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Computer and Internet Use by Great Plains Farmers

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This study uses data from a 2001 survey of Great Plains farmers to explore the adoption, usage patterns, and perceived benefits of computers and the Internet. Adoption results suggest that exposure to the technology through college, outside employment, friends, and family is ultimately more influential than farmer age and farm size. Notably, about half of those who use the Internet for farm-related business report zero economic benefits from it. Whether a farmer perceives that the Internet generates economic benefits depends primarily on how long the farmer has used the Internet for farm business and for what purposes.

Key words: agriculture, competitiveness, net benefits, technology adoption

Introduction

In the last decade, the Internet has become a core global communications technology for business (Kogut, 2003). Firms that use the Internet have greater access to information and can reduce the costs of economic interactions. These benefits of the Internet are exemplified by the extensive use of eBay for auctions, Amazon for online purchasing, and @griculture Online for agriculture-specific activities. There is a growing literature on the impacts of computers and the Internet for various industries (BRIE-IGCC, 2002), but economic research on its use in agriculture is sparse for computers and negligible for the Internet. In this study we examine adoption, usage patterns, and perceived benefits of the Internet for a sample of Great Plains farmers.

Strongly increasing trends in the use of computers and the Internet by agricultural producers suggest that many farmers perceive positive and rising competitive benefits from this technology. A 1997 U.S. Department of Agriculture/National Agricultural Statistics Service (USDA/NASS) survey found that 31% of U.S. farmers owned or leased a computer, although only 13% had access to the Internet; by 2001, these numbers had increased to 50% and 43% (USDA/NASS, 2003). Based on findings of a 1998 national Gallup poll of large agricultural producers, 57% owned computers and 34% had Internet access. Only 2% of these producers reported purchasing "a lot" of farming products and services over the Internet,[1] but 23% obtained "a lot" of farming information in this

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[1] In this poll (Gallup Organization, 1998), "a lot" was defined as more than 40%.

manner.[2] An additional 59% expected to be using the Internet to obtain information within three years.

Farmers' adoption and use of computers and the Internet depends on their anticipated impacts on farm performance and competitiveness. Such impacts could stem from various internal factors associated with computer use, such as better record-keeping, decision-making, and production processes (Holt, 1985). External factors such as researching and marketing on the Internet might play a key role through the accumulation of information that has competitive value (Feder and Slade, 1984; Amponsah, 1995). Purchasing and selling through the Internet may enhance efficiency by "increasing the accuracy with which prices reflect true market conditions" (Henderson, 1984, p. 849). Intensity of use, in terms of the amount of purchases made or the number of tasks carried out through the Internet, may also affect the returns to computer adoption (Feder and Slade, 1984; Putler and Zilberman, 1988). These potential benefits of computers and the Internet have likely increased over time as availability and applicability have risen and as costs have fallen.[3]

Gaining insight into farmers' adoption, usage patterns, and perceived benefits of computers and the Internet seems central to understanding farm economic performance in our E-commerce world. The dearth of economic literature addressing these questions is therefore quite surprising. Most existing empirical studies focus on low computer adoption rates of farmers in the late 1980s (Batte, Jones, and Schnitkey, 1990; Huffman and Mercier, 1991; Putler and Zilberman, 1988; Amponsah, 1995). Two exceptions are Hoag, Ascough, and Frasier (1999), who consider whether computer adoption and its determinants have changed as farmers have moved up the learning curve, and Ascough et al. (2002), who assess types and frequency of computer use and user satisfaction, using data from the mid-1990s.

However, none of these studies ask what types of U.S. agricultural producers are using computers to access the Internet for business purposes, how and to what extent they are using it, and what benefits they obtain from it.[4] In this study we address these questions using year 2000 survey data which include information on computer and Internet use by 517 Great Plains farm operators. A multinomial logit model is employed to explore the patterns and determinants (farm and farmer characteristics) of computer and Internet adoption. We also examine usage patterns (types of applications used and amount they are used) and the resulting perceived benefits of the technology for enhancing competitiveness.

The age of the farmer and the size of the farm are found to be significant determinants of computer and Internet adoption and usage patterns. However, access to the technology through general education and outside employment are more important, particularly for the Internet, which is a newer technology than the personal computer (PC). For the PC, formal education and outside employment are no longer significant determinants, and exposure to the technology through friends and family is most influential. Findings indicate that the perceived benefits of the Internet are primarily

[2] About 15% of farmers had a home page. However, farmers typically work through portals—large websites offering a broad range of information and providing links to other relevant websites—through, for example, trade journals like *Successful Farming* (Sayler, 1995).

[3] Direct costs have fallen as the technology has advanced. Learning costs have dropped as more people gain familiarity with computers through, for example, greater use of computers in schools or outside employment (Wojan, 2000).

[4] The potential for farmers' Internet use to enhance farm business practices was noted, but not empirically evaluated, by Wojan (2000).

determined by how it is used and for how long the farmer has used it. In particular, obtaining input pricing and agricultural commodity market information enhances farmers' perceived competitiveness. The only farm or farmer characteristic that significantly affects perceived benefits is whether or not the farm is classified as a family farm. Family farms tend to exhibit lower perceived benefits of Internet use than other farms.

The Literature

The limited economic literature on farmers' computer use focuses mostly on the farm and farmer characteristics that affect farmers' adoption of computers. The studies in this literature are based on various survey data sets, and somewhat different questions and arguments. The choices, or outcomes, are typically modeled in a qualitative (yes or no) form as functions of farm and farmer characteristics (the explanatory variables, or determinants). In addition to adoption, some studies address net benefits (Batte, Jones, and Schnitkey, 1990; Amponsah, 1995; Ascough et al., 2002), types and numbers of applications (Putler and Zilberman, 1988; Batte, Jones, and Schnitkey, 1990), or alternative computer-oriented choices (Huffman and Mercier, 1991).

