ESTIMATING THE DEMAND OF CROP INSURANCE AND SUPPLY OF INDEMNITY PAYMENTS: NEBRASKA AGRICULTURE SECTOR

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Abstract

The objective of this paper is to examine the potential impacts of crop insurance on farm economic structure using Nebraska agriculture sector data from 1980-1997. We estimate the system of input demand (output supply) equations including policy premium (policy indemnity) in order to examine the economic impacts of crop insurance.

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U.S. agriculture sector is subjected to weather-related and other natural disasters with farmers experiencing unstable prices due to globalization of the economy. Deficiency payment programs for several major crops-wheat, feed grains, cotton and rice administered by U.S. Department of Agriculture (USDA) was intended to protect farmers' income against declines in prices through a complicated array of pricing mechanisms. However with the passage of the Freedom to Farm Act in 1996, farmers were encouraged to produce in response to market forces. As part of this new direction in policy, the act replaced the income support programs with "crop insurance" as the principal means of managing risk associated with crop losses. While the causes of the switch to crop insurance from the other programs are still controversial, as are the predicted outcomes, there is strong public interest in estimates of likely aggregate impacts of crop insurance on farm economic structure.

Crop insurance, one of U. S. Department of Agriculture's (USDA) primary policy instruments in protecting farmers against risk has been the subject of substantial research. The Federal Crop Insurance Corporation (FCIC) through the Risk Management Agency (RMA) and the private insurance companies offers several crop insurance programs contrived on the type of coverage, percent election and, optional units. Several aspects of crop insurance has been examined related to moral hazard (Chambers, 1989; Just and Calvin, 1993; Coble et al, 1997), adverse selection (Atwood and Shaik, 1999; Just and Calvin, 1995; Skees and Reed, 1986; Quiggin et al, 1994), demand for crop insurance (Coble et al, 1996), rating methodologies (Olivier Mahul, 1999; Goodwin and Ker, 1998; Skees, Black and Barnett, 1997; Goodwin, 1993) and the effects of insurance availability upon resource allocation (Horowitz and Lichtenberg, 1993; Atwood et al, 1996; Smith and Goodwin, 1996). Although much of the existing research emphasized on the intended and unforeseen consequences of crop insurance, the associated aggregate impacts on factor use patterns (input demand), agriculture production mix (output supply), agriculture producers, price-quantity adjustments and total factor productivity leads to important policy and ecological implications within the agriculture sector.

In this paper we attempt to econometrically examine the impacts of crop insurance on farm economic structure applied to Nebraska agriculture sector data from 1980-1997. This involves estimation of system of input demand equations given production function to examine the potential impacts of crop insurance on factor use patterns. The inputs included are capital, farm labor, land, intermediate input and crop insurance policy premiums. Further crop insurance shift patterns of comparative advantage within output sectors especially the crop mix or for that matter between crop-livestock production. The estimation of system of output supply equations examines the potential impact of crop insurance on the output sector. The output supply includes insured crops, non-insured crops, vegetables and oils, meat animals, poultry and other livestock and crop insurance policy indemnities given output-producible function. Nebraska agriculture sector was chosen given the availability of crop insurance premiums and indemnities for the three major crops [corn (35%), soybean (29%) and wheat (13%)] which together constitutes 77 percent of the total crop insurance policies issued in the state of Nebraska for the year 1999. This allows drawing conclusions on the potential impacts of crop insurance at the aggregate sector.

In the current analysis, the manner in which crop insurance is accounted for in the firm’s production function needs to be emphasized and clearly presented in order to draw conclusions on the aggregate impacts. Even though crop insurance is yield driven policy program, it can be broken down into crop insurance premiums paid by the farmer, subsidies provided by the government, indemnities received by the farmer. However the main issue that needs to be addressed--would the premiums paid for crop insurance policies and indemnities received due to crop insurance effect the farmer decisions to alter factor use patterns and output production mix. The difficulty associated with this type of analysis is three-fold, first is the unavailability of crop wise allocable input quantity and price data, second is the lack of sufficient time series state level data dis-aggregated at the crop level and last the inability to simultaneously estimate the multiple output-input impacts. So a first attempt would be to estimate the system of input demand (output supply) equations given production function (output-producible function) at the aggregate level to analyze the impacts of crop insurance on the farm economic structure under the assumption of output-input separable technology.

