



The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

Seal
Conservation
C

1982
UNIVERSITY OF CALIFORNIA
DAVIS
OCT 28 1982
Agricultural Economics Library

THE ADOPTION OF REDUCED TILLAGE: THE ROLE OF
HUMAN CAPITAL AND OTHER VARIABLES

by

Michael R. Rahm

and

Wallace E. Huffman

*rev of paper presented at AAEA meetings, Aug 1-4, 1982
Lagan, Utah*

MICHAEL R. RAHM
Assistant Professor of Economics

Macalester College
1600 Grand Avenue
St. Paul, MN 55105

B.A. Loras College, 1975
M.S. Iowa State University, 1978
Ph.D. Iowa State University, 1980

1979- Assistant Professor,
Macalester College

1975-79 Research Assistant,
Iowa State University

WALLACE E. HUFFMAN
Professor of Economics

Iowa State University
Ames, IA 50011

B.S. Iowa State University, 1966
M.A. University of Chicago, 1971
Ph.D. University of Chicago, 1972

1982- Professor of Economics,
Iowa State University

1978-82 Associate Professor of
Economics,
Iowa State University

1974-78 Assistant Professor of
Economics,
Iowa State University

1972-74 Assistant Professor of
Economics,
Oklahoma State University

THE ADOPTION OF REDUCED TILLAGE: THE ROLE OF
HUMAN CAPITAL AND OTHER VARIABLES

Soil maintenance is emerging as one of the most controversial agricultural issues of the 1980's. Economists disagree over the interpretation of soil loss data, and most of the published research is either problematic or descriptive. Some economists, for example, Heady and Short (1981) and Soth (1981), quantify and warn of the impact of expanding U.S. exports on soil loss. This view implies that the utilization of soil conservation practices including reduced tillage is critical to the maintenance of long-run agricultural productivity and that the absence of mass adoption of such techniques is evidence of either managerial inefficiency or market failure. Proponents of this view suggest export limitations, export taxes, soil loss taxes, subsidies for reduced tillage, or legal restrictions on tillage practices as public policies to save the soil.

Other economists interpret the evidence differently. Based upon a comparison of the National Soil Erosion surveys of 1934 and 1977, Mayer (1982) concludes that maintenance of the nation's soil resources has improved substantially over this period. Schultz (1982) emphasizes that: (1) all soil losses cannot be eliminated and (2) advances in plant genetics, while increasing yields and putting additional stress on cropland, have reduced soil losses in the aggregate by decreasing the total area cultivated and forcing significant production relocations.

Although Schultz (1982) stresses the self-interest and large stake that farm operators have in their soil resources, none of the studies develop and test rigorously a model of the microeconomic decision to adopt a soil conservation practice such as reduced tillage.¹ Why do some farm operators

utilize soil conservation practices such as reduced tillage while others do not? What are the key variables determining the economic feasibility of such practices and how do investments in education, health, and experience affect these decisions?

Studies by Fane (1975), Khaldi (1975), Huffman (1977), and Petzel (1978) support the general hypothesis that levels of education and extension contact enhance allocative skills. However, few studies of the adoption and diffusion of new technologies investigate the effect of human capital investments on differential rates of adoption. Griliches (1957), Mansfield (1961), Globerman (1975), and Romeo (1975) explain differential rates of adoption by using variables such as profitability of the investment, size of the initial investment, and the proportion of firms in the industry that have adopted the technology. In addition, few of the studies have empirically tested models with micro data sets. Detailed micro data add a new dimension to the analysis because they enable the use of unique and narrowly-defined measures of pre-school environment, formal and continuing education, information (both public and private), experience, and health.

The objectives of this analysis are (1) to formulate a general model for assessing the impact of specific human capital investments on decisions to adopt or not adopt a single production technology, and (2) to empirically specify and estimate the model in order to analyze and evaluate the adoption of reduced tillage by Iowa farm operators. The data set is the 1976 Iowa Family Farm Survey.

The empirical analysis indicates that investments in formal schooling, managerial experience, and continuing education reduce the inefficiency or error in selecting a tillage practice. In addition, the analysis of the adoption of reduced tillage suggests that the scale of operation, soil characteristics, and cropping system are the major determinants of the economic feasibility of such investments.

We organize the paper into three sections. Section 1 formulates the model; section 2 presents the empirical specification and estimation of the model; and section 3 contains a summary of the work and the conclusions of our analysis.

The Model

We formulate a model consisting of three equations to assess the impact of human capital investments on production efficiency, as measured by the "correctness" of the decision to use or not use a single production technology. The first equation predicts the probability of adopting the technology given a set of firm-specific characteristics. The second equation calculates a measure of adoption error utilizing the predicted probability of equation one. The third equation explains cross-sectional variations in the measure of error using narrowly defined investments in education, experience, information, and health. Each component of the model is described below.