The model providing the foundation for these studies is typically a logit model of the form:

$$\log(p_i/p_j) = \sum_{k=1}^{K} x_k \beta_{ik}, \tag{1}$$

where p_i/p_j is the probability of a class i relative to the probability of a class j choice or outcome, and β_{ik} measures the influence of the explanatory variable x_k on this probability. In most studies there are only two possible outcomes—adopting and not adopting. One example with more than two outcomes is Huffman and Mercier (1991). They jointly model computer adoption and the purchase of computer services, so there are four possible outcomes—neither, one or the other, or both.

The logit model in (1) can be derived from a random profit model with errors distributed according to the type I extreme value distribution (McFadden, 1984). This derivation implies farmers adopt computers if the expected incremental profit from computer use is positive (Huffman and Mercier, 1991). These incremental profits may be implicitly associated with more effective decision making and risk management (Amponsah, 1995), reduced uncertainty (Feder and Slade, 1984), or augmented human capital (Putler and Zilberman, 1988).[5] In studies that allow for more than one outcome (e.g., Huffman and Mercier, 1991), dependence across the outcomes is typically not modeled. In our model of computer and Internet adoption, we test for dependence across outcomes.

The model in (1) represents how the farm and farmer characteristics included in x_k are associated with marginal benefits of computer use. Most studies in the literature include farm size, and farmer age and education, as explanatory variables. However, all studies include at least some other characteristics. For example, information on farmer age is

[5] Human capital augmentation is associated with improvements in allocative or productive ability. Decision support applications are allocative-ability augmenting because the information improves the allocation of fixed factors or use of purchased factors. Transaction processing applications are worker-ability (or productivity-) augmenting because they increase the output/hour of clerical and bookkeeping tasks.

sometimes augmented by data on farming experience (Hoag, Ascough, and Frasier, 1999), although these variables may be sufficiently correlated that one must be dropped from the analysis.[6] Age and farming experience are potential determinants of computer use because younger farmers are expected to have more familiarity with computers and a longer period over which to spread learning (Putler and Zilberman, 1988). Farmer education is similarly interpreted as representing a greater capacity to learn, and perhaps prior experience with computers. Off-farm employment is sometimes included as a proxy for experience with computers or as an indicator of the farmer splitting time across different endeavors (Hoag, Ascough, and Frasier, 1999; Huffman and Mercier, 1991).

In addition to farm size measured in acres, farm income or expenditure is sometimes used as an indicator of the scale of farm operations (Amponsah, 1995; Hoag, Ascough, and Frasier, 1999). Data on the types and numbers of different products produced[7] or enterprises in the farm business are interpreted as indicators of greater complexity (Putler and Zilberman, 1988) or the need to make a greater number of and more varied decisions (Huffman and Mercier, 1991). Other indicators of management intensity or style are tenancy, i.e., the self-owned proportion of the farm operation (Hoag, Ascough, and Frasier, 1999; Batte, Jones, and Schnitkey, 1990; Huffman and Mercier, 1991), and the existence of a formal record-keeping system (Amponsah, 1995; Batte, Jones, and Schnitkey, 1990). Additional proxies for scale or complexity include the share of commercial versus non-commercial production (Hoag, Ascough, and Frasier, 1999),[8] and ownership of a farm-related business (Putler and Zilberman, 1988).[9]

Overall, the early literature documents that size, income (sales), education, and tenancy had positive effects, whereas age (or experience) had a negative effect on computer adoption. Batte, Jones, and Schnitkey (1990) and Amponsah (1995) also found that education had a positive effect and age a negative impact on the number of applications and perceived benefits by farmers.[10] Using data for 1995, Hoag, Ascough, and Frasier (1999) discovered education and farming experience (or age) were less significant influences than in the late 1980s, and tenancy and off-farm employment were insignificant. Their results also indicate that size had an inverted U-shaped impact, implying mid-size producers were the most likely to adopt. Ascough et al. (2002) used the same survey, and found education and experience were positively related to user satisfaction, and computer skill increased both satisfaction and the number of computer applications.

This literature alludes to several potential extensions to these analyses, which we pursue with our data set. First, our data are used to directly assess what determines the different types of Internet use, how frequently various Internet applications are used, and farmers' perceived benefits (e.g., cost savings or enhanced competitiveness). Second, we specifically address the interaction between personal and business use of the Internet. Third, because our data set is more recent than those in other studies, this analysis can

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[6] The age variable was dropped in Hoag, Ascough, and Frasier (1999); similarly, because having a job using a computer was highly correlated with off-farm employment, only the latter variable was included in the final estimation.

[7] For example, studies have distinguished crop versus livestock production (Hoag, Ascough, and Frasier, 1999), and acreage under specialty crops (Amponsah, 1995).

[8] "Commercial" is defined as production in excess of $100,000.

[9] Ownership of a farm-related business is interpreted as an indicator of familiarity with technology.

[10] Baker (1992), by contrast, found no links to farmer age and education, but a positive relationship between manager involvement in computer purchases and the amount of computer use and user satisfaction.

consider whether the impacts of age and education are dropping as farmers are moving further along the learning curve for computer use, a trend suggested by Hoag, Ascough, and Frasier (1999). Finally, we evaluate whether computer-specific education still has the same impact it had in the late 1980s (Iddings and Apps, 1990).

Few insights about usage patterns and benefits emerge from the literature, in part because of limited information about the performance impacts of computers. Although Ascough et al. (2002) address questions about the frequency of computer use and user satisfaction, they state "... measuring computer use and satisfaction can be difficult, and interpretation is often unclear for many reasons" (p. 1264). The conceptual difficulties with such an exercise are compounded by data limitations. For example, only 60 survey responses (out of 219 in total) were complete for the Ascough et al. questions about frequency of and satisfaction from computer use. Similarly, our data provide us less of a foundation for modeling usage patterns and enhanced competitiveness than for modeling computer and Internet adoption. Nonetheless, our data can be used to gain some insight into farmers' computer and Internet usage and the perceived benefits of this technology.

