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DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS
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COMPUTER USE IN AGRICULTURE: EVIDENCE FROM TULARE COUNTY, CALIFORNIA

With the advent of the low-cost microcomputer, the potential now exists for the widespread application of computer technology to problems facing farmers ranging from bookkeeping to planning capital expenditures to pest control. Three groups that have taken an active interest in the use of computers in agriculture are Cooperative Extension, classroom-oriented vocational agricultural education programs, and agricultural software developers.

Despite the interest in agricultural computer use, little work has been done to examine the individual farm-firm's choice of whether or not to adopt a computer. Understanding (and quantifying) the factors that influence the farm computer adoption choice will assist interested parties in developing successful computer-oriented programs by (1) identifying their potential clientele and (2) better understanding the needs of that clientele. Consequently, the goals of this study are twofold: first, to formulate and estimate empirical models of the decision to use a computer and various types of computer applications using a theoretical choice model and discrete econometrics and, second, to identify the most likely clientele groups for both Extension and agricultural education programs.

The remainder of this paper consists of a discussion of the nature of computer technology use in agriculture where a comparison is made with other agricultural innovations that have been the subject of previous studies. A theoretical choice model based on a stochastic utility function is presented. Data from a survey of Tulare County, California, farmers are used to estimate probability models of farm level computer adoption choice and computer application use. The estimated models are used to identify the clientele groups aggregated level, agricultural computer applications can be categorized as belonging to one of two groups--those applications that aid in production decisions and those that reduce the cost of business transactions. Applications in the production decision category include such things as crop and livestock management, irrigation scheduling, pest control, herd improvement, feed formulation, cost accounting, and "what if" types of analyses.[1] Applications that lower the cost of business transactions include general ledger, payroll, and inventory control. This categorization of applications is not perfect (e.g., information from general ledger records can be used as an aid in production decisions). However, it does provide a categorization of applications that is usually accurate.

Previous work by Mann, Feder, and Byerlee and de Polanco suggests that, when a new technology consists of a bundle of several components, there is likely to be a common sequence in the adoption of those components. Understanding the sequence in which different types of applications will be used by a farmer is an important area in the study of computer technology adoption in agriculture.

Schultz distinguishes between two groups of human skills (human capital)--worker ability and allocative ability. The categorization of computer applications into those that are used to reduce the cost of business transactions and those used for production decision-making roughly corresponds to Schultz's categorization of human skills. Applications that reduce the cost of business transactions can be viewed as augmenting worker ability, while production-oriented applications can be viewed as allocative ability augmenting. Computer technology may be unique in its ability to augment both types of human capital.

Since ε_{i0} and ε_{i1} are random, the value of the utility function is also random (Domencich and McFadden). Because U is stochastic, only a probability can be assigned to the accuracy of equation (2).

The farmer's expected profit in both the case of adoption and nonadoption can be viewed as having two components. The first component is "operating profit" π_o, the profit the farmer would realize (given the optimal production level) if all business transactions were costless. The second component of profit is the cost of business transactions (C) incurred while producing and marketing farm output. Expected profit is given by

(3) $$\pi_j = \pi_{oj} - C_j.$$

In turn, operating profit can be written as

(4) $$\pi_{oj} = p'f(x, \gamma_j) - w'x,$$

where f is a well-behaved vector valued production function, p is a vector of output prices, x is a vector of inputs used for production, γ_j is the vector of parameters for the production function given adoption (nonadoption) of computer technology, and w is a vector of input prices. The cost of business transactions associated with production is given by

(5) $$C_j = m_j'f(x, \gamma_j) + t_j'x + h_j,$$

where m_j is a vector of farm level marketing costs given adoption (nonadoption), t_j is a vector of business transaction costs associated with the use of a unit of a given input in the case of adoption (nonadoption), and h_j is the cost of fixed overhead given adoption (nonadoption). By substituting (4) and (5) into (3) and rearranging terms, expected profit can be rewritten as

In equation (9) the terms Δm_i, Δt_i, and Δh_i are associated with the change in the costs of business transactions associated with the adoption of a computer. The term $\Delta \gamma_i$ indicates the ability of computer-provided information to alter the farm's production function. Finally, the terms $\Delta \sigma_{oi}^2$ and $\Delta \sigma_{si}^2$ indicate the change in both objective and subjective variance of profit caused by the adoption of computer technology.

