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Human Capital, Adjustments in Subjective Probabilities, and The Demand for Pest Controls

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Abstract

This study shows, in the case of North Carolina apple farmers that a reduction in the perceived risk of pest damage results in a reduction in the levels of pesticides. Increases in the farmer's human capital stock reduce perceived risks. Schooling and age have the largest elasticities of adjustment in subjective probabilities.

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Introduction

An indiscriminate use of pesticides and other chemical controls of pest populations causes severe side effects on the environment. These adverse effects may include: the development of pest populations that are resistant to pesticides; the extermination of predator populations; the over simplification of the biological system, and the existance of residues which remain on the harvested crop. Despite these social costs, chemicals continue to be the predominant form of pest control (Smith,1973).

The levels of pesticides used by a farmer are influenced by his desire to insure himself against high levels of pest damage. (Norgaard, 1976, Carlson and Main, 1976). In order to make this decision, the farmer is required, among other things, to predict future pest infestation on his farm. Perhaps, in addition to self-insurance, high levels of pesticide use can be explained by hypothesizing a positive bias in the farmer's subjective estimates of pest populations.

This study examines the pest control decisions of North Carolina apple farmers. This study focusses on the relative importance of variability in pest damage and the errors in subjective perceptions on pest populations as they relate to the farmer's use of pesticides.

Expected utility hypothesis was used to model the pest control decisions of a risk averse farmer facing uncertain pest damage.

The process by which the farmer incorporates new information and adjusts his subjective probability estimates of pest damage is formulated using a Bayesian Framework. This study attempted to establish the allocative effect of the errors in subjective probability assessment and the role of human capital in reducing the errors and hence in improving pest control resource allocation.

Demand for short term and long term pest controls

An apple farmer must choose the optimal levels of chemical and labor controls of pest populations on his orchard. Both chemical and labor controls retard the growth of pest populations-- the former by applying pesticides and the latter by changing the habitat. Labor control of orchard pests include pruning, mowing and other forms of labor investment in the orchard. In the maintenance of a pest free environment, investment in labor controls lasts over several seasons while direct chemical controls on pests have to be reapplied each season or more frequently

Expected utility maximizing levels of pest controls

This study uses the Expected Utility Hypothesis to examine the farmer's decisions on chemical and labor controls of pest populations. Assuming the only source of uncertainty for the farmer is pest damage to fruit, two broad categories of pest populations, insect populations and disease density, were considered. It was assumed that in any time period, insect and disease damage to fruit are independent, normally distributed random variables. Given the normality assumption, maximizing expected utility involves only the first two moments of random income.

The production of a pest free environment is represented by a stochastic production function (Just and Pope,1979). The inputs in the production of pest control are insecticides, fungicides, and labor. Insecticides and fungicides are assumed to reduce the mean and variance of current season pest damage while labor controls are assumed to reduce the mean of pest damage over several time periods but do not reduce the variance of damage.

Using the above information, derived demand functions are obtained for insecticides, fungicides and labor. Details on deriving the demand for pest controls for a risk averse expected utility maximizing farmer are specified in Pingali (1982).

The expected utility maximizing levels of chemical and labor controls are a function of the farmer's attitude towards risk, subjective probabilities of pest damage, factor costs, potential revenue, and capital stock. In choosing between chemical and labor controls, the expected utility maximizing farmer faces a trade-off between an increase in the expected discounted future returns from an additional unit of labor investment in a clean orchard environment, and the reduction in current period risk of pest damage from an additional application of chemical controls.

Subjective Probabilities, Human Capital and Pest Control Decisions

The levels of pest controls ~~determined~~ by a risk averse expected utility maximizing farmer depend on his subjective estimates of the mean and variance of pest damage. With other things held equal, changes in the expected utility maximizing levels of pest controls occur due to a reduction in the error in the subjective probabilities of pest damage.

The farmer's subjective probability assessment of random events are a function of the true uncertainty (due to perfect randomness) and perceived uncertainty (due to imperfect information). As the farmer's stock of information on a particular random event increases, conceivably, perceived uncertainty decreases. Additions to information stock occur through both the processing and analysis of messages received from the extension service and other sources and the observation of random events. The farmer's information processing ability is determined by his schooling, experience, and farmsize. In other words, an individual who revises his subjective estimates of the mean and variance of damage with each addition to his information stock, will eventually tend toward the true mean and variance of damage.

Perez (1981) found that in the case of North Carolina apple farmers, information stock has a negative effect on the demand for pesticides. This implies a positive bias in the subjective estimates of the mean and variance of damage to fruit because of insects and disease. From the above discussion the following hypothesis can be derived in the case of North Carolina apple farmers;

i) Holding other things constant, such as risk aversion, potential output, factor costs, output price, and true distributions of random events, increases in the farmer's human capital stock has a negative effect on the demand for pesticides and a positive effect on the demand for labor.

ii) The absolute difference between the true and the subjective value of a parameter of a distribution of a random event diminishes with a rise in the farmer's human capital stock.

iii) With other things constant, absolute errors in the subjective estimates of the parameters of the damage distribution will have a positive effect on the demand for pesticides and a negative effect on the demand for labor.