The Data

The data sample for this study emanates from a 2001 survey of 1,679 farmers in the Great Plains states of Kansas, Iowa, Nebraska, and Oklahoma. The farmers in the survey were randomly selected from the membership rosters of the Farm Bureau Federations in each state. For our analysis we used data for the 517 farmers whose surveys had no missing information on the variables of interest.[11] The relevant survey questions and the mean response to each question are listed in appendix tables A1, A2, and A3, for farmer, farm, and computer/Internet characteristics, respectively.

As observed from table A1, the average farmer was 55 years old (born in 1945) and had 29.9 years of farming experience. Thirty-two percent of farm operators worked off the farm for more than 200 days in 2000. Just over half of the farmers had some post-high school education, and 29% had earned at least a college degree. However, 61% reported they had no formal computer-related education.

Table A2 documents that 81% of farmers characterized their farm as a family farm. The average farm size was 1,070 acres, and the average farm employed 0.36 full-time workers in addition to the operator. Approximately half of the farmed acreage was owned by the farm operator, and the land was split almost evenly between pasture and crops. Gross farm income was greater than $100,000 for 40% of farms, and net income exceeded this amount for 1% of farms. Positive net income was reported by 67% of farmers, and 32% had net incomes greater than $20,000.

Table A3 reveals that 61% of the farmers in our sample had a personal computer (PC), which is greater than the 2001 NASS estimate of 50% for the U.S. overall. In the 1991 and 1995 surveys used by Hoag, Ascough, and Frasier (1999) and Amponsah (1995), 14% and 37% of farmers owned computers, respectively. In our sample, 30% of the farmers said they used a computer for business purposes, and 51% reported their PC was set up to access the Internet. These values also exceed the corresponding 2001 NASS survey estimates of 29% and 43%.

[11] Responses were received from 579 farmers, representing a response rate of 34.5%.

The data summarized in appendix table A3 identify which farmers used computers and the Internet for business purposes, and for what types of tasks. The identified tasks are: (*a*) getting information for running the farm, (*b*) purchasing goods and services, (*c*) marketing commodities, and (*d*) having a web page. Twenty-eight percent of the farmers obtained farm-related information from the Internet, including technical and pricing information about inputs, commodity and financial market information, weather and agricultural policy information, and information from chat rooms. Ten percent used the Internet to purchase goods and services, and 2% used it to market their products; the reported amount of money involved indicates the magnitude of these Internet activities. These data are used to evaluate Internet usage patterns, i.e., the types and amount of Internet use.

Although the extent of farmers' Internet use may implicitly reveal whether they find it useful, we also have direct measures of farmers' perceived economic benefits from their Internet business activity, as shown in table A3. The data include variables representing whether farmers believed information acquired from the Internet increased their financial returns and, if so, by how much. The data also contain farmers' estimates of cost savings from Internet purchases and revenue gains from marketing over the Internet. Finally, as an indicator of the overall benefits, we have information on whether farmers believed the Internet increased their competitiveness. These data allow us to assess the perceived benefits of Internet use.

Adoption of Computers and the Internet

The Model

Computer and Internet adoption decisions are modeled using a nested decision tree. Initially, the farmer decides whether to purchase a PC. If a PC is purchased, the farmer then chooses whether to connect to the Internet. If the computer is connected to the Internet, the farmer then elects whether to use the Internet for business. Hence, this decision problem has four possible outcomes, which we index with the variable $Y \in \{0, 1, 2, 3\}$: no PC ($Y = 0$), PC but no Internet connection ($Y = 1$), Internet connection not used for business ($Y = 2$), and Internet used for business ($Y = 3$). In our sample, the proportions of farmers in each of the four categories are 0.39, 0.10, 0.22, and 0.29 for $Y = 0$, 1, 2, and 3, respectively.

For this analysis a multinomial logit (MNL) model is specified, which can be derived from a random utility model with errors distributed according to the type I extreme value distribution (McFadden, 1984). In this decision problem, the farmer may choose to own a PC and then to connect it to the Internet for both personal and business uses. The random utility received from each choice is implicitly a function of farm earnings.

The model is parameterized as:

$$(2) \qquad \begin{aligned} \log(p_1/p_0) &= \mathbf{X}\beta_1, \\ \log(p_2/p_1) &= \mathbf{X}\beta_2, \\ \log(p_3/p_2) &= \mathbf{X}\beta_3, \end{aligned}$$

where $\mathbf{X}$ denotes the set of explanatory variables, and $p_j = \text{prob}(Y = j)$. Thus, the log odds of a farmer choosing one option relative to the odds of choosing the preceding option in the decision tree are a linear function of **X**. Solving for p_i under the constraint that $p_0 + p_1 + p_2 + p_3 = 1$ yields:

(3)
$$\begin{aligned} p_0 &= D^{-1}, \\ p_1 &= D^{-1}\exp(\mathbf{X}\beta_1), \\ p_2 &= D^{-1}\exp(\mathbf{X}\beta_1 + \mathbf{X}\beta_2), \\ p_3 &= D^{-1}\exp(\mathbf{X}\beta_1 + \mathbf{X}\beta_2 + \mathbf{X}\beta_3), \end{aligned}$$

where $D = 1 + \exp(\mathbf{X}\beta_1)(1 + \exp(\mathbf{X}\beta_2)(1 + \exp(\mathbf{X}\beta_3)))$.

We could equivalently express the model in terms of the parameters $\alpha_i = \Sigma_{j=1}^{i}\beta_j$, in which case equation (3) becomes $p_i = D^{-1}\exp(\mathbf{X}\alpha_i)$. This representation in terms of α, which is the typical textbook representation of an MNL model, implies that $\log(p_j/p_0) = \mathbf{X}\alpha_j$ for each $j = 1, 2, 3$. Thus, α_j measures the benefit of choosing option j relative to not owning a computer. However, because of the sequential nature of the farmer's decision problem, we are interested in the effect of the **X** variable in moving the farmer to the next point in the decision tree, which is captured by β.[12]

The farm and farmer characteristics in appendix tables A1 and A2 are used as explanatory variables. Specifically, the set of explanatory variables includes measures of age, farm size, off-farm income, and computer education, and an indicator for a college degree. We also incorporate age and farm size in squared form to capture nonlinearities suggested, for example, by Putler and Zilberman (1988), and Hoag, Ascough, and Frasier (1999).

