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in lieu of detailed RDA information. Therefore, our results support the hypothesis that at least some consumers are reading nutritional labeling to obtain RDA information.

IV. Conclusions

The estimation of hedonic price functions for durable goods has proved to be a useful methodology. In this paper, we applied the methodology to breakfast cereals, a nondurable good. We expect that for many nondurable goods, information describing the goods' characteristics will be lacking and hedonic price estimates will yield poor results. But for breakfast cereals, information is readily available, and our results proved useful for analyzing pricing policies, consumer preferences, and the use of information and package labeling. The hedonic techniques could prove to be a practical method of measuring consumer response to disclosure of information, if the researcher gathers information on market prices and the characteristics of the good over several time periods to track the implicit prices of the characteristics for which information is disclosed. Combining this information along with knowledge of consumer preferences can reveal whether or not the information is used.

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JOINT ADOPTION OF MICROCOMPUTER TECHNOLOGIES: AN ANALYSIS OF FARMERS' DECISIONS

Wallace E. Huffman and Stephanie Mercier*

Abstract—This study presents an econometric examination of the joint decisions of farmers on the adoption of a microcomputer and (or) purchased computers services. The characteristics of a farmer—schooling, age, off-farm work—are shown to be important variables for explaining the odds of adopting purchased computers services only, a microcomputer only, and both computer technologies. Adoption of computer technologies seems to occur in farming operations where they can be expected to greatly enhance the efficiency.

Recent advances in microcomputer technology and availability of low cost microcomputers have greatly increased the potential for information storage and analysis by small firms. The use of on-site microcomputers and of hired computer services can increase the profitability of farming operations (Sonka, 1983). The need for capability to utilize more sophisticated information and data storage and processing equipment has increased as U.S. farm businesses have become larger and more complex.

This study examines the joint decisions by farmers for adopting microcomputers and computer services for their farm businesses. Purchased computer services are services acquired outside the farm, such as accounting or farm record analyses, that involve the use of a computer. These services do not generally require the use of a computer on the farm. A multivariate logit specification of this adoption model is fitted to data obtained from a survey on ownership and use of different computer-related technologies. The results show that a farmer's schooling and his farm's structure have

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important effects on the odds of adopting computer technologies.

In the following sections, the decision to adopt new technology is outlined, then an econometric model is presented, the data are described, and the econometric results are discussed. Some conclusions are presented in the final section.

Decision to Adopt

Most studies of adoption have considered a single innovation that reduces costs or increases the productivity of a narrowly defined activity. In agriculture, these studies began with an aggregate analysis of hybrid corn adoption by Griliches (1957). Later studies have incorporated a dynamic element (Kislev and Shchori-Bachrack, 1973; Feder and Slade, 1984), uncertainty and attitudes toward risk (Just and Zilberman, 1983), and human capital (Wozniak, 1984; Rahm and Huffman, 1984). Outside agriculture, Hannon and McDowell (1984) examine the effects of banking structure on probability of adopting automatic teller machines, and Levin, Levin, and Meisel (1987) examine the effects of market concentration in the food store industry on the adoption of optical scanners. Firms operating in more concentrated markets are more likely to adopt these new technologies than other firms.[1]

A few studies have considered the joint adoption of multiple technologies. Nerlove and Press (1973) and Feder (1982) examined the joint adoption of several inputs associated with the Green Revolution (e.g., use of new crop varieties, commercial fertilizer, irrigation). Wozniak (1984) considered the adoption of feed additives and growth hormones for beef cattle.

A microcomputer has potentially widespread use in a farming operation, e.g., for hedging and forward contracting, controlling irrigation systems and livestock feeders, keeping farm records, preparing tax returns, and determining least-cost input combinations. Purchased computer services do, however, tend to be tailored to particular needs, e.g., record-keeping and management of dairy herds.

Most uses for computers and computer services involve data that are specific to individual farm operations, i.e., private data. Although public data are generally available at minimal direct cost, the survey on which this study is based suggests that few farmers incorporate this type of information explicitly into their information systems (Yarbrough and Scherer, 1984). Instead, farmers seem to focus on data about inputs they utilize and the outputs they produce, including their prices.