Unfortunately, Δm_i, Δt_i, Δh_i, $\Delta \gamma_i$, $\Delta \sigma_{oi}^2$, and $\Delta \sigma_{si}^2$ are not directly observable. However, there are observable variables which do affect the values of the unobservable variables. The observable variables indicate the types of agricultural products produced on the farm; the number of distinct enterprises that make up the farming operation;[4] the size of the farming operation as measured by gross farm revenues;[5] the education level of the farmer; the farmer's age; whether or not the individual owns a farm-related business; and the type of business owned. For econometric analysis, it is assumed that the left-hand side of equation (9) is a quadratic function of farm size and a linear function of farm products produced, number of farm enterprises, farmer education level, farmer age, and ownership of a farm-related business. Thus, equation (9) becomes

$$(10) \qquad \beta' Z_i = \beta_0 + \beta_1 S_i^2 + \beta_2 S_i + \beta_3' F_i + \beta_4 N_i + \beta_5 E_i + \beta_6 A_i + \beta_7' B_i > \varepsilon_{i0}^* - \varepsilon_{i1}^*,$$

where S is the size of the farming operation, F is a vector which indicates what crops and livestock are produced on the farm, N is the number of distinct enterprises encompassed by the farm, E indicates the grower's education level, A is the farmer's age, B is a vector that indicates the type (if any) of farm-related businesses owned by the farm operator, ε_0^* and ε_1^* are the new computer-provided information (Schultz, Welsh, and Huffman) increasing $\Delta\gamma$, are likely to have an easier time of learning to use a computer system which influences Δh, and are more likely to have been previously exposed to computer technology (and, consequently, have a lower subjective variance associated with computer use); (5) younger farmers have a higher probability of computer adoption because they are likely to perceive a lower subjective variance to computer use due to being exposed to computer technology for a greater proportion of their lives; and (6) the effect of business ownership on the probability of adoption is likely to be highly dependent on the type of business owned, with businesses that receive greater benefits from computer use (such as sales-oriented businesses which undertake a large number of business transactions) more likely to adopt and businesses that receive small benefits from computer adoption less likely to adopt due to the increased opportunity cost of the operator's time.

In the application use models, it is expected that (1) increasing farm size increases the likelihood of specialized application use, but the effect of farm size on the use of more general applications (e.g., spreadsheet and database management) is unknown; (2) livestock sectors are more likely to use management decision applications (due to the complexity of breeding choices and other production decisions), while labor-intensive products (e.g., grapes, tree fruits, and vegetables) are more likely to use applications which reduce the cost of business transactions; (3) multienterprise operations are more likely to use applications which aid in risk assessment due to the increased number of production planning choices that must be made, but are less likely to use product-specific applications; (4) farmers with higher education levels are more likely to use production decision applications, but the effect of education level on collected from 449 individuals, a 45 percent response rate. The response rate was not as high as was desired but is similar to the rate for a recent mail survey of farm operators conducted by Garcia, Sonka, and Mazzacco. Mean age, education level, and farm ownership patterns were found to be very similar to those reported in the 1985 Tulare County Agricultural Census. This suggests that the sample is representative of Tulare County farmers.

Table 1 gives count information from the data on computer ownership and the use of various computer applications. Of the responding producers, 25.6 percent use a computer in their farming operations. There is wide disparity in the use of various types of applications. The most likely applications to be used are general ledger (72.0 percent of computer owners) and payroll (67.3 percent), while the least commonly used applications are crop/livestock management programs (9.4 percent) and production decision aids (16.8 percent).

Estimating the Probability of Computer Ownership

The explanatory variables used to estimate the probability of computer adoption correspond to those in equation (10). The variables include farm size (measured by gross farm revenues in thousands of dollars) squared, farm size, farm products produced, the number of distinct enterprises that make up the farm, the education level of the operator, the age level of the operator, and the type of farm-related businesses owned. The farm product categories are field crops, vegetable crops, tree fruits and nuts, grapes, nursery, dairy, beef, and other livestock (primarily hogs, poultry, and horses). The education variables indicate the highest level of education attained by the farmer and includes junior college degree, less than four years of college, Bachelor's degree, and graduate or professional degree. The age categories include

31 to 35 years, 36 to 40 years, 41 to 50 years, 51 to 60 years, 61 to 70 years, and over 70 years of age. The farm-related business categories are packing shed; other sales (which includes sellers of seeds, fertilizer, or other material inputs and those who have a farm product marketing business); pest control advisors; farm management consultants; and other services (which includes harvesting and other custom work, nut hullers and dehydrators, and equipment services). Farmers with a high school education or below, farmers who are 30 years of age or younger, and farmers with no farm-related business are used as benchmarks for the analysis. The model estimation results can be found in table 2.