In preliminary estimation we found that the effects of many other farm and farmer characteristics were both individually and jointly insignificantly different from zero. The variables found to be insignificant include farm-type measures (proportion of acreage in crops, proportion of acreage owned, whether the farm is a family farm, and hired labor),[13] and farmer characteristics (experience and detailed education measures). Although some studies have included both age and experience as indicators of farmer characteristics, and both acreage and farm income as indicators of farm size, we found that experience and income were dominated by age and acreage; i.e., when both were included, experience and income were not significant.[14] We exclude all of these insignificant variables from our preferred specification.

The multinomial logit (MNL) model assumes independence of irrelevant alternatives (IIA)—i.e., the errors in the random utility model are independent. This assumption would be violated if, for example, the odds of owning a PC without Internet access, relative to not owning a PC, depend on whether or not Internet access is an option. The nested MNL model (McFadden, 1981) is a generalized version of equation (2) that

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[12] Most canned software packages produce the α parameters as output. However, the program we used was written in GAUSS to maximize the likelihood with respect to β, rather than α, so the output from the program is the vector β and its standard errors.

[13] Although some studies have found farm type to be significant, our contrary finding is consistent with Putler and Zilberman (1988).

[14] This is similar to the decision by Hoag, Ascough, and Frasier (1999) to drop the age variable because it was so highly correlated with experience that multicollinearity caused insignificance of the estimated coefficients. Also, although income is often used as a "size" variable, it is very closely correlated with acreage, and also could be considered endogenous if the motivation of the analysis is that computer use augments economic performance. Consequently, income was omitted from this analysis.

Table 1. Maximum-Likelihood Estimates from MNL Computer Adoption Model

Variables	Own Computer $\ln(p_1/p_0)$	Internet Connection $\ln(p_2/p_1)$	Use Internet for Business $\ln(p_3/p_2)$
Age (years)	0.30**	-0.25*	0.41
	(0.13)	(0.13)	(0.88)
Age Squared	-0.0033**	0.0024*	-0.0058
	(0.0012)	(0.0013)	(0.0083)
Total Acreage (000s of acres)	0.50**	0.17	0.34
	(0.22)	(0.26)	(0.21)
Total Acreage Squared	-0.03*	-0.03	-0.04
	(0.02)	(0.03)	(0.03)
More than 200 Days Non-farm Work	-0.11	0.77**	-0.27
	(0.39)	(0.39)	(0.28)
College Degree	-0.62	1.12*	0.05
	(0.48)	(0.45)	(0.28)
Computer Education: ▸ High School	0.24	-0.94	-0.25
	(0.88)	(0.87)	(0.60)
▸ College	0.32	0.71	0.89**
	(0.76)	(0.69)	(0.36)
▸ Friends/Family	2.35**	-0.04	0.64**
	(0.54)	(0.39)	(0.28)
Constant	-7.63**	6.25*	-0.84
	(3.58)	(3.60)	(2.30)

Auxiliary Statistics:

Sample Size	= 517
McFadden's R^2	= 0.21
Proportion of Correct Predictions	= 0.58
Proportion Correct in Naïve Model	= 0.39
IIA Lagrange Multiplier Statistic	= 4.29 (χ^2 critical value = 7.81)

Notes: Single and double asterisks (*) denote statistical significance at the 10% and 5% levels, respectively. Values in parentheses are standard errors.

includes parameters reflecting such a dependence across sub-branches of the decision tree. Using McFadden's (1987) Lagrange multiplier (LM) test to test our MNL model against a nested MNL model, we were unable to reject the null hypothesis of independence (with an LM statistic of 4.29 and χ^2 critical value of 7.81). The MNL model is thus retained as our final empirical specification.

The Results

Table 1 presents maximum-likelihood estimates of the model parameters. This model correctly predicts 58% of the 517 observations, where prediction of the model is the outcome that is assigned the highest probability. This percentage marks a substantial improvement over a naïve model that always predicts no PC, which is the alternative with the highest frequency in the sample. Table 2 further catalogs the predictive ability of the model. The upper panel of table 2 shows that the model successfully identifies 86% of the 201 farmers who do not have a computer, and 73% of the 152 who use the Internet for business. The model does less well at correctly assigning farmers to the two intermediate categories—especially the category of PC owners without an Internet connection.

Table 2. Predictive Success in MNL Computer Adoption Model

		Prediction of Model				
		$Y = 0$	$Y = 1$	$Y = 2$	$Y = 3$	Total
Outcome:	$Y = 0$	173	1	6	21	201
	$Y = 1$	26	2	4	21	53
	$Y = 2$	51	0	12	48	111
	$Y = 3$	34	0	7	111	152
	Total	284	3	29	201	517

Conditional Predictions	Proportion Correctly Predicted	Sample Proportion
Own PC	0.80	0.61
Use Internet | PC	0.84	0.83
Use Internet for Business | Internet	0.65	0.58

Notes: $Y = 0$ denotes no computer, $Y = 1$ denotes a computer without an Internet connection, $Y = 2$ denotes an Internet connection that is not used for business purposes, and $Y = 3$ denotes an Internet connection that is used for business purposes.

This pattern is also evident from the conditional predictive ability of the model, summarized in the lower panel of table 2. In 80% of cases the model is able to correctly predict whether or not a farmer owns a PC; this percentage is substantially higher than the sample proportion of 61%.[15] Conditional on PC ownership, the model correctly predicts Internet connectivity 84% of the time. However, 83% of computer owners had an Internet connection, so this result suggests the model has difficulty identifying non-Internet users. The model also correctly determines 65% of the time whether or not the Internet is used for business, which is somewhat higher than the sample proportion of 58%.