Equation 1: The Adoption Model

The decision rule we assume in this analysis is that a firm manager will adopt a specific production technology if the investment is economically feasible. Because of limited information about each firm, we can neither observe nor calculate directly from sample data a measure of economic feasibility. We observe only the use or non-use of a specific technology and a number of, but not all, firm specific characteristics that determine the economic feasibility of the investment.² Assuming a manager must choose between the current versus a new technology, the adoption model is:

$$U_1 = f(R_1, A_1) = a_0 + \sum_{j=1}^S a_j X_j + e_1$$

$$U_2 = f(R_2, A_2) = b_0 + \sum_{j=1}^S b_j X_j + e_2$$

$$D = 1 \quad \text{if } U_1 \geq U_2$$

$$D = 0 \quad \text{if } U_1 < U_2$$

where:

- U_k - expected utility derived from the utilization of production technology k
($k = 1$ for a new or different technology, $k = 2$ for the current technology)
- D - observed binary variable equal to one if the firm has adopted the new technology, zero otherwise
- R_k - vector of moments describing the distribution of net returns for technology k
- A_k - vector of attributes other than net returns associated with technology k
- X_j - observed characteristics expected to affect the utility associated with each production technology
($j = 1, 2, \dots, s$)
- e_k - additive random error

The firm manager adopts a new technology if the perceived utility (U_1) exceeds the utility associated with the current technology (U_2). Firm managers may derive utility from all moments that describe the distribution of net returns as well as from attributes of the technology other than net returns.³ We hypothesize that, for the typical firm manager, the utility derived from each technology is a linear function of a number of observed firm-specific characteristics. These characteristics may reflect the profitability and risk of the investment and may indicate the firm manager's preferences toward risk and other attributes of the technology.

The qualitative response or discrete choice model is characterized by a univariate dichotomous dependent variable and may be interpreted as a conditional probability model. The dependent variable is limited in that it is endogenous to some underlying unobserved economic relationship, and it is not continuous over the entire real line. The probability of the i th

firm adopting the technology is:

$$\begin{aligned}
 P_i &= P(D_i = 1) = P(U_{1i} \geq U_{2i}) = P(U_{1i} - U_{2i} \geq 0) \\
 &= P\left(c_0 + \sum_{j=1}^S c_j X_{ij} + u_i \geq 0\right) \\
 &= P\left(u_i \geq -c_0 - \sum_{j=1}^S c_j X_{ij}\right) \\
 &= F\left(c_0 + \sum_{j=1}^S c_j X_{ij}\right)
 \end{aligned}$$

where:

$$c_j = a_j - b_j$$

$$u_i = e_{1i} - e_{2i}$$

and:

F - cumulative probability function for
symmetric probability density function P.

The three probability models commonly used by economists are the linear, PROBIT, and LOGIT models. Each model corresponds to a different assumption about the distribution of the error term (u_i). In particular, the linear, PROBIT, and LOGIT models result from the assumption of uniform, normal, and sech^2 distributions respectively. Amemiya (1981) describes the models and estimation techniques and presents a survey of applications.

Equation 2: A Measure of Adoption Error

We employ the following measure of adoption error:

$$AE_i = |D_i - \hat{P}_i| = |u_i|$$

where:

AE_i - adoption error for firm i

\hat{P}_i - predicted probability of adoption given the vector of firm specific characteristics ($X_{i1} X_{i2} \dots X_{si}$).

The symmetric error function draws heavily upon the information obtained from the sample about appropriate adoption behavior. For example, firm specific characteristics such as soil type and cropping system may affect the mean, variance, and higher moments of the distribution of net returns associated with a reduced tillage technology. We hypothesize that such characteristics will affect the expected utility of the typical farm operator and hence the decision to adopt the technology in a predictable and "correct" way. Thus, \hat{P}_i is a predictor of economic feasibility for the new technology.

Correct management decisions include adoption ($D_i = 1$) if the predicted probability is relatively large ($\geq .50$) and failure to adopt ($D_i = 0$) if the predicted probability is relatively small ($< .50$). In both cases, the measure of adoption error is relatively small ($< .50$). Incorrect decisions include adoption when the predicted probability is relatively small and failure to adopt when the predicted probability is relatively large. For both cases, AE_i is relatively large.⁴ Figure 1 illustrates the four possible outcomes.