The objective of this paper is to examine the economic impacts of crop insurance on Nebraska agriculture sector at the aggregate level. This involves econometric estimation of system of input demand (output supply) equations to examine the potential impacts of crop insurance. The remainder of this paper is organized as follows. The system of input and output Translog model is presented in the next section of the paper. The construction of the output, input, crop insurance policy premiums and policy indemnities quantity index for Nebraska agriculture sector for the time period 1980-1997 are detailed in the third section. The fourth section presents the results illustrating the potential impacts of crop insurance on farm economic structure. A summary and conclusion section concludes the paper.

THEORETICAL OVERVIEW

Ideally the potential impacts of crop insurance on individual crop would assist the policy makers to form generalizations. However due to the extended impacts of crop insurance across factor use and output production mix, a useful first step will be estimate and examine the aggregate level impacts. Even the outcome from this aggregate analysis need to be correctly interpreted in order to understand the potential impacts given the structure of crop insurance. Under the assumption of separable output-input technology, the aggregate impacts of crop insurance on factor use patterns and output production mix can be independently estimated or examined. Utilizing the cost shares we estimate the system of input demand equations that includes crop insurance policy premiums to understand the potential impacts of crop insurance on the factor use patterns. Similarly utilizing revenue shares we estimate the system of output supply equations including policy indemnities to examine the impacts of crop insurance on output production mix. Specifically in both system of input demand and output supply equations we examine the quantity impacts of crop insurance premiums and indemnities rather then the price impacts commonly conceived in the system of equation estimation.

PRODUCTION (PRODUCIBLE-OUTPUT) FUNCTION

In aggregate sectoral analysis one observes non-allocable input index vectors $X = (x_1, x_2, \dots x_n) \in \Re_+^N$ used in the production of an output index vector $Y = (y_1, y_2, \dots y_m) \in \Re_+^M$. An explicit production technology assuming input-output separability can be represented by a production function and producible-output function as:

$$(1) \quad F(X,Y) \equiv g(y) - f(x) = 0$$

The other assumptions of a positive[1], linear homogenous function[2] with non-Hicks neutral technical change are postulated. With the purpose of estimating the system of input demand (output supply) independently given the production function (producible-output function) in terms of a single-output (input) index and multi-input (output) index can be represented as:

$$(2a) \quad y = f(X): \; X \; can \; produces \, y, \quad X \in \Re_+^N$$
$$(2b) \quad x = g(Y): \; Y \; produced \; by \; x, \quad Y \in \Re_+^M$$

where the production function is a purely technical relationship that yields the maximum output y for a given vector of input bundle $X \in \Re_+^N$. The producible-output function represents all output bundles $Y \in \Re_+^M$ that can be produced given input x. A Translog function due to its flexibility and ease in imposing properties is used to represent the production function and the producible-output function with non-Hicks neutral technical change as:

$$(3a) \quad \ln y = a_0 + a_t t + \sum_{i=1}^{n} a_i \ln x_i + \frac{1}{2} g_t t^2 + \sum_{i=1}^{n} \sum_{j=1}^{n} g_{i,j} \ln x_i \ln x_j + \sum_{i=1}^{n} b_{i,t} \ln x_i t + e$$

$$(3b) \quad \ln x = a_0 + a_t t + \sum_{i=1}^{m} a_i \ln y_i + \frac{1}{2} g_t t^2 + \sum_{i=1}^{m} \sum_{j=1}^{m} g_{i,j} \ln y_i \ln y_j + \sum_{i=1}^{n} b_{i,t} \ln y_i t + e$$

With $a_t = 0$, $g_t = 0$ and $b_{i,t} = 0$ the above representation degenerates to Hicks-neutral technological change. The homogeneity conditions require the sum of a_i and $g_{i,j}$ are equal to one and zero respectively. The logarithmic first order conditions provide the system of input demand and output supply equations as:

$$(4a)\quad \frac{\partial \ln y}{\partial \ln x_i} = \frac{\partial y}{\partial x_i}\frac{x_i}{y} = \frac{w_i x_i}{Y} = CS = a_0 + \sum_{i=1}^{n} g_{i,j} \ln x_j + \sum_{i=1}^{n} b_{i,t} t + e$$

$$(4b)\quad \frac{\partial \ln x}{\partial \ln y_i} = \frac{\partial x}{\partial y_i}\frac{y_i}{x} = \frac{p_i y_i}{X} = RS = a_0 + \sum_{i=1}^{n} g_{i,j} \ln y_j + \sum_{i=1}^{n} b_{i,t} t + e$$