To aid in interpreting the parameter estimates in table 1, predicted probability effects are computed and reported in table 3. These probability effects represent the incremental effect of a one-unit increase in the relevant X variable on the corresponding probability, holding all other odds ratios constant and setting all other X variables to their means. We did not compute elasticities or marginal effects; because many of our explanatory variables are binary, infinitesimal changes in them do not make sense.

As an example of these computations and their interpretation, consider the probability effect of a college degree on Internet connectivity. We wish to measure the incremental effect of having a degree on Internet connectivity, regardless of whether the Internet is used for business or not. Thus, we add together the probabilities of having an Internet connection that is not used for business purposes (p_2) and is used for business purposes (p_3). For the average farmer, we then compute the difference between this sum with and without a college degree. To isolate the incremental effect on Internet use, the relative odds of computer ownership (p_1/p_0) and business use (p_3/p_2) are held constant by holding $\mathbf{X}\beta_1$ and $\mathbf{X}\beta_3$ constant. The probability effect of a college degree on Internet connectivity is therefore:

[15] In discrete choice models such as this one, it is important to use the sample proportion rather than zero as a benchmark for evaluating model fit (Greene, 2003). This approach is analogous to the use of R^2 in linear regression. The R^2 measures the proportion of variation around the sample mean of the dependent variable that the model explains. It does not measure the proportion of variation around zero that the model explains.

Table 3. Probability Effects from MNL Computer Adoption Model

Variables		Own Computer	Internet Connection	Use Internet for Business
Age:[a]	▸ Initial Age = 35	0.007	-0.007**	0.000
		(0.006)	(0.003)	(0.007)
	▸ Initial Age = 55	-0.013**	0.003	-0.006*
		(0.003)	(0.003)	(0.003)
	▸ Initial Age = 75	-0.044**	0.009**	-0.011
		(0.011)	(0.003)	(0.008)
Total Acreage:[b]	▸ Initial Acreage = 200	0.011**	0.003	0.008*
		(0.005)	(0.005)	(0.005)
	▸ Initial Acreage = 1,070	0.007**	0.002	0.007*
		(0.003)	(0.003)	(0.003)
	▸ Initial Acreage = 2,000	0.005**	0.001	0.005*
		(0.002)	(0.002)	(0.003)
More than 200 Days Non-farm Work		-0.02	0.11**	-0.07
		(0.07)	(0.05)	(0.07)
Computer Education:	▸ High School	0.04	-0.18	-0.06
		(0.14)	(0.20)	(0.15)
	▸ College	0.05	0.10	0.21**
		(0.12)	(0.08)	(0.07)
	▸ Friends/Family	0.29**	-0.01	0.16**
		(0.05)	(0.06)	(0.06)
College Degree		-0.12	0.15*	0.01
		(0.10)	(0.06)	(0.07)

Notes: Single and double asterisks (*) denote statistical significance at the 10% and 5% levels, respectively. Values in parentheses are standard errors.
[a] Age effects measure effect of one extra year.
[b] Acreage effects measure effect of 100 extra acres.

$$(4) \qquad PE = p_2^1 + p_3^1 - p_2^0 - p_3^0 = \frac{\exp(\mathbf{X}^1\beta_2)(1+\exp(\overline{\mathbf{X}}\beta_3))}{D^1} - \frac{\exp(\mathbf{X}^0\beta_2)(1+\exp(\overline{\mathbf{X}}\beta_3))}{D^0},$$

where $D^i = 1 + \exp(\overline{\mathbf{X}}\beta_1)(1+\exp(\mathbf{X}^i\beta_2)(1+\exp(\overline{\mathbf{X}}\beta_3)))$, and $\overline{\mathbf{X}}$ is the mean of $\mathbf{X}$. The vector $\mathbf{X}^0$ denotes the initial value of $\mathbf{X}$ with college degree = 0 and all other variables set to their mean. The vector $\mathbf{X}^1$ is identical to $\mathbf{X}^0$ except that college degree = 1. Similarly, $p_2^0 + p_3^0$ is the probability of using the Internet if the farmer does not have a college degree, and $p_2^1 + p_3^1$ is the probability with a degree.

The calculation of probability effects is identical for each of the dummy variables in the model. For the age and acreage variables, these effects are measured as the difference in probabilities for one-year or 100-acre increments, respectively. The probability effects are evaluated for low, medium, and high values of age and acreage, because the effect of these variables is nonlinear due to the quadratic terms. Standard errors for the probability effects are estimated by the delta method (Greene, 2003, p. 674).

The probability effects for age are calculated at the sample mean, 55 years, and also at 35 and 75 years. Table 3 shows that a one-year increase in age reduces the probability of PC ownership by 0.044 for a 75-year-old. The negative effect is smaller (-0.013) for a 55-year-old, and is insignificant from zero for a 35-year-old. The estimates in table 1 indicate PC ownership is decreasing in age for farmers older than 45 (similar to findings reported by Putler and Zilberman, 1988). The effect of age on business-related Internet use is smaller in absolute value than for PC ownership, and is decreasing after age 35. A one-year increase in age for a 55-year-old farmer reduces the probability of business-related Internet use by 0.006, but has an insignificant impact for a 35- or 75-year-old. The negative but small predicted effects of age on Internet connectivity and business-related Internet use are similar to findings for computer adoption in Batte, Jones, and Schnitkey (1990) and Hoag, Ascough, and Frasier (1999), suggesting farmers' position on the learning curve for the Internet may be likened to that for computer adoption in previous years.

The probability effects for acreage are evaluated at the sample mean, 1,070 acres, and also at 200 and 2,000 acres. The coefficients on the quadratic term for farm size in table 1 are small for all three outcomes (PC ownership, Internet connectivity, and business-related Internet use), causing the probability effects of acreage to be positive over the entire observed range of farms. Nonetheless, although PC ownership is increasing in farm size, the marginal effect is decreasing in farm size. This result is consistent with the findings of Putler and Zilberman (1988), who also noted a decreasing marginal effect. Table 3 shows that the probability effect of acreage is small. Even for small farms of 200 acres, an increase of 100 acres only increases the estimated probability of PC ownership by 0.011. The effects of acreage on Internet connectivity and use of the Internet for business are smaller. For Internet connectivity, the effects are insignificantly positive, and for business-related Internet use the effects are only significant at the 10% level.