[1] Other studies include Mansfield (1963); Romeo (1975); and Bartel and Lichtenberg (1987).

The Econometrics of Joint Adoption

The Model and Hypothesis

Farmers are assumed to make decisions on adoption of microcomputer technologies by comparing farm profit from different outcomes. Let $\pi_j = Z\underline{\beta}_j + \mu_j$, where π_j is stochastic farm profit associated with the jth computer technology outcome, Z is a $(1 \times k)$ vector of prices and environmental variables, $\underline{\beta}_j$ is a $(k \times 1)$ vector of unknown coefficients, and μ_j is a random disturbance term. There are four possible outcomes: $j = 1$ when neither computer technology is adopted, $j = 2$ when only purchased computer services are adopted, $j = 3$ when only a microcomputer is adopted, and $j = 4$ when both computer technologies are adopted. Define

$$D_{ij} = \begin{cases} 1 & \text{if } \pi_{ij} = \max(\pi_{i1}, \pi_{i2}, \pi_{i3}, \pi_{i4}) \\ 0 & \text{otherwise} \end{cases}$$

$i = 1, \ldots, n$; $j = 1, \ldots, 4$. Thus, D_{i3} is a dummy variable taking a value of 1 when the adoption of only a microcomputer results in largest farm profit.

When the random disturbance μ_j has density function $f(\mu_j) = \exp(-\mu_j - e^{\mu_j})$ and distribution function $F(\mu_j < \mu) = \exp(-e^{-\mu})$, the probability that the ith farmer makes the jth choice on computer technology can be written as a multinomial logit function (Maddala, 1983, pp. 60–61):

$$\Pr(D_{ij} = 1|Z) = e^{Z_i\underline{\beta}_j} \Big/ \sum_{j=1}^{4} e^{Z_i\underline{\beta}_j} \qquad i = 1, \ldots, n; \quad j = 1, \ldots, 4.$$

Then the natural logarithm of the odds in favor of the jth choice (for $j > 1$) relative to the first choice is

$$\ln(P_{ij}/P_{i1}) = Z_i(\beta_j - \beta_1) = Z_i\beta_{j1}$$

where β_{jl} is a $k \times 1$ vector, and β_{jl1} represents the marginal effect of the lth variable on the natural logarithm of the jth technology choice relative to the first one. This specification has the advantage of accommodating a relatively large number of choices. It has the disadvantage of requiring that the μ_j's be independent or that the odds associated with making any two choices, say q and r, are unaffected by adding to the total number of choices.

The available data for defining the Z's do not contain farm-specific prices but do contain information on environmental variables that enter the profit function.[2] Output and input prices are not expected to be a major factor for explaining adoption when farmers in the sample are located in a relatively small geographic area.

[2] Data are not available on farm profits for different outcomes.

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A farmer's microcomputer and purchased computer services could be complements or substitutes. If they are strong substitutes, then farmers are more likely to adopt either a microcomputer or purchase computer services relative to not adopting either computer technology. If they are complements, then both could be used by the same farmer.

A microcomputer has extensive potential as a management tool, and this too is believed to be enhanced by formal schooling. Educated farmers can more easily learn to use a microcomputer and its accompanying software. Specific experience with the technology is important for both adoption and implementation (Bartel and Lichtenberg, 1987). This type of experience is highly correlated with more education. Purchased computer services require less skill of the farmer because the vender is providing part of the skill. However, additional schooling is expected to increase the odds of adopting purchased computer services, as well.

If farmers are not capital constrained and take future generations' welfare into account, the primary effect of age is on the likelihood of prior experience with computers. Younger farmers are more likely than older ones to have experience using computers and computer information in school. This tendency implies a larger odds of adopting computer technologies for younger farmers.[3]

Record keeping is important to efficient dairy production, and a number of cooperatives and farm supply firms offer record keeping services. Farms having a dairy enterprise are expected to have a larger odds of using purchased computer services.

In general, complex farming enterprises are difficult to manage efficiently. A microcomputer or purchased computer services can aid in record keeping and management. Other things equal, greater complexity of the farming business is expected to increase the odds of adopting computer technologies. Operators of larger farms are also expected to have larger odds of adopting computer technologies.