The own $s^{AES}_{i,i}$ and cross $s^{AES}_{i,j}$ Allen elasticities of substitution (AES) following Binswanger (1974) are calculated as:

$$(5a)\quad s^{AES}_{i,j} = \frac{g_{i,j}}{k_i k_j} + 1$$

$$(5b)\quad s^{AES}_{i,i} = \frac{1}{k_i^2}(\, g_{i,j} + k_i^2 - k_i)$$

$$where = \; g_{i,j} = parameter\;\; estimates;\; k_i, k_j \;\; are\; \cos t\;\; or\;\; revenue\;\; shares$$

NEBRASKA INPUT, OUTPUT, CROP INSURANCE PREMIUMS AND INDEMNITY DATA

Nebraska agriculture input and output quantity indexes for the 1936-94 time period are constructed accounting for quantity and quality changes. The details are presented in Shaik (1998). However for this paper we use data from 1980-1997. The five aggregated output quantity indexes are constructed from twenty-two commodities including ten livestock commodities, seven field crops and five oils and vegetable crops. Similarly five aggregated input quantity indexes are also constructed from twenty-five variables including four types of farm equipment, farm real estate including three categories of land, building and structures, four types of breeding livestock, hired and family farm labor and eleven types of intermediate inputs. An aggregate crop insurance premium quantity index and the crop insurance indemnity quantity index are also constructed from the three major crops.

OUTPUTS

The outputs were regrouped into insured crops (IC), non-insured crops (NIC), vegetable and oil crops (VO), meat animals (MA), poultry and other livestock including milk, honey and wool production (PO). Annual data on crop production [yield per acre times total harvested acres for each crop] and prices received by the farmers were used in the construction of an output Tornqvist-Theil quantity index. Similarly for livestock commodities, the quantity estimates [pounds of meat produced] and average prices per pound were used in the construction of livestock quantity indexes.

INPUTS

Particular emphasis was given in the construction of farm equipment (FE), breeding livestock (BLS), farm real estate (FRE), farm labor (FL) and intermediate inputs (INT) with different methods used in the construction of indexes for each group to account for quantity and quality changes. In the case of farm equipment, a perpetual inventory method was used in the construction of capital stock for four assets to account for the quantity changes, aggregated by rental value reflecting their marginal products in the construction of a quantity index. In the case of breeding livestock, the number of breeding livestock on January 1 was used as a measure of capital stock. The rental value was used as shares, with zero depreciation [as the value of the calf is assumed to be the same as that of the cull cow sent for slaughter at the end of the life period so depreciation is assumed zero] in the construction of breeding livestock quantity index. In the case of farm real estate, three types of land [non-irrigated, irrigated and pastures] and value of building and structures are included. Acres of land and value of the structures were aggregated by state-level cash rents and rental value respectively to obtain a farm real estate quantity index.

An implicit quantity index was calculated as the logarithmic difference between the rate of change in expenditures and the producer price index share weighted by the expenditures. To account for quantity changes in agriculture labor's contribution to agriculture production, data was compiled on hours worked for hired labor and unpaid and family labor along with the wage rate for hired labor. Wage compensation was used as shares in the aggregation of the farm labor quantity index.

CROP INSURANCE PREMIUMS AND INDEMNITIES

The Risk Management Agency (RMA) complies data on the quantity (number of) and cost of crop insurance policy premiums and indemnities paid based on the insurance type and coverage for each crop, aggregate at the county level for the time period 1980-1997. Utilizing these county data, the state data is computed for each of the three major crops grown in Nebraska that constitutes 77 percent of the total crop insurance policies issued in 1999. A crop insurance premium quantity index is constructed by share weighted average of the number of policy premiums across the three crops. Similarly a crop insurance indemnity quantity index is constructed by share weighted average of the number of policy indemnities across the three crops. Finally the aggregate output and input index are adjusted for the crop insurance indemnities and premiums respectively.

EMPIRICAL APPLICATION AND RESULTS

To examine the potential impacts of crop insurance on agriculture sector, the system of input demand equations including crop insurance premium and the system of output supply equations including crop insurance indemnity are estimated using aggregate Nebraska agriculture sector for the time period 1980-1997. The nonlinear estimates of the Translog function imposing homogeneity and symmetry in system of outputs supply and input demand equations independently are presented in Table 1. Further the Allen elasticities of substitution within inputs and within outputs computed from the coefficient estimates and the shares are presented in Table 2.