Off-farm employment has a strong positive effect on Internet connectivity, but insignificant effects on PC ownership and business-related Internet use (table 3). The relationship between computer use and off-farm employment is broadly consistent with Hoag, Ascough, and Frasier (1999), although our model indicates that the effect is through Internet access rather than PC ownership. Thus, computers have been adopted to the extent that off-farm employment no longer increases the probability of PC ownership. However, farmers have yet to reach the same level of assimilation for Internet use. These results again reveal a learning effect; farmers have progressed along the learning curve for computers. This link also suggests that off-farm employment may play a role in providing computer education for farmers. Alternatively, the causality could flow in the opposite direction whereby computer use on the farm helps develop skills required for off-farm jobs (Wojan, 2000).

As seen from table 3, having a college degree also increases the probability of an Internet connection (by 0.15), but insignificantly affects PC ownership and business-related Internet use. Positive effects of education on computer adoption are common in the existing literature, and Putler and Zilberman (1988) identified a link with college education in particular. For off-farm employment, however, the link we identify is to Internet connectivity rather than to computer ownership. This result further supports Hoag, Ascough, and Frasier's (1999) suggestion that education's effect on adoption and use falls later in the innovative process.

Computer education through friends and family has large positive effects of 0.29 on PC ownership and 0.16 on business-related Internet use (table 3). However, none of the three computer education variables significantly affect Internet connectivity. Computer classes in high school are not significant for any of the choices, but college computer classes increase the likelihood of business-related Internet use by 0.21. These computer education results provide further evidence that formal education promotes the adoption of newer technology such as the Internet, but has less impact on better established technology like computers.

Overall, the results in tables 1 and 3 show that age, farm size, outside employment, and college education do matter for the adoption of PC and Internet technology. However, exposure to computers and the Internet through family and friends is more important as the technology matures. These findings are consistent with Iddings and Apps' (1990) contention that general education and computer courses (which farmers may perceive as irrelevant for their purposes) are less important to farmers than more contained support systems and information. These results also support Iddings and Apps' assertion that attempts (such as through extension services) to enhance farmers' performance by encouraging the use of computers require more attention to farmers' specific needs rather than just providing general formal classes, except perhaps when the technology is new.

Internet Usage Patterns and Perceived Benefits

Internet Usage Patterns

Farmers use the Internet for their business in various ways and in differing amounts. In our sample, 93% of farmers who used the Internet for their business gathered information, 6% marketed products, and 35% purchased goods and services on the Internet.

Although it is difficult to evaluate the extent of Internet use by those farmers who obtained information on the Internet, the different types of information they sought can be categorized. Of those farmers who used the Internet to obtain business information, 67% got information on commodity markets, 58% got technical information on inputs, and 51% obtained pricing information on inputs. Furthermore, financial information was sought by 38%, weather information by 78%, and information on agricultural policy by 39%. Most farmers obtained multiple types of information; 92% retrieved more than one type of information, and 50% collected at least four types of information.

The average value of the goods and services marketed on the Internet was $29,071, but only seven farmers used the Internet to market their products. Four of the seven had gross earnings greater than $100,000, and six had gross earnings exceeding $25,000. In the full sample, 40% reported gross earnings greater than $100,000, and 70% had gross earnings exceeding $25,000. While these differing proportions provide some indication that size may be related to Internet use, with such a small number of marketers it is difficult to draw general conclusions.

Nevertheless, we do have a sufficiently large sample of farmers who purchased goods and services over the Internet, as well as information on the dollar value of the products they purchased, to gain some insights about Internet usage patterns. Because 65% of business-related Internet users made no purchases over the Internet, a standard linear regression model cannot be used to evaluate such purchases. Rather, we assume that farmers who use the Internet for business make two decisions simultaneously—whether to make Internet purchases and how much to purchase. A two-equation Heckman selection model (Heckman, 1979) is used to characterize these decisions. A total of 131 farmers used the Internet for business and had no missing data on the variables of interest.

Table 4. Maximum-Likelihood Estimates from Purchasing Model

Variables	ln(Purchases)	pr(Purchases > 0)
Age (years)	-0.04	-0.01
	(0.03)	(0.01)
Acreage (000s of acres)	0.003	0.26**
	(0.207)	(0.11)
ln(*Gross Income*)	0.45**	-0.36**
	(0.22)	(0.11)
College Degree	-1.05*	-0.14
	(0.59)	(0.26)
Family Farm		0.35
		(0.29)
More than 200 Days Non-farm Work		-0.29
		(0.27)
No. of Years Using Internet for Business		0.19**
		(0.07)

Auxiliary Statistics:

Sample Size	= 131
% Correct in Selection Equation	= 0.76
Sample Proportion w/Purchases > 0	= 0.31
Error Correlation (ρ)	= -0.62
Likelihood-Ratio Test for ρ = 0	= 2.25 (*p*-value = 0.13)

Notes: Single and double asterisks (*) denote statistical significance at the 10% and 5% levels, respectively. Values in parentheses are standard errors.

These farmers are included in the sample for the selection equation, which models the choice of whether to purchase. Of the 131 farmers, 40 reported the dollar amount of their Internet purchases, and so comprise the sample for the equation for the effect of spending on Internet purchases.

In our purchasing model, we use most of the same explanatory variables as in our examination of Internet adoption. However, the computer education variables and the quadratic terms for age and acreage were insignificant and thus were excluded from the final model. The number of years using the Internet for business and gross farm income are also added, enabling us to estimate the elasticity of purchases with respect to income.[16]

Maximum-likelihood estimates for this purchasing model are presented in table 4. Farm size and Internet experience are the most important variables determining whether business-related Internet users chose to make Internet purchases. The positive effect of years using the Internet indicates farmers become more likely to use the Internet as they gain experience with it. This finding is consistent with Iddings and Apps' (1990) conclusion that farmers avoid using computers if they do not initially have positive experiences with this technology. Conversely, this finding suggests more use of the technology is encouraged by positive experiences.