		Predictor of Economic Feasibility (\hat{P})	
		$\hat{P} \geq .50$	$\hat{P} < .5$
Observed Adoption Decision	$D_i = 1$	correct decision $AE_i < .50$	incorrect decision $AE_i \geq .50$
	$D_i = 0$	incorrect decision $AE_i \geq .50$	correct decision $AE_i < .50$

Figure 1. Classification of Adoption Decisions

A relatively large value for the measure of adoption error indicates either managerial inefficiency or atypical preferences. For a new and economically feasible technology, an inefficient farm manager may be

unaware of its existence, unable to evaluate accurately the profitability and risk of the technology, or unable to understand and implement successfully the technology. Firm managers who are aware of the technology and who are capable of evaluating accurately and implementing successfully may still adopt when the sample data suggest infeasibility or fail to adopt when the sample indicates feasibility because of preferences that differ significantly from other managers in the sample.

Equation 3: The Human Capital Model

The measure of adoption error reflects managerial inefficiency and thus is a measure of allocative inability. Following human capital theory, we assume allocative skills are learned rather than innate. In particular, we hypothesize that investments in general education, job training or experience, information, and mental and physical health serve to develop and enhance allocative skills and thus reduce adoption error. Firm managers with greater allocative skill will be more knowledgeable of the "state of the art", better able to determine economic feasibility of different technologies, and better informed to take quick and decisive action than managers with lesser skills.

Empirical Analysis

We empirically specify the model to explain the corn tillage decisions of farm operators.⁵ The data set is a 1976 survey of nearly 1000 Iowa farm operators. Erbach, et al., (1980) note that Iowa farm operators used reduced tillage on less than one-half million acres in Iowa in 1968, but by 1976 they utilized reduced tillage on 7.2 million acres or one-third of the state's row crop acres. In 1977, Iowa farm operators used reduced tillage systems on 9.1 of 24.9 million crop acres. Full-width non-moldboard plow technologies (chisel plows, primary tillage discs, or field cultivators) tilled 8.7 of the

9.1 million acres.

Evaluation of Reduced Tillage Systems

Reduced tillage may affect the mean, variance, and higher moments of the yield distribution as well as the optimal factor proportions used in crop production. Because reduced tillage retains crop residues on the soil surface, this technology has the potential to decrease soil losses from wind and water erosion and to increase soil moisture by improving water infiltration and decreasing evaporation.⁶ While decreases in soil and moisture losses may improve yields, the moist residue cover and shallow tillage may cause other production problems.⁷ The net impact on yield is directly related to the soil characteristics and cropping system of the farm firm. Reduced tillage may increase yields on hilly, lighter, and better drained soils as a result of improved moisture retention. The variance of yields, however, may also increase especially in continuous corn cropping systems. Griffith, et al., (1977) indicate that reduced tillage is likely to increase the mean but not the variance of yields on any soil type when corn follows any crop other than corn.

Changes in tillage technologies over the past 15 years have not been factor-neutral. Reduced tillage systems require less labor and machinery hours, especially at critical planting time, and most systems require greater quantities of herbicides, insecticides, and fungicides for weed and pest control. The reduction in the cost of producing a given level of output resulting from a change in optimal factor proportions depends upon the cost of labor relative to the cost of other inputs. Because quantities, qualities and the opportunity cost of family labor vary significantly across farms, the economic feasibility (or appropriateness) of a labor-saving reduced tillage practice will depend upon the relative cost of labor. This factor

proportion or allocative impact, however, appears to be less important than the technical impacts on the mean and variance of yields.

Soil maintenance is the primary reason given by Iowa farm operators for the adoption of reduced tillage. Results from a 1976 survey of Iowa farm managers (USDA, 1976) who had adopted reduced tillage indicated that 52 percent of the farm operators had adopted the technology to reduce soil loss while 24 percent of the farm operators had adopted the technology to decrease field time requirements at critical periods.

The Data Set

The data set is the 1976 Iowa Family Farm Survey. The Iowa State University Experiment Station sponsored and the Statistical Laboratory of Iowa State University designed and directed the 1977 survey of 933 Iowa farm families. Interviewers of the Statistical Laboratory collected extensive information about the characteristics of farm businesses and households for 1976.

The population included all farms with gross sales of agricultural products greater than or equal to \$2,500. The Statistical Laboratory grouped Iowa counties into 12 strata corresponding to the 12 state extension areas and applied a sampling rate of nearly 1 in 110 across all strata to obtain a desired sample size of approximately 1,000.⁸

Empirical Specification of the Adoption Model

We assume that a farm operator will adopt reduced tillage if the investment is economically feasible. We observe neither a measure of feasibility nor the variables required to calculate such a measure directly from the sample. However, the sample data include the tillage practice and a number of, but not all, firm specific characteristics such as the scale of operation,

cropping system, and soil type that determine the economic feasibility of a reduced tillage practice. In particular, we hypothesize that the probability of adoption is:

$$\begin{aligned} P_i &= P(D_i = 1) = P(U_1 \geq U_2) \\ &= P(u_1 \geq -c_0 - c_1 X_{i1} - c_2 X_{i2} - \dots - c_{26} X_{i26}) \\ &= F(c_0 + c_1 X_{i1} + c_2 X_{i2} + \dots + c_{26} X_{i26}) \end{aligned}$$

where all terms are defined as before and:

X_{i1} = ACRES - acres of corn planted in 1976

X_{i2} = ACRESQ - (ACRES)²

X_{i3} = SBRATIO - ratio of soybean to corn acres in 1976

X_{i4} = SBRSQ - (SBRATIO)²

X_{i5} = RAINFALL - normal annual rainfall (20-year average annual precipitation for the U.S. Weather Bureau Station closest to the farm)

X_{i6} = SEASON - growing season (average number of growing-degree-days between the spring and fall dates of a 50 percent frost probability)

X_{i7} = TENURE - ratio of cropland acres rented in to total cropland acres farmed

$X_{i8} - X_{i26}$ = SD_{ij} - soil association dummy variables ($j = 1 \dots 19$)

We present complete empirical definitions and descriptive statistics in Appendix A. Of the 870 operators responding, 506 (58 percent) reported using a reduced tillage practice in their corn enterprise (i.e., they did not use a moldboard plow to prepare all of their corn acres for planting). An increase in mean net farm income resulting from the adoption of reduced tillage is the product of the increase in per acre net returns from corn production and the number of corn acres. For a given per acre net return, the expected return to adoption is proportional to the size of the corn enterprise, and farm firms with large corn enterprises will have greater absolute incentive to adopt and utilize more efficient tillage technologies

than farm firms with smaller corn enterprises. Thus, we hypothesize that the probability of adoption is positively related to the number of corn acres per farm (ACRES).

In the previous evaluation of reduced tillage systems, we noted that per acre profitability depended largely upon the soil characteristics and cropping system of the farm firm. We include a number of variables that identify per acre profitability in the empirical specification. The cropping system variable is the ratio of soybean to corn acres (SBRATIO). We assume that the cropping system is an exogenous factor affecting the tillage decision and that it is unaffected by the choice of tillage practices.⁹ Because soybean root systems break up the soil naturally, farm operators may prepare harvested soybean acres for corn in the following crop year with commonly used tillage equipment such as the chisel plow, heavy tillage disk, or field cultivator. Assuming an identical cropping system from year to year, a large ratio of soybean to corn acres would indicate the feasibility of such tillage. In addition, a small ratio may signal the existence of a large risk factor due to an increase in the variance of yields in a continuous corn operation. Thus, we hypothesize that the probability of adoption is greater for managers of farms with larger ratios of soybean to corn acres (SBRATIO) than for managers of farms with smaller ratios.

We utilize soil association dummy variables to categorize soil characteristics. The state of Iowa is classified into 21 geographical soil associations. The soil association classification is based upon parent material (loess, glacial till, and alluvium) and topology. These characteristics determine the soil's natural fertility, drainage characteristics, and erosion susceptibility.¹⁰ Based on the above analysis, we hypothesize that the probability of adoption is greater for managers who farm hillier, lighter, and better-drained soil, than for managers who farm flatter, heavier and poorly drained soils.

Because reduced tillage systems decrease evaporation and increase infiltration, we hypothesize that the profitability and the probability of adoption will be greater in those areas with less annual rainfall. In addition, because reduced systems conserve time at critical planting and harvesting periods, we hypothesize that the probability of adoption will be greater in those areas characterized by shorter growing seasons. Finally, we include the ratio of acres of cropland rented into total cropland acres to test the hypothesis that the lack of an adequate planning horizon may discourage farm operators from following sound long-run conservation practices.

Functional Forms and Estimation Procedures

We estimate linear and PROBIT probability models in this analysis.¹¹ As noted earlier, each functional form depends on the assumption about the distribution of the error term (u_i). In this analysis, the error term reflects unobserved firm-specific characteristics such as the operator's degree of risk aversion and planning horizon, unique soil or cropping system characteristics of the firm, and the human capital characteristics of the operator that influence the economic feasibility and thus probability of adopting a reduced tillage practice. Although the uniform distribution of u_i may seem like an unlikely distribution for the error term in this application, the cost of estimating the linear probability model is low relative to the cost of other models. Thus, we utilize the linear probability models for much of the preliminary analysis.

Estimation of the Adoption Model

We present parameter estimates of this model in Table 1. Results indicate that the coefficients of the number of corn acres, the ratio of soybean to corn acres, and a number of soil association dummy variables have expected signs and are statistically different from zero at the

1 percent level of significance. The estimated coefficients and t-ratios of the ACRES and SBRATIO variables are relatively large. The exceptional performance of the SBRATIO variable may indeed indicate that a particular type of reduced tillage practice such as disking or chisel-plowing soybean acres is feasible in a corn-soybean crop rotation.