One substitute for a larger farming operation (especially livestock) is off-farm employment of the farm operator. Farm operators who participate in off-farm employment have smaller farms on average, which reduces the benefits from a microcomputer as a farm decision tool. They also may have a higher opportunity cost of their time which increases the costs. These arguments suggest that a larger odds of off-farm work will reduce microcomputer adoption.

There are transactions costs associated with finding and learning to use a microcomputer and finding computer services. When these costs are lower, the odds of adopting will be increased. The last two variables are associated with transactions costs of acquiring and learning to use a microcomputer. These costs are expected to be larger when farms are farther from cities or when per capita county income is lower.

[3] If there is a credit constraint and farmers plan for only the current generation, then the highest probability of adoption will occur for middle-aged farmers.

Data

The model is to be fitted to data from a sample of Iowa farmers obtained by merging two panel surveys conducted by the Journalism and Mass Communication Department at Iowa State University. The surveys were conducted during 1982–84.[4] For these data, sample mean values for the decisions on microcomputer technology outcomes, D_1–D_4, are 76.4%, 15.3%, 4.1%, and 2.1%, respectively.

The farm operator is assumed to be the primary decision-maker, and an adopter is defined as using a microcomputer or purchasing computer services. The following variables were defined for explaining adoption:

SCHOOL	is farmer's schooling completion index; a 1 if 1–8 years, 2 if 9–11 years, 3 if 12 years, 4 if some college, and 5 if college graduate;[5]
AGE	is farmer's age; *AGESQ* is *AGE* squared;
DAIRY	has a value of 1 if a dairy enterprise is present and 0 otherwise;
FMCMPX	represents complexity of farm decision-making; 0 if small cash grain farm, 1 if small diversified farm, 2 if medium sized farm, 3 if large cash crop farm, 4 if large livestock farm, 5 if large diversified farm;[6]
ACRES	is acres operated;
POFF	is predicted probability of off-farm work by farmer (see Mercier, 1988).
GPRICE	is local county average grain price index;
RENT	is cropland rental rate for local crop reporting district;
URBAN	is a dummy taking a value of 1 if resident in a county having a city with population >10,000, and 0 otherwise;

[4] The data for this study consist of observations from surveys of random samples of Iowa farmers and from surveys of farmer microcomputer owners. The two types of surveys were combined using weights derived from a post-stratification sampling technique. See Mercier (1988) for details.

[5] Alternatively, schooling effects could be entered as four separate dummy variables. Marginal effects are, however, more difficult to interpret.

[6] Dairy cattle are excluded from the farm complexity variable. See Mercier (1988) for exact definition of *FMCMPX*. Alternatively, four separate dummy variables could be used to represent this information.

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TABLE 1.—MULTINOMIAL LOGIT MODEL: PROBABILITY OF ADOPTING COMPUTER TECHNOLOGY BY IOWA FARMERS, 1982–84 (n = 2381)

	Weighted Means (std. dev.)	Adoption Outcomes: Computer Services Only	Micro-computer Only	Computer Services and Microcomputer
SCHOOL	3.24	0.52[a]	1.10[a]	0.84[a]
	(1.18)	(4.43)	(8.39)	(5.3)
AGE	48.84	−0.03[a]	−0.04[a]	−0.07[a]
	(13.59)	(−4.0)	(−3.6)	(−4.8)
AGESQ	2,571.4	−6 × E-5	3 × E-4	−0.003[a]
	(1,357.3)	(−0.14)	(−0.46)	(−2.9)
DAIRY	0.097	0.933[a]	0.303	0.737
	(0.30)	(3.58)	(0.72)	(1.81)
FMCMPX	1.091	0.304[a]	0.355[a]	0.405[a]
	(1.23)	(5.6)	(6.27)	(4.25)
ACRES	429.03	2 × E-5	7 × E-5	6 × E-5
	(910.87)	(0.35)	(0.92)	(0.79)
POFF	0.28	−0.95	−3.45[a]	−1.88
	(0.45)	(−1.0)	(−2.6)	(−1.2)
CPRICE	100.25	−2 × E-3	−1 × E-3	−7 × E-4
	(2.20)	(−1.2)	(−1.0)	(−0.4)
RENT	106.39	−4 × E-3	−1 × E-3	−2 × E-3
	(13.01)	(−0.6)	(−1.5)	(−0.2)
URBAN	0.246	0.038	−0.073	0.048
	(0.43)	(0.20)	(−0.30)	(0.18)
PCINC	10,356.2	−4 × E-5	2 × E-4[a]	−1 × E-4
	(1,262.0)	(−0.6)	(2.8)	(−1.2)
INTERCEPT	—	1.59	−5.84[a]	−1.87
		(−1.5)	(−4.8)	(−1.1)

