farms with nine or more optional units.

The probability of the ordered discrete choice to insure number of optional units defined in equation (9) can be represented as:

$$
\begin{aligned}
Prob(y_i = 0) &= Prob\left[\beta' x_i \le 0\right] &&= \Phi\left[\beta' x_i\right] \\
(y_i = 1) &= Prob\left[\beta' x_i \le \mu_1\right] - Prob\left[\beta' x_i \le 0\right] &&= \Phi\left[\mu_1 - \beta' x_i\right] - \Phi\left[-\beta' x_i\right] \\
(y_i = 2) &= Prob\left[\beta' x_i \le \mu_2\right] - Prob\left[\beta' x_i \le \mu_1\right] &&= \Phi\left[\mu_2 - \beta' x_i\right] - \Phi\left[\mu_1 - \beta' x_i\right] \\
&... \\
(y_i = j) &= Prob\left[\beta' x_i \ge \mu_{j-1}\right] &&= 1 - \Phi\left[\mu_{j-1} - \beta' x_i\right]
\end{aligned} \tag{10}
$$

where $\Phi\left[\beta' x_i\right]$ is the cumulative normal function, $\mu' s$ is the threshold values, and i is the number of observations used in the analysis. Since the probabilities sum to one, it is possible to set one (farms with one optional unit) of the parameter vectors equal to zero.

The coefficients of the ordered probit model defined in the probability is used to compute the marginal effects by differentiating equation (10) for each of the nine choices by independent variables. The marginal effects can be readily used in the interpretation of the results and defined as:

$$
\frac{\partial Prob\left[y_i = j\right]}{\partial x_i} = \left[f\left(\mu_j - \beta' x_i\right) - f\left(\mu_{j-1} - \beta' x_i\right)\right](-\beta) \tag{11}
$$

Here the exogenous variables includes the four moments of the yield distribution -- first moment, temporal, spatial, and residual risk or second moments respectively, third moment or skewness, and the fourth moment or kurtosis. The other exogenous variables include average acreage of the farm, crop insurance premium rate, number of actual yields reported by the producer, dummy for irrigated acreage, and dummy for farms with more than 640 acres. For the second model, all the variables remain the same except the second moments of the yield distribution is normalized by the representative farm's second moments.

IV. U.S. cotton data

Information on each producer who purchased cotton insurance for the year 1998 is extracted from RMA's data files[7]. The producers were restricted to those who purchased additional coverage i.e., buyup policies under yield insurance. Information on the number of units insured within a farm is computed from the yield history data. In the yield history file, each producer at the time of purchasing insurance is required to submit self-reported but verified yield and acreage data for the last 6-10 years of actual data. These 6-10 years of unit level yield and acreage information within a farm represents the cross-sectional time-series data. Each producer's farm yield risk decomposed into temporal, spatial, and residual risks is estimated using a two-way random effects panel model defined in equation (1) or computed using equation (4) for each farm. The average acreage is used to account for any changes in the acreage over time for each farm. For each of the unit yield observation over time, the multiple peril crop insurance rates published by RMA are extracted to form the premium rate. Information on other exogenous variables available for the yield history file are obtained from RMA and used in the analysis.

The dependent and independent variables are defined in Table 4. The number of insured cotton farms and the arithmetic mean of variables used in the analysis by number of units insured within a farm are presented in Table 5. The number of farms seems to indicate a decreasing trend with units, with 15,585 farms insured as a single-unit farm compared to 10,171 multiple-unit farms. The mean of the temporal risk (spatial and residual) is higher (lower) for a single-unit farm and decreases (increases) with the number of units. The mean temporal and spatial normalized shares portray similar trend, i.e., the normalized temporal (spatial) shares decrease (increase) with the number of units insured. The means of other variables used in the analysis are also presented.

V. Empirical application and results

To examine the presence of potential moral hazard and adverse selection due to the optional unit provision, an empirical application of the producer decision to insure a single-unit farm, two-unit farm and up to 9 or more-unit farm is modeled for all the U.S. producers who purchased cotton insurance for the year 1998 using RMA's yield database. An ordered probit model is estimated with the number of optional units (*Optional Units*) insured within a farm policy as the dependent variable coded as 0 through 8, where 0 corresponds to a single-unit farm and 8 corresponds to a nine or more multiple-unit farm. The ordered probit with heteroskedasticity model can be represented as:

$$\begin{aligned} Optional\ Units_i &= \alpha_0 + \alpha_1 Mean\ yield_i + \alpha_2 Temporal\ Yield\ Risk_i + \alpha_3 Spatial\ Yield\ Risk_i \\ &+ \alpha_4 Residual\ Yield\ Risk_i + \alpha_5 Yield\ skewness_i + \alpha_6 Yield\ kurtosis_i \\ &+ \alpha_7 Acreage_i + \alpha_8 Premium_i + \alpha_9 Actuals_i + \alpha_{10} A640_i + \varepsilon_{1,i} \end{aligned}$$