The analysis indicates that, as farm size increases, the likelihood of computer adoption also increases but at a decreasing rate. This finding was expected and is in line with the theoretical model presented earlier.

The production of different farm products does not appear to have as strong an effect on adoption choice as one might expect. However, the analysis indicates that nursery producers are the most likely group of producers to adopt computer technology followed by tree fruits and nuts, field crops, dairy, grapes, vegetable crops, beef, and other livestock. The comparatively high rate of adoption by nursery producers is not surprising since many may well directly market their output. What is surprising is that vegetable producers are less likely to adopt than are field crop growers; the opposite had been expected to be the case due to the labor intensity of vegetable crops. The negative sign on the number of enterprises coefficient was also somewhat surprising. However, there are two reasons why this is the case. First, the variable is essentially adjusting for the individual product coefficients when the farm produces more than one product. Second, multiple enterprise operations cannot specialize clerical tasks to the same extent that a single enterprise operation of the same size can.

The results indicate the likelihood of computer adoption first increases with operator age (up to the 36-40 year age group) and then begins to decrease with age. Further, farmers over the age of 70 are particularly unlikely to have adopted a computer.

A strong relationship exists between education level and computer ownership. Those farmers with either a Bachelor's or graduate degree are much more likely to adopt a computer than those with less than a Bachelor's degree.

Owners of a sales-related business (packing shed or a business in the other sales category) are more likely to adopt a computer than farmers without a farm-related business. With the exception of pest control advisors (who are more likely to adopt), those farmers who own a service-oriented business (farm management consultant or a business in the other service category) are less likely to adopt than operators who own no farm-related business. These results are in line with the theoretical analysis and suggest that pest control advisors and sales-related businesses receive greater benefits from computer use than do service-related businesses.

Several formal hypothesis tests (likelihood ratio tests) were carried out. The hypothesis tests were whether or not (1) farm size (2) farm products produced; (3) operator age, (4) operator education, and (5) ownership of a farm-related business have an effect on computer adoption patterns. Since the education and age groups are essentially both single continuous variables that have been broken into discrete categories, tests on these two groups have (in some sense) more meaning than the individual t-statistics. The tests indicate that the effect of farm size and farmer education level is significant at the is much higher than for allocative ability augmenting applications (cost accounting, crop and livestock management, and production decision aids). This suggests (at least at this time) that computer technology is used primarily to automate practices that were formerly done by hand.

The basic set of explanatory variables used to explain computer adoption are also used to explain application use, with several exceptions. First, the categories, beef and other livestock, are combined. Second, the 61 to 70 years and over-70 years age groups have been combined to form an over-60 years age group, and (in the case of decision aid and crop/livestock management) farmers 35 years of age and younger form the age benchmark. The third exception is that, for all applications (except crop/livestock management and production decision aids), the number of education groups have been condensed to two. The first education group is called the posthigh school group and includes the some college and junior college groups of the last section. The second education group combines Bachelor's degree recipients with graduate and professional degree recipients and is called the college group. For crop and livestock management and production decision aids, only a single education group (college) is used. The fourth exception is the inclusion of a variable to indicate the years of computer ownership. Finally, categorical variables are omitted from individual models if no one in the category uses that application.

The results for applications in the business transaction cost lowering category are contained in table 3; table 4 contains the results for applications in the management decision category and the results for spreadsheet and database management use. In general, the statistical results for the use of individual applications are not as good as for computer ownership choice.

Table 3--continued.

Variable	General ledger	Payroll	Inventory
Posthigh school	0.317 (0.221)	-3.759 (-1.441)	0.678 (0.378)
College	0.990 (0.755)	-3.266 (-1.333)	-0.008 (-0.005)
Packing shed	0.967 (1.042)	2.847** (2.169)	1.641 (1.621)
Other sales	0.075 (0.077)	-0.188 (-0.157)	2.296** (2.311)
PCA	-1.839 (-1.504)	-2.696 (-1.531)	b b
Farm management	-1.011 (-0.733)	-2.223 (-1.203)	0.604 (0.410)
Other service	0.548 (0.409)	0.233 (0.159)	-0.754 (-0.426)
Years own	-0.169 (-1.393)	-0.209 (-1.208)	0.126 (0.986)
Constant	-3.148 (-1.322)	-0.249 (-0.076)	-1.767 (-0.670)
McFadden R^2	0.3253	0.4708	0.3791
Log L	-42.830	-35.790	-34.574
Log L, restricted	-63.484	-67.636	-55.688
Chi-squared	41.307	63.691	42.227
Restrictions	23	23	21
Correct prediction	89/107	92/107	96/107

*Significant at the 1 percent level.

