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THE USE OF COMPUTER TECHNOLOGY IN CALIFORNIA AGRICULTURE

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Abstract: Empirical analysis shows that the likelihood of computer adoption in California increases with farm size and complexity, and with farmer's education level. Computers are mostly used for record keeping and accounting purposes, but there are significant levels in the use of managerial applications, especially among dairy and swine operations.

Keywords: Adoption, diffusion, computer technology, human capital.

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The Use of Computer Technology in California Agriculture

Agricultural economists have studied the diffusion of biological, chemical, and mechanical technological innovations (see the survey by Feder, Just, and Zilberman). This paper will analyze a new type of technology that is being diffused: the managerial and accounting technologies embodied by the use of computers. Unlike technologies studied in the past (e.g., irrigation, fertilizer, and no till cultivation practices), computer technology is not process specific. The tractor is the only technology that has had as diverse a use in agriculture as the computer. The tractor augments human muscle, however, whereas the computer augments the human brain. We will explore the unique issues associated with the diffusion of computer technology and will present empirical results explaining the factors affecting computer ownership, computer technology use, and the use of computers for managerial and accounting purposes.

Features of Computer Technology and their Implications

1. Computer technology can be used by all sectors of agribusiness

Many of the technologies in which diffusion has been studied are crop specific (see Griliches's classic study of the diffusion of hybrid corn). Others are process specific such as fertilizer (Hiebert), or irrigation technology (Caswell and Zilberman). Computer technology can be useful in all sectors of agribusiness. It is interesting to compare the diffusion patterns between these sectors. The multiplicity of users results in large cross sectional variation. This variation allows for the use of shorter time series than for a crop specific innovation.

2. <u>Computer technology is a bundle of many components</u>

Computer technology consists of many kinds of equipment and applications. The work of Mann and Feder 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 processes will be automated is another important area of study in the adoption of computer technology.

The bundled nature of computer technology suggests that there are numerous ways to categorize this technology. One way to categorize it is through software and hardware, subdividing each group between ownership and hired services. Another way is according to application (accounting, payroll, herd improvement, etc.). Different classifications suggest several measures of adoption. At the farm level there exists two groups of measures: whether or not a farmer owns, rents, or uses the services of a certain item (or group of items) of hardware or software, and whether or not a farmer uses computer technology for a particular application. The measures at the aggregate level include the percentage of farmers that own, rent, or hire the services of a certain type of computer product, and the percentage of farmers that use a computer for specific applications.

The measures of computer adoption at the farm level are discrete variables. This is unlike the measures of adoption of other technologies which include both discrete and continuous variables (e.g., measures of adoption of a high yielding variety include a variable indicating whether the farmer uses the variety at all, and a second continuous variable that measures the extent of adoption).

3. <u>Computer technologies augment all types of human capital</u>

Schultz distinguishes between two groups of human skills, both of which can be augmented by computer use: worker ability (e.g., computer use for data management, accounting, and payroll), and allocative ability (e.g., computer use for financial management, pest control, and feed formulation). Although many technologies augment worker ability, the computer is unique in its augmentation of allocative ability. It is important to study the difference in the adoption process for worker versus allocative ability augmenting technologies.

<u>A Model of Computer Technology Adoption</u>

In this section we develop a farm level model of computer technology adoption. It is assumed that a farmer will adopt a given computer technology if the perceived benefits of using the technology outweigh its perceived costs.

The benefits of using a given computer technology derive in part from an increase in profits resulting from either a cost savings in the use of variable inputs per unit of output, or an increase in revenues per production unit (i.e., per acre of land or per animal). The other benefits of using a particular computer technology are external, resulting from knowledge gained in using one technology that can be transferred to another, and from the development of data bases that can be used with more than one technology. These external benefits reduce the fixed costs of later adoption of other computer technologies.

The costs associated with the use of computer technologies consist of fixed costs (the acquisition of computer hardware and software), and opportunity costs (learning to use a computer system and the new information it provides).

Our model can be stated more formally as:

$$CB = \Delta\Pi + E - I$$

where CB is the net benefit from the use of a given computer technology, $\Delta\Pi$ is the change in profits attributable to the use of the technology, E is the external benefits from using the computer technology in concert with other computer technologies, and I is the fixed cost of using the technology. It is assumed that the grower will adopt the computer technology if the perceived value of CB is greater than zero.