(11) $$Variance\ function\left(\varepsilon_{1,i}\right)^2 = \beta_1 Mean\ yield_i + \beta_2 Acreage_i + \beta_3 Premium_i + \varepsilon_{2,i}$$

where *i* is the number of observations or farms, μ_y is the first moment of yield distribution, σ_y^T, σ_y^S *and* σ_y^R are the temporal, spatial, and residual second moment of yield distribution respectively, $\sqrt{\beta_1}$ is the third moment of yield distribution or skewness, and β_2 the fourth moment of yield distribution or kurtosis[8]. The other exogenous variables include *fsize* is the average acreage of the farm, p is the crop insurance premium rate, *actuals* is the number of actual yields reported by the producer, *irr* is the dummy for irrigated acreage, $A640$ is the dummy for farms with more than 640 acres, $\varepsilon_{1,i}$ is an error term and $\left(\varepsilon_{1,i}\right)^2$ is the variance of disturbance term, $\varepsilon_{1,i}$.

Table 4. Definitions of Variables Used in the Analysis

Variable	**Units**	**Definitions**
Number of units	Number	Number of units insured within a farm policy
Mean yield	Pounds	Mean of yield
Temporal yield risk	Pounds	Yield variation over time
Spatial yield risk	Pounds	Yield variation across units
Residual yield risk	Pounds	Remaining residual yield variation across units and over time
Normalized temporal yield risk	Ratio	Temporal variation over the representative farm temporal variation
Normalized spatial yield risk	Ratio	Spatial variation over the representative farm spatial variation
Normalized residual yield risk	Ratio	Residual variation over the representative farm residual variation
Skewness	Value	Skewness, a measure of symmetry relative to a normal distribution
Kurtosis	Value	Kurtosis, a measure of whether the data are peaked or flat relative to a normal distribution.
Acreage	Acres	Average acreage of the farm
Premium	Percentage	Yield based premiums rates published by RMA
Number of actuals	Dummy	Number of actual yields reported < 4 and > 4 are coded as 0 and 1 respectively
Irrigated	Dummy	If irrigated then Dummy is coded as 1
Acres more than 640	Dummy	If acreage > 640 acres then A640 is coded as 1

Table 5. Mean of the variables Used in the Analysis by Number of Optional Units

	Units	1	2	3	4	5	6
Number of farms		**15585**	**4836**	**2132**	**1257**	**748**	**485**
Mean yield	Pounds	414.6	424.3	457.8	462.1	451.3	475.9
Temporal yield risk	Pounds	188.8	175.4	172.6	166.7	164.7	159.9
Spatial yield risk	Pounds	0.0	38.0	57.4	69.7	74.1	88.3
Residual yield risk	Pounds	0.0	64.0	85.6	95.8	102.8	104.4
Normalized temporal risk	Ratio	1.000	0.854	0.766	0.660	0.729	0.660
Normalized spatial risk	Ratio	0.000	2.052	2.447	3.546	2.440	2.511
Normalized residual risk	Ratio	0.000	1.288	1.380	1.757	1.259	1.478
Skewness	Pounds	-0.198	-0.161	-0.153	-0.148	-0.105	-0.138
Kurtosis	Pounds	0.147	0.170	0.135	0.149	0.127	0.200
Acreage	Acres	125.7	134.9	134.7	130.4	125.8	123.9
Premium	Percentage	0.172	0.173	0.169	0.162	0.162	0.164
Number of actuals	Dummy	0.887	0.813	0.709	0.710	0.672	0.581
Irrigated	Dummy	0.369	0.384	0.385	0.383	0.332	0.280
Acres more than 640	Dummy	0.006	0.048	0.134	0.240	0.318	0.402