**Significant at the 5 percent level.

***Significant at the 10 percent level.

[a]Figures in parentheses indicate asymptotic t-statistics.

[b]None of the observed individuals in this category use inventory control applications.

Table 4--continued.

Variable	Cost accounting	Decision aids	Crop/ livestock management	Spread sheet	Data base management
Posthigh school	-1.889	e	e	0.902	2.555
	(-1.276)	e	e	(0.740)	(1.337)
College	-1.878	1.090	1.145	0.740	2.736
	(-1.355)	(1.014)	(0.815)	(0.685)	(1.439)
Packing shed	0.410	0.348	b	0.413	-0.383
	(0.539)	(0.335)	b	(0.507)	(-0.512)
Other sales	1.423	b	b	0.179	-0.468
	(1.535)	b	b	(0.204)	(-0.526)
PCA	0.252	4.831*	b	0.014	-0.525
	(0.194)	(2.913)	b	(0.011)	(-0.488)
Farm management	0.001	b	1.958	2.862**	2.321**
	(0.001)	b	(1.261)	(2.040)	(1.966)
Other service	1.532	b	b	-2.070***	1.982
	(1.340)	b	b	(-1.677)	(1.623)
Years own	0.037	0.051	0.006	0.136	0.232**
	(0.344)	(0.449)	(0.037)	(1.215)	(2.240)
Constant	-6.879**	-5.429**	-4.612***	-3.518***	-6.684**
	(-2.340)	(-2.149)	(-1.772)	(-1.776)	(-2.33)
McFadden R^2	0.3406	0.3716	0.4037	0.2843	0.2106
Log L	-48.012	-30.461	-19.809	-51.867	-52.176
Log L, restricted	-72.811	-48.477	-33.22	-72.471	-66.107
Chi-squared	49.597	42.227	26.821	41.207	27.862
Restrictions	23	16	14	23	23
Correct prediction	88/107	97/107	100/107	82/107	83/107

*Significant at the 1 percent level.

**Significant at the 5 percent level.

***Significant at the 10 percent level.

[a] Figures in parentheses are asymptotic t-values.

[b] None of the observed individuals in this category use this type of application.

[c] The 30-35 year age group is combined with the under 30-year age group as the age benchmark.

[d] The 51-60 year age group is combined with the over-60 age group.

[e] Posthigh school is combined with high school and below as the education benchmark.

has been the development of spreadsheet templates ranging from whole farm budgeting systems to templates designed to aid a farmer in deciding whether or not to participate in a federal commodity program. Much of Extension's efforts in this area was brought about as a response to the farm financial stress crisis; thus, the assisting of small- and medium-sized, full-time farm operators has been one of its underlying goals.[6] The second set of activities involves the development of computer-based production decision aids by university researchers and county Extension agents. These production decision aids range from feed ration and degree day calculators to crop-specific biological simulation models. Much of this effort is still in the development stage and has not been made available to farm operators. However, current users of production decision aids are likely to be the initial users of Extension-developed computer programs.

Farm management education programs at the adult education, community college, and university levels have used the computer to improve the teaching of general accounting and cost accounting. Software used in the classroom includes the use of both spreadsheet templates and specialized accounting software. Therefore, the clientele for these programs (particularly the adult education programs) are the users of spreadsheet and accounting programs.

Since these programs are oriented to the use of certain types of application software, the logit models of the previous sections can be used to identify the characteristics of the likely participants in computer-oriented Extension and farm management education programs.