The characteristics of the individual farmer and his or her operation are expected to alter the perceived value of CB, and thus the likelihood of adopting a particular computer technology. The most important characteristics in determining the value of CB are farm size, farm sector, the number of sectors encompassed by the farm, and the farmer's education level.

The changes in profitability ($\Delta\Pi$) are accrued on a per unit of production basis, while most of the costs [(I), primarily the opportunity cost of learning to use the technology] are independent of the scale of production. Thus, the value of CB, and the likelihood of adoption, increases as farm size decreases.

Both the number of transactions per unit of output and the complexity of the production process vary greatly across sectors. The latter difference is primarily due to the existence of extremely complex biological relationships that a farmer must oversee in some parts of the production processes for certain sectors. Sectors that have more complex production processes are expected to gain higher levels of increased profits through the use of allocative ability augmenting computer technologies such as irrigation scheduling, or herd improvement relative to other sectors.

The more commodities produced by a particular farm, the more complexity it faces in its production activities. This is due to both the larger number of cropping patterns that can be undertaken, and the increased number of production sub-processes that are being conducted. Thus, a multi-commodity operation will receive a relatively greater benefit from both the worker and allocative ability augmenting nature of computer technologies than a similar single commodity operation.

The farmer's education level effects both the profits to be gained from the use of a computer technology ($\Delta\Pi$), and the cost involved in using the technology (I). The human capital literature (see Schultz, Welsh, and Huffman) suggests that as a grower's education level increases he or she is better able to take advantage of the new information that the technology provides. Therefore, the gain in profits associated with the use of a computer technology (and thus the likelihood of adoption) will increase with the grower's education level. We would also expect that the cost of learning to use the computer technology decreases as the farmer's education level rises, further increasing the benefits of the technology.

Using the above analysis, we form the following testable hypotheses: (1) the likelihood of computer technology adoption increases as farm size increases; (2) the incidence of computer technology adoption increases as the number of transactions per unit of output increases; (3) the likelihood of computer technology adoption increases as the biological production process becomes more complex; (4) multi-sector farming operations have a higher likelihood of adoption than single sector operations; and, (5) the likelihood of computer technology adoption increases as the farmer's education level increases. These five hypotheses are tested in the following section.

An Empirical Analysis of Computer Technology Adoption in California

There are many different measures of the adoption of computer service technology at both the farm and aggregate level. While it would be desirable to perform an empirical analysis of all these various measures, available data preclude us from accomplishing this task. In this section we present an empirical exploration of the following four measures of computer technology adoption in California agriculture. Three aggregate measures of adoption: (1) the percentage of farmers that use any computer technology; (2) the percentage of farmers that use accounting (worker ability augmenting) computer technologies; (3) the percentage of farmers that use managerial (allocative ability augmenting) computer technologies. Finally, we examine the farm level choice of whether or not to purchase computer equipment.

The empirical analysis in this paper was conducted using two different data sets. The three measures of the aggregate level of computer technology adoption are based on interviews of twenty University of California Cooperative Extension Farm Advisors done in June and July of 1985. Each farm advisor gave an estimate of the percentage of farm operations that made use of various computer technologies for the county and sector s/he advised. The analysis of the farm level choice of whether or not to own a computer is based on a survey of farmers that attended an agricultural computer fair held in January of 1984.

1. Empirical Analysis of the Three Measures of Aggregate Adoption

From the farm advisor survey we were able to obtain variables relating to sector and farm size (for the overall computer use measure only). In addition to farm size and sectors, a county's location within the state could have an effect on the level of computer technology usage within the county, since there could be regional differences in the rate of diffusion of computer service technologies. For this reason, regional variables were also used in this analysis. To test these hypotheses, the following model was formulated for overall computer technology adoption:

$$\%USE = \alpha + \beta_1 LRG + \beta_2 MED + \gamma_1 DAIRY + \gamma_2 SWINE + \gamma_3 RCROP + \gamma_4 T\&V + \delta_1 SV + \delta_2 IMP + \delta_3 COAST + e$$

where %USE is the farm advisor's estimate of the percentage of growers in the county of a particular size that use a computer technology for the sector s/he advises; LRG is a 0-1 dummy variable to indicate use estimates involving farms with over $1 million in annual gross sales;