Under the null hypothesis, with degrees of freedom equal to number of restrictions, Hick neutral technical change is tested using the likelihood ratio test statistic[3]. This is done by estimating 25 (20) unknown parameters in an unrestricted (restricted) model based on system of equations at the point of approximation. In both systems of input demand and output supply functions the likelihood ratio test does not support the Hicks neutral technical change at a 5% level of significance. The calculated value for the restriction is greater than the χ^2 critical value, so we fail to reject the null hypothesis of the existence of non Hick neutral technical change within inputs and within outputs even with aggregate Nebraska agriculture sector data. The necessary and sufficient conditions for monotonicity are not violated given that the cost and revenue shares are greater then zero. Even the curvature conditions based on the Hessian matrix equivalent to the direct or own Allen elasticities of substitution are negative, thus satisfying the curvature condition in both input and output.

The estimates from the system of input demand equations presented in Table 1 indicate the number of policy premiums issued had a negative but insignificant trend change for the time period 1980-1997. Further with increased participation or purchase of crop insurance policy premiums, i.e., increased share of insurance premium in the total cost of production, had a negative but insignificant impact on farm equipment, breeding livestock and intermediate inputs that includes chemicals and fertilizers. This negative sign on the intermediate inputs is indicating that with increased crop insurance less of purchased inputs (since the intermediate input variable consist of purchased inputs) are applied implying the existence of moral hazard. Further a positive sign on the farm real estate including acreage under cultivation is an indication of conversion of marginal lands into cultivation in order to receive indemnity due to crop insurance.

Similarly the coefficient estimates from the system of output supply equations in Table 1 indicated the number of policy indemnities received had a positive and significant technical change. However the coefficient estimates on the insured crops (aggregate index of corn, soybean and wheat) indicated a negatively significant technical change over the time period 1980-1997. As would be the case the increase in the policy indemnities received would shifts cropping pattern leading to a negative impact on other noninsured crops produced. Even though it has not been significantly indicated, the increase in indemnities received had a positive impact on the supply or production of insured crops.

Further the coefficient estimates from the system of equation estimation and the cost (revenue) shares are used in the computation of input (output) own and cross Allen elasticities of substitution (AES) as defined in equations 5a and 5b. The relationships between inputs or between outputs can be easily interpreted based on the elasticities of substitution results presented in Table 2. The input and output elasticities of substitution presented in Table 2 indicate correct signs (negative) on the own AES within inputs and within outputs. In the input side, crop insurance policy premium is complimentary with farm real estate and acts as a substitute to all other inputs. The remaining substitutes within inputs are between farm equipment - farm real estate and breeding livestock and also between farm labor - intermediate inputs and breeding livestock. In the output category the best substitutes are crop insurance policy indemnity and noninsured crops. The other substitutes within outputs are between insured crops - noninsured crops and between poultry – meat animals and insured crops.

Overall the empirical analysis of Nebraska agriculture sector aggregate data from 1980-1997 indicate potential impacts of crop insurance on the farm economic structure. This is based on the estimation of input demand functions including demand for policy premium and the output supply functions including supply of policy indemnities received. A more through investigation of estimating individually insured crop's acreage and premiums purchased would provide clear and robust impacts due to crop insurance on factor use. Further simultaneous estimation of system of input demand and output supply equations along with the profit function would provide the detailed impact analysis of the potential impacts of crop insurance premium on the factor use as well as shifts in the crop production mix.

CONCLUSIONS

This paper examines the potential impacts of crop insurance on Nebraska agriculture sector based on the system of input demand equations including crop insurance premium and the system of output supply equations including crop insurance indemnity for the time period 1980-1997. The likelihood ratio tests fail to support the hypothesis of Hick-neutral technical change in both inputs and outputs for the same time period. So under non Hicks-neutral technical change, the overall impacts of crop insurance on agriculture sector based on the system of input demand and output supply equation even though indicate correct signs on the coefficient estimates, are not statistically significant.

Further research needs to be explored based on longer time series and disaggregate input data to isolate the crop wise impacts of crop insurance on the farm economic structure.

Table 1. Nonlinear Estimates of the Translog Function Imposing Homogeneity and Symmetry in Outputs and Inputs.