The effects of acreage and gross farm income work in opposite directions in the selection equation. For a given income level, large farmers are more likely to purchase goods

[16] Our data on gross income are measured on a discrete scale from 1 to 10. In this model, we measure gross income using the midpoint of each of the 10 intervals.

and services on the Internet. However, for a given farm size, higher income farmers are less likely to make Internet purchases. It is unclear why this is so, especially because gross income has a strong positive relationship with the amount of Internet purchases. The estimated income elasticity of Internet spending shows that a 1% increase in gross income is associated with a 0.45% increase in Internet purchases (table 4). Thus, although high gross income farmers are less likely to make Internet purchases, when such purchases are made, they tend to be larger.

The estimated correlation between the errors in the selection and spending equations is -0.62 (table 4). The negative error correlation implies that farmers who make Internet purchases when not predicted to by the model tend to make relatively small purchases. However, this estimate is imprecise because of the small sample size, and a likelihood-ratio test only rejects the null hypothesis of zero correlation at the 13% level of significance.

Perceived Benefits of Internet Use

The benefits of Internet use are measured by farmers' estimates of returns from various Internet applications and by a qualitative variable measuring whether the Internet contributed to farm competitiveness. These perceived benefits vary substantially, and many farmers report zero returns from Internet use. The only direct costs of Internet use captured in our data are connection and subscription expenditures. However, the true cost of the Internet also includes the purchase of the PC and the learning process required for its effective use.

The average annual cost of an Internet connection for business-related Internet users was $237. The incremental cost of connecting to the Internet for business is less than this amount because 99% of business users also use the Internet for personal matters. For those who collected information about running their farm from the Internet, the average subscription cost for this information was $10 (including the 129 out of 141 farmers who reported zero costs). Thus, the combined direct cost of Internet connection and subscription services to farmers is very low. However, for many farmers, the time cost of learning to use the Internet may be large, and therefore may present the greatest barrier for effective use. This assertion is supported by the importance of the computer education and off-farm employment variables in our Internet adoption model.

Of the 141 farmers who used the Internet to obtain business information, only 30% reported that the information helped them increase their financial returns. A zero increased return was reported by 61% of these farmers, and the remaining 9% did not respond to the question. Conditional on reported returns being nonzero, average reported returns were $3,753 (see appendix table A3). This value drops to $1,160 if averaged across all 141 farmers who used the Internet for business, with returns set to zero for nonrespondents.

Of the farmers who used the Internet to make business-related purchases and reported the dollar value of total purchases, average cost savings were $1,036. Their average purchases totaled $7,655, implying a cost saving of 14% (see table A3). However, only 42% of the farmers who made Internet purchases reported positive cost savings; for these farmers, cost savings averaged $1,836, representing 23% of their total purchases. For the seven farmers who marketed their products on the Internet, average reported increased returns were $6,188, or approximately 20% of the value of the marketed goods

Table 5. Maximum-Likelihood Estimates from Perceived Enhanced Competitiveness Logit Model

Variables	Parameter Estimates	Probability Effects
Family Farm	-1.10**	-0.25**
	(0.51)	(0.10)
No. of Years Using Internet for Business	0.29**	0.07**
	(0.12)	(0.03)
Type of Information Collected:		
▸ Technical for Inputs	-0.07	-0.02
	(0.42)	(0.10)
▸ Pricing on Inputs	1.13**	0.27**
	(0.44)	(0.10)
▸ Ag Commodity Markets	1.20**	0.29**
	(0.44)	(0.10)
▸ Financial	-0.16	-0.04
	(0.44)	(0.11)
▸ Weather	-0.26	-0.06
	(0.51)	(0.12)
▸ Ag Policy	-0.02	-0.01
	(0.45)	(0.11)
Use Internet for Purchases	0.68	0.16
	(0.45)	(0.11)

Auxiliary Statistics:

Sample Size	= 152
McFadden's R^2	= 0.20
Proportion of Correct Predictions	= 0.71
Sample Proportion	= 0.53

Notes: Single and double asterisks (*) denote statistical significance at the 10% and 5% levels, respectively. Values in parentheses are standard errors.

(see table A3). Although these gains seem substantial, it is difficult to generalize due to the small sample of farmers whose data provide this returns information.

However, 53% of the 152 farmers who used the Internet for business reported that Internet use enhanced their competitiveness. Thus, we have a large enough sample to generate some inference about the overall perceived benefits of the Internet. To explain which farmers found the Internet beneficial, a logit model is estimated for whether farmers believed the Internet helped them compete. This model is estimated only for those farmers who used the Internet for business. The resulting parameter estimates and probability effects are presented in table 5, computed as for our MNL adoption model.

The only farm or farmer characteristic that significantly affects perceived benefits of the Internet is whether the farm is a family farm. The probability that the Internet is deemed beneficial is 0.25 lower for family farms, suggesting such farmers may have a higher propensity to use the Internet primarily for personal tasks. This finding provides support for Hoag, Ascough, and Frasier's (1999) conclusion that small family farmers value computers less than do large corporate farmers. However, the perceived benefits of the Internet as a business tool appear to be unrelated to the size of a farm, the age of the farmer, or the education level of the farmer.

The variables found to matter most for perceived improvements in competitiveness relate to how the Internet is used in the business. Farmers who make purchases on the Internet are not significantly more likely to report that Internet use improved their competitiveness. However, using the Internet to obtain information on input pricing or agricultural commodity markets increases the probability of finding the technology useful by 0.27 and 0.29, respectively (table 5). These estimates support Amponsah's (1995) argument that information contributes to efficiency if it helps farmers make better decisions and manage risk. This evidence is also consistent with Iddings and Apps' (1990) claim that enhancing farmers' performance may require convincing them of the importance of quality management and information.