Data Collection

Production, biological,and managerial information required for this study were collected as part of a larger, multidisciplinary research effort at North Carolina State University initiated in 1976 and known as the Integrated Pest and Orchard Management (IPOMS) Project. The IPOMS data sets contain five years of data from 47 orchard blocks in Henderson County, North Carolina. This study used data from 28 of the 47 orchard blocks.

The subjective probability distributions required for this study were obtained by direct elicitation from individual farmers. Twenty eight of the farmers in the IPOMS project were asked to give the modal value, the lowest value, and the highest value of the percentage damage they expect due to insects, disease and weather in their orchard block. Based on the three data points, triangular distributions were fit for each farmer for each type of damage.

The true probability distributions were determined from five years of data on the actual percentage damage due to insects, disease, and weather on each orchard block. The actual percentage damage was determined by analysing random samples of fruit from each orchard block in the laboratory. The farmers were not informed about the results of this analysis. True probability distributions were deduced for each orchard block by using the sparse data technique.(Anderson,1973).

Empirical Analysis

The objective of the empirical analysis was to test the above hypothesis and to trace through the effect of an adjustment in subjective probabilities on the demand for pest controls.

Human Capital and the Adjustment in Subjective Probabilities

The error in the subjective probabilities was defined as the absolute difference between the true and the subjective estimates of the expected damage due to insects, disease and weather for each orchard block. An OLS regression was used to test hypothesis ii. The human capital variables were schooling, age, number of times the farmer attended apple extension school, time spent scouting for pest populations, and farmsize. A transcendental power function was used to relate the human capital variables to the absolute errors in subjective probability estimates. Results in Table I support the hypothesis that the absolute errors in subjective probabilities are inversely related to the farmer's human capital stock.

A t-test on the difference in the sample means of the true and the subjective expectations of damage revealed a significant positive bias in the subjective expectations of insect damage to fruit. The null hypothesis of equality between true and subjective means could not be rejected in the case of disease and weather damage to fruit.

Simultaneous estimation of pest populations and pest controls

Hypothesis i and ii were verified using a simultaneous estimation of pest populations and pest controls. The pest populations considered included the levels of insect populations and disease density. The pest controls considered were; pounds of active ingredients of insecticides, fungicides, and the level of pruning. The level of pruning was determined by IPOMS investigators by ranking the growers on a continuous scale from 1 to 5, where an ideally pruned orchard was given a five. This ranking was known as canopy rating.

Two measures of risk were used in this estimation-- variance of pest damage and potential income. Increases in the variance of pest damage cause a risk averse farmer, in his pest control strategy, to increase the proportion of pesticides and decrease the proportion of pruning. Potential income was used to represent, size of prospect risk. (Zeckhauser and Keeler,1970 and Menzes and Hanson, 1970). An increase in the size of the prospect was assumed to have a positive effect on pesticides and a negative effect on the demand for pruning.

Results in Table II verify hypothesis i that increases in the farmer's human capital stock has a negative effect on the demand for pesticides and a positive effect on the demand for pruning.

To test hypothesis iii the human capital variables in the pest controls equations were replaced by the absolute errors in the subjective estimates of mean insect and disease damage to fruit. The human capital variables in the pest populations equations were retained to capture the production effect of human capital.

Results in Table III support the hypothesis that the absolute errors in the subjective probabilities of damage have a positive effect on the demand for pesticides and a negative effect on the demand for pruning.

Conclusions

In the case of North Carolina apple farmers, it is possible to conclude that a reduction in the perceived risk of pest damage results in a reduction in the levels of pesticides used and hence in the social cost of pesticide use. Perceived risks were found to be reduced by an increase in the farmer's human capital stock.

More specifically, this research concluded, in the case of NC apple farmers that;
a) a definite positive bias exists in the subjective estimates of the expected levels of insect damage to fruit; b) the absolute error in the subjective probability estimates was inversely related to the farmers human capital stock, and c) increases in schooling, age, apple school, and scouting reduced the errors in subjective probabilities of pest damage.

North Carolina apple farmers with above average human capital stock used lower quantities of pesticides and higher quantities of pruning relative to the average.

Farmers with one additional year of schooling, above the average, reduced insecticide use by 0.4 pound per acre and fungicide use by 0.2 pound per acre, from the average.

Farmers who were one year above the mean age used 0.14 pound per acre less of insecticides and 0.1 pound per acre less of fungicides, relative to the average use.

Farmers who spent six additional minutes per acre scouting for pest populations, used insecticides half a pound per acre less than the average and fungicdes 0.2 pound per acre less than the average.

Similarly, one additional attendance at apple school reduced insecticides by 1.1 pound and fungicides by half pound per acre.