Note: All coefficients are expressed relative to the non-adoption of both computer technologies. Numbers in parentheses are t-ratios.
[a] Significantly different from zero at the 5% level.

PCINC is county average income for resident county.

Empirical Results

The results from fitting the multivariate logit model of adoption to 2,381 observations are reported in table 1.[7] The outcomes refer to adoption of purchased computer services only, of a microcomputer only, and of a microcomputer and purchased computer services. The coefficients reported in these columns are estimates of the marginal effects on the natural logarithm of the odds in favor of adopting the outcome indicated at the top of the column relative to not adopting either innovation.

Farmer's schooling has a large positive and significantly different from zero effect on all computer technology adoption decisions. Completion of an additional one-half unit of schooling increases the $\log_e$ odds by 55% that a farmer adopts a microcomputer only relative to not adopting either computer technologies. The increase in $\log_e$ odds for adopting both computer technologies is 0.42 and for computer services only is 0.26. Therefore, farmers' schooling is one of the most important variables explaining computer technology adoption.

An increase in farmer's age causes a reduction in the probability of adopting all combinations of computer technologies. The marginal effect of age is linear in *AGE* and is evaluated at the sample mean. An additional year of age reduces the $\log_e$ odds of adoption by 2.5% to 3.5% for joint technologies (relative to non-adoption) evaluated at the sample mean. Thus, the results suggest that the probability of adopting computer technology by farmers is largest for the youngest farmers, other things equal, and decreases as they become older. Furthermore, they imply a rapidly decreasing odds of adopting both a microcomputer and purchased computer services relative to adopting neither one (i.e., the coefficient of *AGESQ* is significantly different from zero).

The results show that the presence of a dairy enterprise causes a large (93%) increase in $\log_e$ odds of adopting purchased computer services only. A smaller increase (74%) in the $\log_e$ odds of adopting both a microcomputer and purchased computer services also occurs. Operating a dairy enterprise does not have a

[7] The equation was fitted using the program *PCCARP* which was developed by the Iowa State Statistical Laboratory, Ames, Iowa.

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significant effect on the $\log_e$ odds of adopting a microcomputer only.

Greater farm complexity increases the $\log_e$ odds of adopting computer technologies. The largest marginal effect (0.405) is on the $\log_e$ of adopting both a microcomputer and purchased computer services. Thus, a microcomputer and purchased computer services are complementary inputs on farms having complex farming activities.

Although an increase in farm size (*ACRES*) has a positive effect on the $\log_e$ odds of adopting computer technology, the coefficient is not significantly different from zero at the 5% level. These results are surprising, and attempts were made to refit the model with $ACRES^2$ included as a regressor. All of these attempts failed; the likelihood function refused to converge.[8]

The results suggest that farmers who participate in off-farm work have a lower odds of adopting computer technologies. The largest reduction occurs for the probability of adopting a microcomputer only. Smaller, but not significant, reductions occur in the probabilities of adopting both technologies and adopting purchased computer services only.

The results provide only weak support for the idea that a reduction in transactions costs associated with buying and learning to use a computer or computer services increases the $\log_e$ odds of farmers adopting computer technologies. Farms that are located in a county having a city of 10,000 or more (*URBAN*) do not have a significantly higher odds of adopting computer technology than other farmers. Location in a county with larger average personal income (*PCINC*) results in a higher odds of adopting a microcomputer only, but does not have a statistically significant effect on adoption of purchased computer services or of adopting both.

The crop price index (*CPRICE*) and cropland rental rate (*RENT*) have statistically weak effects on the odds of adopting computer technologies.