The intercept of the model includes the Clarion-Nicolett-Webster soil classification. This soil association represents flat, heavy, and poorly drained soils. Thus, the positive and significant coefficients on other soil associations such as S19--the Shelby-Sharpsburg-Macksburg soil classification--is consistent with our hypothesis that the probability of adoption is greater on more hilly, lighter, and better-drained soils.

We employ the predicted probabilities obtained from the PROBIT model to derive the measure of adoption error ($AE_i = |D_i - \hat{P}_i| = |u_i|$). Table 2 contains the frequency distribution and descriptive statistics for the predicted probability (P_i) of adopting reduced tillage. The frequency distribution is relatively bell-shaped and appears to be centered at about 0.65.

Empirical Specification and Estimation of the Human Capital Model

The empirical specification of the human capital model is:

$$AE_i = a_0 + \sum_{j=1}^9 a_j X_{ij} + e_i$$

where:

AE_i = measure of adoption error ($|D_i - \hat{P}_i| = |u_i|$)

X_{11} = EDUCATION - years of formal schooling completed by the farm operator

X_{12} = EDFATHER - years of formal schooling completed by the father of the farm operator

X_{13} = EDDUM1 - binary variable equal to one if the operator received vocational agricultural training in high school, zero otherwise

X_{14} = EDDUM2 - binary variable equal to one if the farm operator completed an agricultural major such as agronomy, animal science, or agricultural business in college, zero otherwise

X_{15} = CONTINUED - binary variable equal to one if farm operator and/or spouse attended any short courses, conferences, and meetings on the Iowa State campus, zero otherwise

X_{16} = EXTENSION - binary variable equal to one if the farm operator attended sometimes or frequently meetings, field days, or demonstrations sponsored by the extension service

X_{17} = MGSERVICE - binary variable equal to one if the operator sometimes or frequently utilized media sources published and marketed by private information and management services, zero otherwise

X_{18} = EXPERIENCE - years since operator first began independently managing a farm firm

X_{19} = HEALTH - binary variable equal to one if the operator had a health condition that limited the amount of type of work that could be done, zero otherwise

e_i - random error

We utilize the years of formal schooling completed by the father of the farm operator as a proxy for the pre-school environment of the operator. Because of missing data on father's schooling, we estimate a second equation excluding this variable. Table 3 contains estimates of the human capital model of efficient adoption. There is considerable "noise" in the model, but this is expected. The estimated coefficients of a number of variables differ statistically from zero. In particular, the results show that farm operators who completed more years of formal schooling, who have more years of managerial experience, or who continue their education through short courses, meetings, and conferences have smaller adoption errors on average.

Most of the other variables have expected signs but are not statistically different from zero. There are, however, two notable exceptions. The

years of schooling completed by the operator's father has a positive sign which is statistically different from zero at the 5 percent level of significance. This suggests that operators whose fathers completed more years of formal schooling tended to make larger adoption errors. The second exception is the positive coefficient on the binary variable for the completion of a college major in an agricultural business. The positive sign suggests overmanagement but the coefficient is not statistically different from zero at the 5 percent level of significance.

Summary and Conclusions

We have formulated a model consisting of three equations to assess the impact of human capital investments on the "correctness" of a decision to adopt or not adopt a single production technology. The first equation predicts the probability of adoption given the firm-specific characteristics that influence the economic feasibility of the investment. The second equation calculates a measure of managerial inefficiency or adoption error. This measure is simply the absolute error or absolute value of the difference between the observed binary variable (for use or non-use) and the predicted probability of adoption. The final equation, termed the human capital adoption model, explains cross-sectional variations in this measure of allocative efficiency by accumulated investments in human capital.

The empirical results indicated that the scale of operation, cropping system, and soil type significantly affect the economic feasibility of the investment in a reduced tillage practice (and, thus, the predicted probability of adoption). Furthermore, farm operators who have invested in more formal schooling, managerial experience, and continuing education tended to make "correct" tillage decisions.

The conclusions of this analysis help to identify the specific investment activities that contribute to the development of allocative skills. This identification has important micro and macroeconomic implications. Once economists understand clearly and evaluate accurately the relationships between human capital investment activities and the development of particular skills and abilities, the sooner they will be able to guide policy makers in their allocation of public education, research, and extension funds as well as individuals in their allocation of limited investment resources.

Table 1. Estimates of linear and PROBIT probability models, adoption of reduced tillage practices by Iowa farm operators, 1976.