MED is a 0-1 dummy variable for use estimates involving farms with between $1 million and $100,000 in annual gross sales; DAIRY, SWINE, RCROP, and T&V are 0-1 dummy variables to indicate if the farm advisor was a dairy, swine, row crop, or tree or vine crop farm advisor; SV, IMP, and COAST are 0-1 dummy variables to indicate if the farm advisor was located in either the southern San Joaquin Valley, Imperial valley, or coastal regions of California. The intercept term has imbedded within it small farms, beef operations, and farms in the northern San Joaquin Valley and the Sacramento Valley.

Two similar models were estimated for the use of accounting/ payroll use, and for the use of non-accounting computer services. The form of these two models are:

$$\%USE = \alpha + \gamma_1 DAIRY + \gamma_2 SWINE + \gamma_3 RCROP + \gamma_4 T\&V + \delta_1 SV + \delta_2 IMP + \delta_3 COAST + e$$

Data was unavailable to access the effect of farm size on application use.

Least squares was chosen as the correct estimation procedure. Since the the dependent variable is a farm advisor estimate of the proportion of farmers that use a computer technology, the total number of farmers is unknown. Therefore, neither a proportional logit or probit model could be estimated. The estimation results for all three measures of adoption are reported in table 1.

Table 1. Regression Analysis for Three Aggregate Measures of Computer Technology Adoption

	Computer Use	Accounting/Payroll Use	Managerial Use
Constant	-0.08479	0.01861	0.16524**
	(1.0519)	(0.18461)	(2.3934)
LRG	0.69976***	–	–
	(9.3106)		
MED	0.14476*	–	–
	(1.9072)		
DAIRY	0.51392***	0.29375	0.43214***
	(4.3098)	(1.6417)	(3.5316)
SWINE	0.30329**	0.73139***	0.58476**
	(2.2486)	(3.3825)	(3.9638)
RCROP	0.14568	0.34479**	0.06643
	(1.6775)	(2.3392)	(0.6604)
T&V	0.10158	0.17979	-0.06000
	(1.2086)	(1.2198)	(0.56365)
SV	0.17419**	0.20556	-0.04095
	(2.2765)	(1.6619)	(0.45023)
IMP	0.10446	0.33660	-0.13167
	(0.84745)	(1.4589)	(0.83498)
COAST	0.13845	0.02528	0.35524***
	(1.4633)	(0.16904)	(3.4781)
R^2	0.780	0.725	0.899
$\bar{R}^2$	0.727	0.484	0.799
Obs	47	16	15

Notes: The figures in parentheses are t-values.
*Denotes statistical significance at the 90% level.
**Denotes statistical significance at the 95% level.
***Denotes statistical significance at the 99% level.

The econometric results indicate that there are large differences in the level of computer technology adoption across sectors and across farm size. There is virtually complete (between 90% and 100%) adoption of computer technology among large dairy and swine operations, while small tree and vine, and beef operations show adoption rates of less than 2%.

The results confirm our hypothesis that the level of computer use increases as farm size increases. The relatively large difference between the coefficient for large farm usage versus medium size farm usage (0.69976 versus 0.14476) may indicate that there exists a size threshold after which the level of adoption greatly increases.

The level of usage across sectors was in line with our a priori expectations. The results indicate that the dairy and swine sectors are comparatively heavy users of managerial applications, and that crop sectors are light user of these applications. These results are in agreement with our hypothesis of an increasing level of use of production choice applications as the complexity of the biological production process increases, since both swine and dairy production often require a farmer to make complex breeding choices.

Our a priori expectations of accounting/payroll application use due to the number of transactions was not completely borne out by the statistical analysis. We had expected to find that in general crop sectors would be comparatively heavy users of accounting and payroll services, and that livestock sectors were relatively light users of these computer services. Instead we found no strong pattern between accounting/payroll usage levels in crop sectors and livestock sectors. These results could be due to our sector definitions. We expected the vegetable crop sector to be a heavy user of accounting and payroll applications due to its labor intensity, while we expected the field crop sector to be a relatively light user of these services. However, in our sector definition of row crops these two sectors were combined. Another reason for these results could be due to the omission of a farm size variable.