Conclusions

The characteristics of a farmer—schooling, age, off-farm work—were shown to be important variables for explaining the odds of adopting purchased computer services only, a microcomputer only, and both computer technologies. An additional unit of a farmer's schooling, however, has the largest impact on the odds of adopting a microcomputer only. The complexity of farm business decision making is an important farm characteristic affecting computer technology adoption. Farms with a larger value of the complexity index have a higher odds of adopting all combinations of computer technologies, but the largest effect is on adopting both a microcomputer and purchased computer services. Thus, by considering all possible combinations of these two computer technologies, we have learned whether a given explanatory variable has its largest impact on adopting only one or both technologies.

Finally, the adoption of computer technologies seems to occur with highest probability in those environments where they can be expected to greatly enhance technical and (or) allocative efficiency of business operations.

[8] Because acreage operated is one component in defining farm decision making complexity, some multicollinearity undoubtedly exists between *ACRES* and *FMCMPX*.

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GEOGRAPHICAL INTEGRATION AND THE RETAIL CD-PRICING DECISIONS OF LARGE DEPOSITORY INSTITUTIONS

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Abstract—This paper focuses on the six-month retail certificate of deposit (CD) rates of large depository institutions in six major cities during 1983–1988 to test the integration of their retail CD markets. Using Granger's (1986) concept of co-integration, we find a long-run equilibrium relationship between the city CD-rate offers and the six-month Treasury bill rate. After filtering out this relationship, a vector autoregressive model is employed with Granger (1969) causality tests to determine the significance of intercity rate dependencies. Our results indicate an increasing number of intercity relations over time, consistent with an emerging integrated market. Since our sample represents a subset of bank CDs for the largest firms operating in six of the nation's largest cities, the results should not be generalized to other smaller bank markets, CD maturities, or bank products. The periods examined are also close together in time, which could affect the robustness of the results.

I. Introduction

Traditional depository institution regulatory policy, based on a structural analysis of local markets, generally operates under the assumption of the U.S. banking system as a collection of segmented markets versus an integrated national banking system. Studies examining deposit price/concentration relationships for a broad cross-section of banks are consistent with this assumption (see Berger and Hannan, 1989a, b; and Neumark and Sharpe, 1989). From this perspective, banks and thrifts in local regions have little or no effect on the pricing decisions of firms operating in other localities. With imperfect information provided across regions, such a collection of markets would not be as efficient as an integrated system operating in a single market. A segmented banking system may exist as a consequence of previous regulations restricting banks to operate in local areas, or as a function of the particular nature of institutional transactions which occur directly between depository institutions and the public in a direct search versus an organized market (see Osborne, 1988).

In contrast to the traditional policy view, some researchers have challenged the assumption of segmented bank markets. Black (1975) notes that even in a regulated environment, banks are able to create loopholes to allow them to operate as if they were in an efficient, unregulated, competitive environment. The nature of banking markets may also differ for different banking activities and types of banks. Large banks have been observed by researchers to operate in national markets for negotiable certificates of deposit (CDs), as well as for large business loans (see Oxborne, 1988, and Fama, 1985). Since loans and negotiable CDs typically involve large sums of money, search and transaction costs may be small relative to the opportunity cost of not seeking the best rate available.

In the deregulated banking environment of the 1980s, some bank retail deposit markets may also be better characterized as integrated markets. As of October 1983, all depository institutions were permitted to offer competitive market rates on interest-sensitive deposits, including retail certificates of deposit (CDs). With greater dependence on purchased funds to finance asset growth, many institutions have used national advertising and brokers to attract nonlocal retail (insured) deposits. In particular, large thrifts attempting to grow out of insolvency under "bet the bank" strategies have been active in seeking out-of-state retail deposits by offering rate premiums (to compensate depositors for potential costs associated with FSLIC foreclosure) and packaging deposit funds in amounts less than $100,000 to effectively trade on their deposit guarantees (see Kane, 1989). Agencies have also developed to provide national deposit rate information for the nation's largest banks and thrifts.

An examination of the integration of bank markets is important to bank managers, analysts, and regulators in terms of defining relevant markets and measuring the competitive effects of greater deregulation. This study provides a preliminary analysis of retail CD markets by focusing on the six-month retail CD rates of

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