	Notation	7	8	9		1	>=2
Number of farms		**314**	**232**	**167**		**15,585**	**10,171**
Mean yield	μ_y	497.7	498.5	516.7		415	473
Temporal yield risk	σ_y^T	163.8	162.2	156.1		189	165
Spatial yield risk	σ_y^S	96.2	106.8	112.4		0	80
Residual yield risk	σ_y^R	115.1	121.1	125.6		0	102
Normalized temporal risk	$N\sigma_y^T$	0.648	0.641	0.583		1.000	0.692
Normalized spatial risk	$N\sigma_y^S$	2.853	2.649	2.741		0.000	2.655
Normalized residual risk	$N\sigma_y^R$	1.348	1.290	1.486		0.000	1.411
Skewness	$\sqrt{\beta_1}$	-0.183	-0.071	0.088		-0.198	-0.109
Kurtosis	β_2	0.118	0.141	0.057		0.147	0.137
Acreage	*fsize*	122.1	119.0	95.1		126	123
Premium	*p*	0.144	0.148	0.145		0.172	0.158
Number of actuals	*actuals*	0.522	0.496	0.479		0.887	0.623
Irrigated	*irr*	0.258	0.241	0.186		0.369	0.306
Acres more than 640	*A*640	0.468	0.440	0.401		0.006	0.306

Results from the two ordered probit models (equation 11) with first, temporal, spatial, and residual, second (normalized temporal, spatial, and residual second), third, and fourth moments of yield, premiums rates, farm size, number of actual yield reported, dummy for irrigated acreage, and dummy for farm with more than 640 acres are reported in Table 6. The difference between the two models stems from the use of temporal, spatial, and residual, second moments in Model 1 compared to the use of normalized temporal, spatial, and residual, second moments in Model 2 to examine the presence of potential moral hazard and adverse selection.

Based on the trend in the shares reported in Table 3, results from Model 1 indicate the parameter estimates on the temporal (spatial and residual) risk components are negative (positive) and significantly related to the number of optional units insured within a farm policy. To examine potential moral hazard and adverse selection due to an optional unit provision in federal crop insurance, we focus on the results from Model 2 in Table 6. The three yield risks in Model 2 are normalized shares i.e., shares over and above the representative or normal farm's yield distribution. A positive parameter estimate of spatial, temporal, and residual shares, *ceterus paribus*, would be an indicator of potential moral hazard and adverse selection due to optional unit provision. Model 2 results with positive and significant parameter estimates of residual, temporal, and spatial support the presence of potential moral hazard (spatial and residual) and adverse selection (temporal and spatial) with optional unit provisions in federal crop insurance.

Mean yield, a measure of individual farm productivity, was negative and significantly correlated with the number of optional units in Model 1. This indicates producers with higher average yields tend to insure as a single-unit farm. However, it is positive and significant in Model 2 indicating producers with a higher mean yield at farms are insuring as a multiple-unit farm to address the spatial mean yield difference across units within a farm. As expected, farms with extreme events and thickness of the tails reflected by the measures of skewness and kurtosis of yield respectively indicate a positive and significant relationship with the number of optional units. Farms with higher than average acreage or farm size tend to insure as single-unit farm. Similarly, if the premium rate is higher, the producers are more inclined to insure as a single-unit farm. The remaining variables, number of actual yields reported, practice dummy for irrigated acreage, and farms with more than 640 acres exhibit the expected negative, negative and positive parameter estimates, respectively. Producers with a higher number of actual yields reported tend to insure as single-unit farm as they do have anything to hide with respect to the yields or not leaning towards the use of assigned yields. Irrigated producers tend to insure as single-unit farms as the yields are higher and variation is lower for farms with irrigation.

The variance function variables mean yield, acreage, and premium exhibit positive, negative and positive results, respectively. Producers with higher mean yield and premium are faced with a larger variance of the errors despite accounting for the four moments of the yield distribution. In contrast, farms with a higher average acreage or farm size have lower error variance.

Next, the marginal effects of the normalized spatial, temporal, and residual risk from Model 2 reflecting potential moral hazard and adverse selection due to optional unit provision is discussed. The marginal effects of the variables for each of the choices are computed based on equation (11) and presented in Table 7. An examination of the marginal effect indicates that as the normalized temporal risk is up by one percent, probability of insuring as single-unit farm is expected to decrease by 2.24 percent. In contrast, if the normalized temporal risk is up by one percent, probability of insuring as a two-unit farm, three-unit farm, four-unit farm, and so forth up to 9 or more optional unit farm is expected to increase by 2.00, 0.19, 0.036, and 0.0001 percent respectively. The normalized spatial and residual risk also indicate a declining trend in the probabilities of insuring as a two-unit farm, three-unit farm, four-unit farm, and so forth up to 9 or more optional unit farm. This indicates the presence of potential moral hazard and adverse selection is highest with farms insured as a two-unit farm and declines with an increase in the number of optional units.