Table I : Human Capital and the Adjustments in Subjective Probabilities

	Log Abs. Error	Elasticity of Adjustmen[1]
School	0.51*** (0.13)	-0.43
Log(School)	-6.8*** (1.7)	
Age	-0.13*** (0.03)	-0.45
Log(Age)	5.28*** (1.13)	
Log Apple School	-0.23** (0.10)	-0.23
Log Orchard Size	-0.03 (0.09)	-0.03
Log Scout	-0.31** (0.17)	-0.31
d.f.	74	
f-ratio	178.9	
R-Square	0.94	

***Significant at 1%

** Significant at 5%

* Significant at 1%

1. Elasticity of Adjustment = $\frac{\text{\% change in absolute errors}}{\text{\% change in Human Capital Variables}}$

Table II : Simultaneous Estimation of Pest Populations and Pest Controls

Dependent Variables	Insects	Disease	Insecticides	Fungicides	Canopy Rating
Independent Variables					
Insecticides	-o.17 * (0.13)				
Fungicides		0.17 (0.52)			
Canopy Rating	0.003 (0.45)	-0.06 (1.10)	0.31 (0.50)	0.63 ** (0.31)	
Disease Density				-0.007 (0.09)	0.08 (0.18)
Insect Populations			0.13 (0.34)		0.17 (0.18)
Variety of Trees	-0.06 (0.11)	-0.39 * (0.25)	0.26 * (0.16)	0.10 * (0.08)	0.11 ** (.06)
Spacing	0.09 (0.14)	-0.33 (0.70)	0.26 (0.23)	0.30 ** (0.15)	0.08 (0.14)
Humidity		-0.26 (0.55)		0.24 * (0.17)	-0.17 (0.19)
Temperature	0.23 ** (0.12)		0.08 (0.16)		
Rainfall		1.46 (1.33)			
Cost/unit Insecticide			-1.30 *** (0.33)	0.25 ** (0.15)	-0.014 (0.13)
Cost/unit Fungicide			-0.30 (0.57)	-1.21 *** (0.28)	-0.22 (0.24)
Additional Labor				-0.07 * (0.05)	0.06 * (0.04)
Potential Income			0.21 ** (0.11)	0.17 *** (0.06)	-0.002 (0.05)
Tree Age * Stock					0.06 (0.06)
Variance of Insect Damage			0.15 * (0.11)		
Variance of Disease Damge				0.03 (0.05)	-0.03 (0.04)
Fruit Output per Tree	0.09 (0.08)	-0.11 (0.16)			
Schooling	-0.14 (0.29)	0.31 (0.55)	-0.62 * (0.45)	-0.38 ** (0.23)	-0.22 (0.18)
NCSU Publications	-0.36 (0.47)	-1.1 (0.87)	0.14 (0.63)	-0.22 (0.32)	0.34 * (0.25)
Degrees of Freedom	63	62	60	59	58

1. Two stage least square estimates

2. All variables are transformed in terms of Natural Logarithms (except Publications)

3. Figures in parenthesis are standard errors of estimates.

4. *, **, ***, represent significance at 10%, 5%, and 1% respectively

5. Time period of data is from 1976 to 1980.

Table III : Absolute Errors in Subjective Probabilities and the Demand for Pest Controls

Dependent Variables	Insects	Disease	Insecticides	Fungicides	Canopy Rating
Independent Variables					
Insecticides	-0.17 * (0.13)				
Fungicides		0.17 (0.52)			
Canopy Rating	0.003 (0.45)	-0.06 (1.10)	1.33 ** (0.67)	0 .98 *** (0.38)	
Disease Density				-0.12 (0.12)	0.13 * (0.08)
Insect Populations			0.28 (0.36)		0.14 (0.17)
Variety of Trees	-0.06 (0.11)	-0.39 * (0.25)	0.17 (0.16)	0.04 (0.08)	0.08 (0.06)
Spacing	0.09 (0.14)	-0.33 (0.70)	-0.07 (0.23)	0.13 (0.15)	0.10 (0.14)
Humidity		-0.26 (0.55)		0.19 (0.19)	-0.12 (0.18)
Temperature	0.23 ** (0.12)		0.09 (0.17)		
Rainfall		1.46 (1.33)			
Cost/unit Insecticide			-1.39 *** (0.35)	0.17 (0.17)	0.06 (0.14)
cost/unit Fungicide			-0.45 (0.61)	-0.92 *** (0.32)	-0.35 * (0.24)
Additional Labor				-0.09 ** (0.05)	0.06 * (0.04)
Potential Income			0.15 * (0.10)	0.14 *** (0.06)	-0.04 (0.05)
Tree Age * Stock					0.10 ** (0.06)
Variance of Insect damge			0.18 * (0.12)		
Variance of Disease damge				0.05 (0.05)	-0.02 (0.04)
Fruit	0.09 (0.08)	-0.11 (0.16)			
Schooling	-0.14 (0.29)	0.31 (0.55)			
Ncsu Publications	-0.36 (0.47)	-1.1 (0.87)			
Abs.Error Insect Mean			0.39 *** (0.15)		
Abs.Error Disease Mean				0.14 * (0.09)	-0.14 *** (0.06)
Degrees of Freedom	63	62	61	60	59

1. Two stage least square estimates.
2. All variables are transformed in terms of Natural Logarithms (except Publications).
3. Figures in parenthesis are standard errors of estimates.
4. *, **, ***, are significance levels of 10%, 5%,and 1% respectively.
5. Time period of data is from 1976 to 1980.

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