New Theoretical Framework for Analysis of the Effect of Crop Insurance on Fertilizer Use: Two-Period Discrete Model

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Selected Poster prepared for presentation at the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Joint Annual Meeting, San Francisco, CA, July 26-28

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Motivation

- Contradicting results from previous research: some find crop insurance and fertilizer use to be complements, while others find they are substitutes.
- A myopic model (one period) suggests they are substitutes while a dynamic model (multiple periods) suggests they are complements.

Objective

- Develop a two-period theoretical model to account for the effect of changes in fertilizer use in initial period on the crop insurance premiums and probability of indemnities in current and future periods.
- Compare derived marginal conditions for a one-period and two-period models.
- Empirically test which conditions are supported by producer data.

Rational for implementing a two-period model

- Producers use a multiple-period planning horizon
- Changes in fertilizer rates affect yields in a current year and average production history (APH) in consecutive periods which in its turn affects the cost of premium and probability of crop insurance indemnities in current and future periods.

Theoretical Framework

- One-period profit maximization problem

$$\max_{x_0,c_0} \pi = \left[p y_0(x_0(c_0)) - p_f(x_0(c_0)) - w_0(c_0,\overline{y_0}) + I_0(y_0(x_0(c_0)),c_0,\overline{y_0})\right]$$

- Two-period profit maximization model:

$$\max_{x_0,c_0}(\pi_0 + \beta\pi_1) = \underbrace{\left[p y_0(x_0(c_0)) - p_f x_0(c_0) - w_0(c_0,\overline{y_0}) + I_0(y_0(x_0(c_0)),c_0,\overline{y_0})\right]}_{\text{Profit in period zero}} +$$

$$\underbrace{\beta\left[p y_1(x_1(c_1)) - p_f x_0(c_0) - w_1(c_1,\overline{y_1}(y_0(x_0(c_0)))) + I_1(y_1(x_1(c_1)),c_1,\overline{y_1}(y_0(x_0(c_0))))\right]}_{\text{Profit in period one}}$$

Notation

$\beta = \frac{1}{1+r}$, discount factor
p, exogenous output price of commodity
p_f, price of fertilizer
i, period (i=0,1)
x_i, fertilizer use in period i
c_i, crop insurance choice in period i
w_i, premium in period i
$\overline{y_i}$, APH in period i
I_i, indemnity received in period i

Major Assumptions

- Fertilizer use is a function of crop insurance but not vice versa.
- Fertilizer is defined as "yield-enhancing input" and includes lime and soil conditioner.
- Producers decide on the choice of crop insurance first (in March) and then determine fertilizer use.
- Yields and prices are assumed to be deterministic.

Marginal Conditions

From a one-period profit maximization model:

$$\underbrace{p\frac{\partial y_0}{\partial x_0}}_{1} + \underbrace{\frac{\partial I_0}{\partial y_0}\frac{\partial y_0}{\partial x_0}}_{2} = \underbrace{p_f}_{3}$$

Signs: (+) (-) (+)

From a two-period profit maximization model:

$$\underbrace{p\frac{\partial y_0}{\partial x_0}}_{1} + \underbrace{\frac{\partial I_0}{\partial y_0}\frac{\partial y_0}{\partial x_0}}_{2} + \underbrace{\left(\frac{1}{1+r}\right)\left(\frac{\partial I_1}{\partial \overline{y_1}}\frac{\partial \overline{y_1}}{\partial y_0}\frac{\partial y_0}{\partial x_0}\right)}_{4} = \underbrace{p_f}_{3} + \underbrace{\left(\frac{1}{1+r}\right)\left(\frac{\partial w_1}{\partial \overline{y_1}}\frac{\partial \overline{y_1}}{\partial y_0}\frac{\partial y_0}{\partial x_0}\right)}_{5}$$

(+) (-) (+) (+) (+)

1: value of marginal product of fertilizer.

2: change in the probability of indemnity payments in current period due to a small change in current year's yield resulting from the use of fertilizer. Indemnity payments are non-negative.

3: marginal cost of fertilizer.

4: discounted change in probability of indemnity payments in the next period due to changes in APH (which is a function of yield and fertilizer use in previous period).

5: discounted change in the cost of premium in the next period as a result of a change in APH. Higher APH increases the cost of premiums.

Interpretations and Implications

- Two extra terms (4 and 5) in marginal conditions from two-period model account for the effect of changes in APH over time on cost of premiums and probability of sizable indemnity payments in future periods.
- Extra terms affect the optimal choice of fertilizer use by shifting marginal cost curve (with term 5) and marginal benefit curve (with term 4) compared to a one-period model.
- With subsidized premiums, (4) is larger than (5), implying that (1) + (2) is smaller in the two-period model than in the single period model.
- Thus, under standard production function assumptions, x_0 is higher with a two-period model than with a single period.

Image was downloaded from National Agriculture News Portal, www.krishijibeconsl.in

Data

- Crop Producer Survey conducted by the Policy Research Group at the University of Nebraska-Lincoln (2014).
- 208 observations on irrigated corn producers in Nebraska.
- NASS and USDA Agricultural Census were used to compute/approximate several other variables (prices, county yields, fertilizer expenses).

Methodology

The simple ordinary least squares (OLS) regression was used to predict the demand for fertilizer with the purpose to compare the sign and magnitude of coefficients on the crop insurance variable in models.

Preliminary Empirical Results: Dependent Variable = Fertilizer Use

	One-period model	Two-period model
$Intercept$	-53.42**	42.82**
$Yield_{2006}$	0.97**	-
APH_{2008}	-	0.93**
$Corn\ price_{2007}$	6.51**	6.19**
$Crop\ Insurance_{2007}$	-3.39*	-
$Crop\ Insurance_{2012}$	-	-3.82*
R^2	0.78	0.71

Significance at the 0.05 and 0.01 levels are denoted by * and ** respectively. These results are initial estimates. Additional analysis will be conducted when more accurate data becomes available.

Conclusions

- One-period model does not account for effects of increases in APH over time on probability of sizable future payments and cost of premiums in future periods.
- Preliminary empirical results did not yield significantly different estimates between one- and two-period models. Further estimation is needed to gain a better confidence in empirical results and their interpretation.
- Discounted increase in cost of premium in two-period model is expected to be lower than the discounted increase in probability of sizable future payments since premiums are heavily subsidized. However, future losses may be discounted less than future gains, as some behavioral research suggests. More in-depth analysis will be done to identify the existing relationships more accurately.

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Special acknowledgement

Thanks to US DA-NIFA Policy Research Grant 2012-70002-19387 for financial support for the survey research.

Special acknowledgement is to Dr. Gary A. White for valuable insights on this issue from the decision-maker's perspective.