VI. Conclusions

Using orthogonal error decomposition of the two-way random effects panel model, measures of temporal, spatial, and residual risk components are developed that correspond to the presence of potential moral hazard and adverse selection. The decomposed components form the basis for examining the presence of potential moral hazard and adverse selection using a discrete choice ordered probit model. Second, the normalized (over and above the representative farm variation) temporal, spatial, and residual supports potential moral hazard and adverse selection due to optional unit provisions in the crop insurance program. However, the extent of the potential moral hazard and adverse selection due to optional unit provisions need to be quantified using actual loss data.

Apart from statistically differentiating moral hazard and adverse selection, the implications of the research would form the basis for (1) streamlining the premium rate discounts for optional units to maintain actuarial standards, and (2) providing alternative statistical measures to identify potential moral hazard and adverse selection due to potential fraudulent yield switching activity with optional unit provision in crop insurance.

Table 6. Regression Results of Ordered Probit Model with Actual and Normalized Spatial, Temporal and Residual Risk

Model 1			Model 2		
Variables	**Parameter Coefficients**	**P[|Z|>z]**	**Variables**	**Parameter Coefficients**	**P[|Z|>z]**
Index function for probability of number of optional units					
Intercept	1.1207	< 0.00	Intercept	-7.9210	< 0.00
Mean Yield	-0.0008	< 0.00	Mean yield	0.0004	< 0.00
Temporal Risk	-0.0055	< 0.00	Normalized temporal risk	7.0798	< 0.00
Spatial Risk	0.0043	< 0.00	Normalized spatial risk	0.7546	< 0.00
Residual Risk	0.0314	< 0.00	Normalized residual risk	2.4548	< 0.00
Skewness	0.0069	0.32	Skewness	0.0002	< 0.00
Kurtosis	0.0007	< 0.00	Kurtosis	0.0005	< 0.00
Acreage	-0.0016	< 0.00	Acreage	-0.0029	< 0.00
Premium	-1.2698	< 0.00	Premium	-0.6232	< 0.00
Number of actuals	-0.9501	< 0.00	Number of actuals	-0.8921	< 0.00
Irrigated	-0.4245	< 0.00	Irrigated	-0.3134	< 0.00
Acres more than 640	2.3223	< 0.00	Acres more than 640	2.1253	< 0.00
Variance function					
Mean yield	0.0007	< 0.00	Mean yield	0.0003	< 0.00
Acreage	-0.0003	< 0.00	Acreage	-0.0003	< 0.00
Premium	0.6879	< 0.00	Premium	0.3600	< 0.00
Threshold parameters for index					
LIMIT1	1.7819	< 0.00	LIMIT1	2.0282	< 0.00
LIMIT2	2.8018	< 0.00	LIMIT2	2.7595	< 0.00
LIMIT3	3.6233	< 0.00	LIMIT3	3.2474	< 0.00
LIMIT4	4.3144	< 0.00	LIMIT4	3.5915	< 0.00
LIMIT5	4.9670	< 0.00	LIMIT5	3.9226	< 0.00
LIMIT6	5.6041	< 0.00	LIMIT6	4.2424	< 0.00
LIMIT7	6.4086	< 0.00	LIMIT7	4.6646	< 0.00

Table 7. Marginal Effects of the Explanatory Variables on Number of Optional Units

	1	2	3	4	5	6	7	8	9
Mean yield	-0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Normalized temporal risk	-2.2403	2.0043	0.1866	0.0355	0.0088	0.0033	0.0012	0.0005	0.0001
Normalized spatial risk	-0.2388	0.2136	0.0199	0.0038	0.0009	0.0004	0.0001	0.0001	0.0000
Normalized residual risk	-0.7768	0.6950	0.0647	0.0123	0.0031	0.0012	0.0004	0.0002	0.0001
Skewness	-0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Kurtosis	-0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Acreage	0.0009	-0.0008	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Premium	0.1972	-0.1764	-0.0164	-0.0031	-0.0008	-0.0003	-0.0001	0.0000	0.0000
Number of actuals	0.2823	-0.2525	-0.0235	-0.0045	-0.0011	-0.0004	-0.0002	-0.0001	0.0000
Irrigated	0.0992	-0.0887	-0.0083	-0.0016	-0.0004	-0.0002	-0.0001	0.0000	0.0000
Acres more than 640	-0.6725	0.6017	0.0560	0.0107	0.0027	0.0010	0.0004	0.0001	0.0000
Mean yield	1.1927	-0.5315	-0.4822	-0.1208	-0.0348	-0.0145	-0.0057	-0.0025	-0.0008
Acreage	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Premium	-1.0660	0.4751	0.4310	0.1080	0.0311	0.0130	0.0051	0.0022	0.0007