The probability that the ith farmer uses a given application is contingent upon whether or not he adopts a computer and whether or not he uses the application given computer adoption. Formally, the probability of application use is given by

Table 5. Estimated Probability of Spreadsheet, Production Decision Aid, and Cost Accounting Uses for a 41- to 50-Year-Old Farmer with No Farm-Related Business

Gross revenue dollars	Trees	Grapes	Field crops	Trees and grapes	Dairy and field crops	Trees and field crops
			SPREADSHEET USE			
			High school education			
100,000	0.08	0.05	0.06	0.13	0.04	0.07
500,000	0.09	0.06	0.06	0.15	0.04	0.10
1,000,000	0.09	0.07	0.06	0.16	0.04	0.12
4,000,000	0.02	0.03	0.01	0.04	0.01	0.07
			College education			
100,000	0.29	0.20	0.24	0.39	0.18	0.26
500,000	0.32	0.24	0.25	0.44	0.20	0.33
1,000,000	0.32	0.27	0.22	0.45	0.19	0.39
4,000,000	0.06	0.07	0.03	0.09	0.03	0.18
			PRODUCTION DECISION AID USE			
			High school education			
100,000	0.003	0.000	0.001	0.002	0.022	0.004
500,000	0.005	0.000	0.002	0.003	0.036	0.007
1,000,000	0.008	0.000	0.004	0.005	0.062	0.013
4,000,000	0.091	0.001	0.041	0.042	0.452	0.155
			College education			
100,000	0.024	0.000	0.010	0.012	0.140	0.037
500,000	0.036	0.000	0.016	0.018	0.200	0.057
1,000,000	0.057	0.000	0.025	0.028	0.290	0.092
4,000,000	0.271	0.004	0.137	0.132	0.772	0.422
			COST ACCOUNTING USE			
			High school education			
100,000	0.039	0.048	0.001	0.106	0.003	0.061
500,000	0.070	0.076	0.002	0.164	0.006	0.095
1,000,000	0.13	0.124	0.004	0.255	0.015	0.152
4,000,000	0.687	0.604	0.113	0.793	0.325	0.659
			College education			
100,000	0.025	0.066	0.000	0.099	0.002	0.080
500,000	0.047	0.116	0.001	0.165	0.003	0.138
1,000,000	0.092	0.207	0.002	0.275	0.007	0.24
4,000,000	0.603	0.788	0.025	0.829	0.118	0.813

Summary

This study examines computer use in agriculture in an effort to understand computer adoption and application use patterns. The paper develops a choice theoretic model of computer adoption and application use. The theoretical model is empirically quantified using discrete econometrics and a survey of Tulare County, California, farm operators. In addition, the likely clientele groups for Cooperative Extension and adult education computer-oriented programs are identified.

The statistical results indicate that farm size greatly influences both computer adoption and application use. Increasing farm size is associated with higher probabilities of computer adoption and the use of most types of application software. However, smaller farmers are more likely to use spreadsheet and database management programs.

Production of different agricultural products does not appear to greatly influence the farm-firm's computer adoption choice. However, producers of different farm products differ in application use. Livestock producers are more likely to use production decision-making (allocative ability augmenting) applications, while crop producers are more likely to use business transaction cost-reducing (worker ability augmenting) applications.

Farmer age and education level do influence computer adoption choice although these farm operator characteristics appear to only weakly affect application use given computer adoption.

The ownership of a farm-related business does appear to influence both computer adoption choice and application use. Owners of sales-oriented businesses (packing sheds or other sales) and pest control advisors are more likely to adopt a computer than farmers without a farm-related business.

Footnotes

[1]"What if" analysis is a term for financial scenario analyses which allow a farmer to assess the potential risks associated with different decisions.

[2]The possible choices for a measure of intensity of computer use are the number of different types of applications used by the farmer, the number of hours per period time a computer is used, or the percentage of decisions influenced by computer-provided information. However, farmers who are considered heavy users of computer technology using one measure may be considered light users of the technology using another measure.

[3]Recall by individuals on intensity of use is likely to be influenced by unaccountable factors separate from actual use.

[4]Distinct enterprises include row crops, perennial crops, nursery, dairy, and beef and other livestock. Thus, if a farmer grows both cotton and walnuts, his farming operation consists of two distinct enterprises; but if he grows walnuts and grapes, his farming operation consists of a single enterprise.

[5]Farm revenue is not a perfect measure of farm size. However, it is the only available measure which allows for a comparison between the size of dissimilar (e.g., grape vis-à-vis a dairy) farming operations.

[6]Small to medium full-time farmers are those generally thought to be owners of an operation with annual gross revenues of between $50,000 and $1 million.

[7]Based on table 5, the probability of production decision aid use is higher for all livestock operations compared to crop operations.

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