There appears to be some fairly significant differences in regional computer service use patterns in California. Both the southern San Joaquin Valley and coastal areas appear to have higher overall computer service use levels then do the northern San Joaquin Valley-Sacramento Valley and Imperial Valley areas. Further, the Northern San Joaquin Valley-Sacramento Valley and coastal areas have a higher level of usage of managerial applications, while the southern San Joaquin and Imperial Valleys have a higher usage of accounting and payroll applications.

Comparing the levels of adoption of one application versus that of another gives some indication of the sequence of adoption of different applications for a given sector. The above results indicate that, with the exception of swine, the sequence of computer technology adoption differs greatly between livestock and crop sectors. The sequence of adoption in livestock sectors appears to be the adoption of managerial applications followed by the adoption of accounting applications. The reverse is true in crop sectors, where accounting applications are adopted first and managerial applications follow. This difference in the sequence of adoption between crop and livestock sectors is not surprising. Breeding choices have always been a problem in livestock sectors, while payroll has always troubled labor intensive crop industries. This seems to indicate that the initial reason for adopting a computer technology is typically to automate a process that was formerly done without a computer, and not to undertake some new analysis (such as irrigation scheduling in crop sectors) that had not been done in the past.

2. Empirical Analysis of Farm Level Computer Ownership

The data from the farmer questionnaire included variables on whether or not a computer was owned that was used for farming operations, what sectors the grower's farming operations included, the farmer's age, and the farmer's education level. Unfortunately, no questions were asked that would allow for the creation of a farm size variable.

Since computer ownership is a discrete choice, the dependent variable in this analysis may only take on the values of zero or one. Thus the use of a limited dependent variable model (such as logit or probit) is warranted in estimating a model of farm level computer ownership. A logit estimator was used since the estimates provided using either logit or probit for our relatively small sample (65 observations) are statistically indistinguishable (see Amemiya).

Under the logit formulation, it is assumed that the probability that a grower adopts the technology is dependent upon factors that are both nonstochastic and stochastic. The nonstochastic portion is assumed to be a function of observable characteristics, while the stochastic portion is assumed to be a function of unobservable alternative or individual characteristics.

In a logit model, it is assumed that the probability that a grower adopts the technology is given by:

$$POWN = 1/[1 + \exp(-B'X)]$$

where POWN is the probability of a farmer owning a computer, B' is a row vector of parameters, and X is a column vector of exogenous variables (Amemiya).

For our analysis we assume that:

$$B'X = \alpha + \beta_1 FC + \beta_2 VC + \beta_3 TC + \beta_4 G + \gamma MULT + \delta_1 CD + \delta_2 AD$$

where FC, VC, TC, and G are 0-1 dummy variables that indicate whether or not the grower's farming operations include field crops, vegetable crops, tree crops, and vine crops respectively; MULT is a variable that takes on the value of 1 if a grower's farming activities include more than one sector, and takes on a value of 0 otherwise; CD, and AD are 0-1 variables that indicate the highest educational degree a farmer has received. CD indicates if a farmer has received either a community college or Bachelor's degree, while AD indicates whether or not a grower has received an advanced degree (e.g., Master's, Ph.D, DVM, MD, etc.). Imbedded within the intercept term are the variables that indicate whether a grower is a beef operator, and whether the highest educational degree he has received is a high school diploma. Our estimation results are shown in table 2.

Table 2. Estimation Results for Farm Level Computer Ownership

Variable	Coefficient		t-statistic
Constant	-1.2034		1.6324
Field Crops	-1.5115		1.5823
Vegetable Crops	0.44653		0.67871
Tree Crops	-0.36351		0.59911
Vine Crops	0.32788		0.44923
Multi-Sector	1.7333*		1.7018
College Degree	0.39985		0.51146
Advanced Degree	1.5911*		1.7341
McFadden R^2		0.14703	
L.R.T. (χ^2)		12.8636	
Correct Prediction (proportion)		47/65	

Note: *Denotes statistical significance at the 90% level.