Independent Variable	Probability Model			
	Linear		PROBIT	
	Estimate	t-ratio	Estimate	t-ratio
Intercept	.5130	-	.0469	.05
ACRES	.0018	8.61	.0055	8.14
ACRESQ	.87E-6	-4.81	-.26E-5	-4.64
SBRATIO	.3785	6.97	1.0785	6.43
SBRATIO SQ	-.0834	-5.06	-.2460	-4.17
RAINFALL	-.0141	-1.34	-.0410	-1.34
SEASON	.73E-5	.03	.35E-4	.05
TENURE	-.0057	-.14	.0053	.05
SD1	.2991	1.91	.8818	1.89
SD2	.1920	1.65	.5780	1.66
SD3	.1844	1.73	.5305	1.69
SD4	-.0862	-.65	-.2255	-.57
SD6	-.0555	-.30	-.2094	-.33
SD7	.2071	1.86	.6351	1.90
SD8	.1566	1.84	.4727	1.89
SD9	.0564	.43	.2150	.54
SD10	.1116	1.72	.3173	1.67
SD12	.0352	.48	.1112	.52
SD13	.2720	2.36	.7846	2.28
SD14	.0979	.52	.2841	.52
SD15	.1399	1.62	.4113	1.61
SD16	.1911	2.05	.5374	1.99
SD17	-.1329	-.56	-.3139	-.47
SD18	.2220	2.44	.6524	2.36
SD19	.2546	3.06	.7394	2.95
SD20	.1867	2.47	.5633	2.48
SD21	.3240	1.66	.9657	1.62

n = 869

R² = .18

F = 6.90

n = 869

Log likelihood: -507.4

Chi square: 166.8

Table 2. Number of farms by predicted probability, adoption of reduced tillage practice by Iowa farm operators, 1976.

Predicted Probability (\hat{P}_i)		Number of Farms	
0 - .10		4	
.11 - .20		33	
.21 - .30		73	
.31 - .40		78	
.41 - .50		111	
.51 - .60		144	
.61 - .70		168	
.71 - .80		141	
.81 - .90		90	
.91 - 1.00		36	
Mean	.581	Minimum	.03
Standard Deviation	.205	Maximum	.99

Table 3. Estimates of the human capital model, adoption of reduced tillage practices by Iowa farm operators, 1976.

Dependent Variable: $AE_i = D_i - \hat{P}_i = u_i $				
Independent Variables	Equation 1		Equation 2	
	Estimate	t-ratio	Estimate	t-ratio
INTERCEPT	.4601	-	.5245	-
EDUCATION	-.0098	-2.25	-.0079	-2.05
EDFATHER	.0096	2.79	-	-
EDDUM1	-.0100	-.54	-.0016	-.09
EDDUM2	.0138	.40	.0288	.86
EDDUM3	.1554	1.89	.1571	1.93
CONTINUED	-.0504	-2.63	-.0451	-2.54
EXTENSION	-.0125	-.75	-.0201	-1.31
MGSERVICE	-.0309	-1.33	-.0340	-1.57
EXPERIENCE	-.0008	-1.12	-.0008	-1.33
HEALTH	.0239	1.18	.0206	1.11
n	676		797	
R ²	.04		.03	
F	2.89		2.83	

ENDNOTES

¹Schultz writes: "We proclaim to the world that U.S. farmers are second to none in their agricultural achievements. When it comes to soil erosion, the prevailing implicit assumption is that farmers have no perception of the value of their soil resources and that they are indifferent to soil loss."

²We do not define an explicit measure of economic feasibility. Under conditions of certainty, traditional investment criteria such as the net present value, internal rate of return, or the benefit-cost ratio measure economic feasibility of an investment. Uncertainty, however, complicates considerably the concept of economic feasibility. The simplest and most widely used approach for analyzing decision-making under conditions of uncertainty is the expected utility hypothesis with a restrictive assumption of either a quadratic utility function or normally distributed outcome. Critics of this approach suggest game theory or, more recently, stochastic dominance as alternative methods of analysis.

³Utility is an unobserved or latent variable. As a result, we do not address any of the familiar problems associated with the traditional analysis of decision-making under conditions of uncertainty. We assume that all moments of the distribution of net returns and attributes of the technology other than net returns may affect utility. Higher moments and other attributes may be important factors affecting the decision to adopt a new production technology. For example, aesthetic preferences for neatly tilled and clean-looking fields may inhibit some farm operators from adopting reduced tillage.

⁴The first error is an example of "overmanagement"--adopting an infeasible technology because it is new on the market and offers a solution to a perceived problem. The second error is an example of "undermanagement"--failing to adopt a feasible technology because one is unaware of its existence or has incorrectly evaluated its economic feasibility.