Parameter Estimates	System of Equations	
	Input Demand	Output Supply
"1	1.33159	-1.05522
"2	-0.40305**	0.24364
"3	0.88173	3.60989**
"4*	-1.32204	8.48526
"5	0.46419	-9.82898**
"6	0.04758	-0.45458**
$t1	-0.00065	0.00076
$t2	0.00021**	-0.00010
$t3	-0.00035	-0.00180**
$t4*	0.00072	-0.00408
$t5	0.00010	0.00499**
$t6	-0.00002	0.00023**
(11	0.00013	0.00143**
(12	0.00003	0.00024
(13	0.00027**	-0.00026
(14*	-0.00010	-0.00083
(15	-0.00033**	-0.00056
(16	-2.170E-06	-0.00002
(21*	0.00003	0.00024
(22	0.00001	-0.00031
(23	-9.690E-06	0.00011**
(24*	0.00001	-0.00001
(25	-0.00004	-0.00002
(26	-7.100E-07	-2.570E-06
(31*	0.00027**	-0.00026
(32*	-0.00001	0.00011**
(33	0.00188**	0.00006
(34*	-0.00051	0.00012
(35	-0.00165**	-0.00003
(36	9.970E-06	6.032E-06
(41*	-0.00010	-0.00083
(42*	0.00001	-0.00001
(43*	-0.00051	0.00012
(44*	0.00055	0.43335
(45*	0.00005	-0.43267
(46*	-0.00001	0.00004
(51*	-0.00033**	-0.00056
(52*	-0.00004	-0.00002
(53*	-0.00165**	-0.00003
(54*	0.00005	-0.43267
(55	0.00197**	0.00105**
(56	-1.490E-06	-0.00003
(61*	-2.170E-06	-0.00002
(62*	-7.100E-07	-2.570E-06
(63*	0.00001	6.032E-06
(64*	-0.00001	0.00004
(65*	-1.490E-06	-0.00003
(66	9.143E-07**	2.788E-06

Where * the estimates have been retrieved and ** indicates significance at 5% level.

(1=meat animals, (2=poultry, (3=insured crops, (4=noninsured crops, (5=vegetables and oils, and (6=crop insurance indemnity policies in the system of output supply.

(1=farm equipment, (2=breeding livestock, (3=farm real estate, (4=farm labor, (5=intermediate, and (6=crop insurance premium policies in the system of input demand.

Table 2. Allen Elasticities of Substitution

Input Elasticities of Substitution

	FE	**BLS**	**FRE**	**FL**	**INT**	**CIprem**
FE	-25.9189	1.1730	1.3183	0.9942	0.9944	0.9936
BLS		-226.2246	0.9887	1.0006	0.9993	0.9979
FRE			-4.0672	0.9702	0.9719	-3.8573
FL				-10.4388	1.0008	0.9808
INT					-0.4752	0.9956
Ciprem						-1985.1020

Output Elasticities of Substitution

	MA	**PO**	**InsC**	**NInsC**	**VO**	**CIind**
MA	-1.3053	1.0171	0.9799	0.9762	0.8451	0.8705
PO		-30.4434	1.0083	0.9996	0.9945	0.9834
InsC			-1.4762	1.0034	0.9917	0.8058
NinsC				47.6091	-118.6443	1.2832
VO					-22.2616	0.8058
Ciind						-270.1046

Where,

FE = farm equipment, BLS = breeding livestock, FRE = farm real estate, FL = farm labor, INT = intermediate, and Ciprem = crop insurance policy premiums in inputs

MA = meat animals, PO = poultry, InsC = insured crops, NInsC = non insured crops, VO = vegetables and oils, and Ciprem = crop insurance policy indemnity in outputs

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FOOTNOTES

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[1] $f(X) > 0 \; \mathit{for} \; X >> 0;$
$g(Y) > 0 \; \mathit{for} \; Y >> 0;$

[2] $f(l\,X) = l\,f(X) \; \mathit{for} \; l \geq 0, \mathit{and} \; X \geq 0$
$g(q\,X) = q\,g(Y) \quad \mathit{for}\, q \geq 0, \mathit{and} \; X \geq 0$

[3] The likelihood ratio test statistic is –2 [restricted model – (–unrestricted model)] and is chi-squared, with the degrees of freedom equal to the number of restrictions imposed.