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FOOTNOTES

[1] Due to the unique public-private partnership, the Federal Crop Insurance Corporation through U.S. Department of Agriculture, Risk Management Agency provides reinsurance (subsidy) to approved commercial insurers, which insure agricultural commodities using FCIC-approved acceptable plans through standard reinsurance agreement (SRA). With SRA, the crop insurance sold and serviced through private insurance companies receives subsidies on a portion of the premium, administrative and operating expenses by the federal government. The three available SRAs' - Standard Reinsurance Agreement, the Livestock Price Reinsurance Agreement, and the Aquatic Crop Reinsurance Agreement are considered cooperative financial assistance agreements between the FCIC and the insurance company named on the agreement. Since 1998, the private insurance companies reinsured by FCIC have sold and serviced all multiple peril crop insurance authorized under the Federal Crop Insurance Act.

[2] Under RMA's current procedures, producers have the option to a) insure or not insure; b) choose the level of insurance coverage; c) choose yield or revenue insurance product; and d) basic or optional unit based on his/her perceived risk in order to maximize profits each crop year. Shaik and Atwood, 2002, have examined the presence of adverse selection due to above choice of insurance policy.

[3] Subdivision of the farm into optional units is allowed for land in different sections under rectangular survey, and for irrigated versus dryland production. A section is one square mile (or 640 acres) and where legal descriptions are not based on rectangular survey, alternative criteria such as Farm Agency Service farm serial number and non-contiguity are used to define insurable units. For details see pp 36-44 under section 4 of the 2002 Crop Insurance Handbook (APH), Issued: 06/2001 and available at the following website http://www.rma.usda.gov/FTP/Publications/directives/18000/pdf/02_18010.pdf.

[4] The current yield, revenue and area insurance policies offer the producers the choice to insure optional, basic, enterprise and whole farm unit. A unit is defined as that acreage of the insured crop in the county, which is taken into consideration when determining the guarantee, premium, and the amount of any indemnity (loss payment) for that acreage. The basic insurance unit is all insurable acreage of the insured crop in the county on the date coverage begins for the crop year in which the producer has a 100 percent share or which is owned by one entity and operated by another specific entity on a share basis. Basic units may be further divided into optional units. Optional units are determined by section, section equivalents, FSA Farm Serial Number, noncontiguous land (for certain perennial crops), and irrigated and non-irrigated practices. When the policy allows, optional units may be established, provided the crop is planted in a manner that results in a clear and discernible break in the planting pattern at the boundaries of each optional unit, and the producer keeps separate identifiable records of planted acreage and harvested production for each optional unit. An enterprise unit includes all insurable acres of a single crop in a county. A whole-farm unit includes all insurable acres of all crops in a county.

[5] Since we are addressing the issue of moral hazard due to potential yield switching it does not matter if the unit is a basic, optional, enterprise unit within a farm policy.

[6] Issues of adverse selection (see Stilgtiz, 1977; Chiappori and Salanie, 2000; Bev Dahlby, 1983; and Dionne and Doherty, 1994) and traditional moral hazard (Pauly, 1974; Whinston, 1983; Boyer and Dionne, 1989; and Arnott and Stiglitz, 1988) have been addressed in the literature. Recently there has been increased focus on the identification and empirical examination of insurance fraud (see the chapters by Picard; and Dionne from the Handbook of Insurance, 2000; September issue of Journal of Risk & Insurance, 2002; and http://www.insurancefraud.org/downloads/Research_reports.pdf) in the literature.

[7] Risk Management Agency's database consists of a number of different databases containing information with respect to insurance companies, agents, adjusters, and producers. RMA's yield history data set contains producers' reported historical yields used in establishing an average or "approved" yield at the beginning of the insurance year. RMA's loss history data set collects indemnities paid at the end of the insurance year.

[8] Negative values for skewness indicate data are skewed to the left. Positive values for skewness indicate data are

skewed to the right. The kurtosis for a standard normal distribution is three and for this reason kurtosis is defined as $(\beta_2 - 3)$. A positive value for kurtosis indicates a peaked distribution, i.e., leptokurtic or thick tailed $(\beta_2 - 3) > 0$ and a negative value of kurtosis indicates a flat distribution, i.e., platykurtic or thin tailed $(\beta_2 - 3) < 0$. For the analysis, the left or right skewness and thin or thick-tailed kurtosis is not differentiated.