⁵Agriculture is a logical industry to choose for investigating the relationship between specific human capital investments and production efficiency. Modern agriculture is characterized by a dynamic and complex production environment, sophisticated production technologies, dynamic product and factor markets (resulting from, among other things, rapid technological change), and a relatively simple management structure. Given these industry characteristics, there exist potentially large economic incentives to invest in activities that improve allocative and technical abilities.

⁶Soil losses from wind and water erosion are greatest during the early part of the growing season when: (1) a large percentage of rain falls; (2) winds are stronger; and (3) crops have not developed a protective soil cover.

⁷The moist residue cover also provides an excellent germination environment for weeds, insects, and other pests. Pest control requires the correct doses and proper application of effective herbicides and pesticides. The moist residue cover may impede herbicide and pesticide effectiveness. In addition, the moist residue cover may decrease soil temperatures 3° F. to 6° F.

in the early growing season. The cooler and wetter soils may reduce the availability of important nutrients such as copper, zinc, boron, and manganese, and it may also lengthen the time required for seed germination (thus shortening the effective growing season). Also, because reduced tillage systems do not incorporate fertilizers to the depths of conventional tillage systems, fertilizer utilization and soil acidity may be affected by the type of tillage system. Tillage depth and residue cover also affect root mass, root size, and rooting patterns. Roots concentrate near the soil surface with reduced tillage technologies. Finally, reduced tillage systems increase both soil aggregation and soil density. Highly aggregated and compacted soils restrict root growth and water movement. For further discussion of production problems see Amemiya (1977) and Griffith (1977). Thus, the profitable use of reduced tillage may require better management skills--especially the technical ability to implement the technology successfully.

⁸ The questionnaire was divided into two parts. The first part pertained to the farm household and the second pertained to the farm business. The farm operator was defined as the primary decision-maker or manager of the firm and was identified by a separate screening process. If more than one decision-maker was identified initially, the number of days worked on the farm was the criterion used to determine the farm operator. Persons residing in the household and operating a separate farm business were identified and information relative to these operations was collected also. The operator responded to the farm business section of the questionnaire and the spouse of this individual, if one was present, responded to the household section.

The sample for this empirical analysis is limited to farm firms in the Iowa Family Farm Survey that produce corn. This limitation reduced the number of firms in the project sample from 933 to 877. Missing information further reduced the size of the project sample used in the analyses of adoption of reduced tillage practices.

Survey results indicate that the typical Iowa farm is multi-product. Of the total number of farms surveyed, 97 percent produced some type of crop. In particular, 94 percent of all farms surveyed produced corn and 68 percent produced soybeans. Of the total farms surveyed, 87 percent produced some type of livestock and poultry. In particular, 62 percent of all farms surveyed produced cattle and swine. Nearly 85 percent of the farms surveyed produced a combination of crops and livestock. For further descriptions of farms in the sample, see Hoiberg and Huffman (1978).

⁹ This appears to be a reasonable assumption given the importance of other factors such as the expected crop and livestock prices and tradition in determining the farm enterprise mix.

¹⁰ For further discussion and description, see "Highway Guide of Iowa Soil Association", Iowa State Cooperative Extension Service, Pm 389 (1977).

¹¹ Amemiya (1981) notes that for a univariate dichotomous model, it makes little difference whether the PROBIT or LOGIT probability model is utilized unless data are heavily concentrated in the tails of the distribution (the LOGIT probability model has slightly fatter tails).

REFERENCES

- Amemiya, Minoru. "Conservation Tillage in the Western Corn Belt," in Conservation Tillage: Problems and Potentials. Ankeny, IA: Soil Conservation Society of America, 1977.
- Amemiya, Takeshi. "Qualitative Response Models: A Survey." Journal of Economic Literature 29 (1981):1438-1536.
- Cooperative Extension Service, "Highway Guide of Iowa Soil Association" Pm 389. Ames, IA: Iowa State University, 1977.
- Erbach, Donald R.; Lovely, Walter G.; and Ayres, George E. "Conservation and Conventional Systems for Continuous Corn." Iowa Agricultural Experiment Station, Miscellaneous Bulletin 14, 1980.
- Fane, George. "Education and the Managerial Efficiency of Farmers." Review of Economics and Statistics 57 (November 1975):452-61.
- Globerman, Steven. "Technological Diffusion in the Canadian Tool and Die Industry." Review of Economics and Statistics 57 (November 1975):428-34.
- Griffith, Donald R., et al. "Conservation Tillage in the Eastern Corn Belt," in Conservation Tillage: Problems and Potentials. Ankeny, IA: Soil Conservation Society of America, 1977.
- Griliches, Zvi. "Hybrid Seed, an Exploration in the Economics of Technical Change." Econometrica 25 (October 1957):501-522.
- Heady, Earl O. and Short, Cameron. "Interrelationships among Export Markets, Resource Conservation, and Agricultural Productivity." American Journal of Agricultural Economics 63(December 1981):840-47.
- Hoiberg, Eric O. and Huffman, Wallace E. "Profile of Iowa Farms and Farm Families: 1978." Cooperative Extension Service, Iowa State University, April 1978.
- Huffman, Wallace E. "Allocative Efficiency: The Role of Human Capital." Quarterly Journal of Economics 91 (1977):59-79.
- Khalidi, Nabil. "Education and Allocative Efficiency in U.S. Agriculture." American Journal of Agricultural Economics 57 (November 1975):650-57.
- Mansfield, E. "Technical Change and the Rate of Imitation." Econometrica 29 (October 1961):741-66.
- Mayer, Leo V. "Farm Exports and Soil Conservation." Proceedings of the American Academy of Political Science, 1982.