The econometric results show that the probability of owning a computer varies greatly across sectors and differing education levels. Farm operators with advanced degrees who run certain multi-sector operations have a probability of owning a computer of over 90%, while high school educated field crop operators have only a 6% probability of owning a computer.

The results tend to confirm our hypotheses. From the results it can be seen that the likelihood of computer ownership increases as the grower's educational level increases (as we had hypothesized). The critical value of the asymptotic t-statistic at the 90 percent level is 1.645, thus we can reject the hypothesis that the advanced degree coefficient is zero at the 90 percent level of significance for the computer ownership model. Further, a likelihood ratio test was performed to test the hypothesis that people with above a high school education level are more likely to own a computer. The test statistic is 3.914, which allows us to reject the hypothesis that the two education coefficients are zero at the 80 percent level of significance.

Multiple sector farms were expected to display a higher level of computer ownership. The statistical results confirm this hypothesis. The t-ratio on the multi-sector coefficient is 1.701 for the model, which allows us to reject the hypothesis that the coefficient is zero at the 90 percent level of significance.

Summary and Conclusions

Empirical analysis shows that the likelihood of adoption of computers in California increases with farm size and complexity, and with farmer education level. Computers are mostly used for record keeping and accounting purposes, but there are significant levels in the use of managerial applications, especially among dairy and swine producers.

References

Amemiya, T. "Qualitative Response Models: A Survey." J. Econ. Lit. 19(1981): 1483-536.

Caswell, M., and D. Zilberman. "The Choices of Irrigation Technology in California." Amer. J. Agri. Econ. 67(1985): 224-233.

Feder, G. "Adoption of Interrelated Agricultural Innovations: Complementarity and Impact of Risk, Scale, and Credit." Amer. J. Agri. Econ. 64(1982): 94-101.

Feder, G., R. E. Just, and D. Zilberman. "Adoption of Agricultural Innovations in Developing Countries: A Survey." Econ. Develp. and Cult. Change 34(1985): 355-98.

Griliches, Z. "Hybrid Corn: An Exploration in the Economics of Technological Change." Econometrica 25(1957): 501-22.

Hiebert, D. "Risk, Learning, and the Adoption of Fertilizer Responsive Seed Varieties." Amer. J. Agri. Econ. 56(1974): 764-768.

Huffman, W. E. "Allocative Efficiency: The Role of Human Capital." Quart. J. Econ. 91(1977): 59-80.

Judge, G. G., R. C. Hill, W. E. Griffiths, H. Lutkepohl, and T. C. Lee. Introduction to the Theory and Practice of Econometrics. New York: John Wiley and Sons, 1982.

Mann, C. K. "Packages of Practices: A Step at a Time with Clusters." Studies in Develop. 21(1978): 73-81.

Pindyck, R. S., and D. L. Rubinfeld. Econometric Models & Economic Forecasts, 2 ed. New York: McGraw-Hill, 1981.

Rodger, E. M. Diffusion of Innovations. New York: Free Press of Glencoe, 1962.

Schultz, T. W. "The Value of the Ability to Deal with Disequilibrium." _J. Econ. Lit._ 13(1975): 827-46.

Simon, H. A. "Theories of Bounded Rationality." _Decision and Organization_. ed. by C. B. Radner and R. Radner, pp. 161-176. Amsterdam: North-Holland Publishing Co., 1972.

Welch, F. "Education in Production." _J. Polit. Econ._ 78(1970): 35-59.

Yugoslavia

Robinson, Sherman and Laura D. Tyson (1985). "Foreign Trade, Resource Allocation, and Structural Adjustment in Yugoslavia: 1976-1980." Journal of Comparative Economics, vol. 9, pp. 46-70.

Robinson, Sherman, Laura D. Tyson, and Mathias Dewatripont (1986). "Yugoslav Economic Performance in the 1980's: Alternative Scenarios." In Joint Economic Committee, U.S. Congress, East European Economies: Slow Growth in the 1980's. Volume 2: Country Studies, Washington, D.C.: U.S. Government Printing Office.

World Bank (1983). Yugoslavia: Adjustment Policies and Development Perspectives. Washington, D.C.: World Bank.