Petzel, Todd E. "The Role of Education in the Dynamics of Supply." American Journal of Agricultural Economics 60 (August 1978): 436-44.

Pindyck, Robert S. and Rubinfeld, Daniel L. Econometric Models and Economic Forecasts. Second edition. New York: McGraw-Hill, 1981.

Romeo, A. A. "Interindustry and Interfirm Differences in the Rate of Diffusion of an Innovation." Review of Economics and Statistics 57 (August 1975):311-19.

Schultz, Theodore W. "The Dynamics of Soil Erosion in the United States: A Critical View." Unpublished paper. University of Chicago. Agricultural Economics Paper No. 82:8.

Soth, Lauren. "The Grain Export Boom: Should It be Tamed?" Foreign Affairs 59 (Spring 1981):895-912.

U.S. Department of Agriculture, Iowa Crop and Livestock Reporting Service. Iowa Farm, Fuel, and Equipment. Des Moines: Government Printing Office, 1976.

APPENDIX A

EMPIRICAL DEFINITIONS AND DESCRIPTIVE STATISTICS OF VARIABLES

Farm managers did not identify the particular type of reduced tillage practice used in their corn enterprise. Operators specified only the number of corn acres on which they used a moldboard plow (full tillage) to prepare the seedbed in 1976. We assumed farm operators adopted reduced tillage ($D = 1$) if they reported not using a moldboard plow on all of their corn acres. Table A.1 presents a frequency distribution of the number of farms by the percentage of corn acres on which a reduced tillage practice was used (or the percentage of corn acres on which a moldboard plow was not used). The rate of utilization varies from 0 to 100 percent, but the frequency distribution is bi-modal. A large number of firms (364 or 42 percent) use no reduced tillage practice on their corn acres and a large number of firms (209 or 24 percent) use a reduced tillage practice on all of their corn acres. The remaining firms (297 or 34 percent) use a reduced tillage practice on some, but not all, of their corn acres.

Operators specified the number of crop acres owned and operated, the number rented-in, and the number allocated to each crop enterprise of the farm in 1976. Table A.2 lists the descriptive statistics for the number of corn acres (ACRES), the ratio of soybean acres to corn acres (SBRATIO), and the ratio of crop acres rented-in to total crop acres (TENURE) as well as the descriptive statistics for the ecological data (RAINFALL, SEASON).

Table A. 2 also presents descriptive statistics for quantitative variables used in the human capital model. Table A-3 presents frequency distributions for the qualitative variables used in the human capital model.

Table A.1. Number of farms by utilization of reduced tillage practice,
Iowa farm operators, 1976.

Percentage of corn acres on which reduced tillage was utilized	Number of farms
0	364
1-10	6
11-20	28
21-30	21
31-40	33
41-50	55
51-60	32
61-70	36
71-80	42
81-90	29
91-99	15
100	<u>209</u>
TOTAL	870

Table A.2. Descriptive statistics of quantitative survey variables,
Iowa farm operators, 1976

Variable name	Mean	Standard Deviation	Minimum	Maximum
<u>Adoption model</u>				
ACRES	145.1	136.2	4	1,877
SBRATIO	.51	.52	0	5.4
TENURE	.58	.41	0	1
RAINFALL (inches)	31.1	2.40	22.0	34.0
SEASON	2,951.5	149.0	2,750	3,250
<u>Human Capital Model</u>				
EDUCATION (yrs.)	11.3	2.2	6	18
EDFATHER (yrs.)	9.1	2.5	0	16
EXPERIENCE (yrs.)	22.9	13.0	1	65

Table A.3. Frequency distribution for binary independent variables,
Iowa farm operators, 1976

Variable name	Values equal to	
	<u>1</u>	<u>0</u>
EDDUM1	198	717
EDDUM2	47	861
CONTINUED	198	727
EXTENSION	285	642
MGSERVICE	112	816
HEALTH	166	761