Gathering other types of information from the Internet does not appear to help farmers compete. For information on weather, this may be because close substitutes exist in the form of newspapers, television, and radio. The marginal cost of obtaining weather information is likely to be low for all sources, so the benefit of obtaining it through the Internet is correspondingly low. In contrast, for example, information on commodity markets and input prices is less readily available from other sources. Obtaining information on agricultural policy or technical characteristics of inputs also does not seem to enhance competitiveness. An explanation for this result is that such information is difficult to use in production decisions and so is gathered more out of curiosity.

The number of years using the Internet for business is also associated with a higher probability of enhanced perceived competitiveness (table 5). This association could indicate a learning effect; farmers find the Internet more useful as they spend time using it and discover where the benefits lie. This result epitomizes Feder and Slade's (1984) contention that "... improved knowledge regarding new technologies through the accumulation of information over time is ... one of the main dynamic elements of innovation adoption processes" (p. 312). In reverse, farmers may simply continue to use the Internet for business because they find it useful.

Concluding Remarks

In this study we have explored farmers' adoption, usage patterns, and perceived benefits of computers and the Internet, using a more recent data set than employed in the existing literature. Our results are consistent with the assertion of Hoag, Ascough, and Frasier (1999) that factors like age and formal education become less relevant for technology adoption as farmers move up the learning curve. Not surprisingly, given the Internet was only introduced commercially in 1995, the learning curve for the Internet lags behind that for computers. This lag suggests additional benefits will be internalized for farmers as they become more familiar with the Internet and its potential for enhancing their competitiveness.

The effects of age, general education, and farm size on computer use patterns seem less significant than found in earlier studies, particularly for PC ownership. However, increasing familiarity and experience with computers through family, friends, college, outside work, and simply over time have important impacts on the use of computers and the Internet. In turn, the perceived benefits of these technologies for farm business depend on how long the farmer has used the Internet for business and for what purposes. Using the Internet to obtain information on input prices and commodity markets appears to be especially valuable for enhancing competitiveness.

However, only about half of the farmers in our sample who use the Internet for business believe it has increased their competitiveness, and even fewer report positive economic returns. This limited perception of the technology's impacts on farm performance may be partially explained by its general-purpose attributes.[17] Because a computer becomes a fixed cost once it is purchased, and Internet access is typically priced at a flat rate, there can be a conflation of business and non-business use. If a farmer already has a computer with Internet access for personal use, the marginal cost of performing some business applications on the Internet is close to zero. This farmer will therefore use the Internet to gather, for example, business-related information even if the financial benefits of this information are negligible.

Perceived benefits of Internet use for farm business will likely increase as more farmers move up the learning curve, as the technology becomes more applicable to farm business, and as new applications and services become available. For example, voice over Internet Protocol (Voice over IP) will eliminate long distance charges, and wi-fi wireless networks will permit mobile Internet applications on the farm. Further research tracking these changes and better identifying and distinguishing both business and non-business benefits of farm Internet use are particularly important for understanding how it might change farm production processes and competitiveness in the future.

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[17] For more on general-purpose technologies, see Bresnahan and Trajtenberg (1995); Helpman (1998).

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Appendix: Survey Data Tables

Table A1. Survey Questions: Farmer Characteristics

Question	Mean
How many years have you been a farm operator or rancher?	29.9
In what year was the principal farm operator or rancher born?	1945.7
Did the principal farm operator or rancher work more than 200 days in non-farm work in 2000?	0.32
How much education does the principal farm operator or rancher have?	
1. No formal education	< 0.01
2. Some grade school	0.01
3. Completed grade school	0.03
4. Some high school	0.04
5. Completed high school	0.38
6. Some college	0.25
7. Completed college	0.21
8. Some graduate work	0.04
9. Graduate degree	0.04
How much formal computer-related education does the principal farm operator or rancher possess? (Check all that apply)	
1. None	0.61
2. High school courses	0.06
3. Computer courses offered by a computer store or vendor	0.06
4. College computer courses	0.14
5. Online instruction or courses	0.02
6. Instruction from friends or family	0.24
7. Instruction available in software programs	0.10

Notes: Total number of observations = 517. For yes/no questions, means comprise the proportion of yes answers.

Table A2. Survey Questions: Farm Characteristics

Question	Mean
During 2000, which of the following best describes your farm or ranching operation?	
1. Family farm	0.81
2. Farm in partnership	0.04
3. Farm in corporation	0.08
How many full-time workers did you employ on your farm in 2000?	0.36
What is the total acreage of the land you operated in 2000?	1,070
Of the total acres you operated in 2000, how many did you own?	522
Of the total acres you operated in 2000, how many did you rent or lease?	551
Of the total acres you operated in 2000, how many were used for the following purposes?	
1. Acres of cropland	553
2. Acres of pastureland	481
In 2000, what was your total gross farm income? (Gross farm income is your total farm income before subtracting expenses.)	
1. $2,499 or less	0.08
2. $2,500 to $4,999	0.04
3. $5,000 to $9,999	0.04
4. $10,000 to $24,999	0.14
5. $25,000 to $49,999	0.12
6. $50,000 to $99,999	0.18
7. $100,000 to $249,999	0.25
8. $250,000 to $499,999	0.11
9. $500,000 to $999,999	0.03
10. $1,000,000 or more	0.01
In 2000, what was your net farm income? (Net income is gross farm income minus expenses.)	
1. Costs exceeded income in 2000	0.21
2. Broke even	0.12
3. $4,999 or less	0.13
4. $5,000 to $19,999	0.22
5. $20,000 to $49,999	0.24
6. $50,000 to $99,999	0.07
7. $100,000 to $249,999	0.01
8. $250,000 or more	< 0.01

Notes: Total number of observations = 517. For categorical questions, means comprise the proportion in each category.

Table A3. Survey Questions: Computers and the Internet

Question	Mean	
Adoption:		
▸ Do you have a personal computer?	0.61	
▸ Do you use your personal computer as a business tool for your farm or ranching operation?	0.43	
▸ Is your computer set up to access the Internet?	0.51	
How much do you pay per month for Internet access?		$19.98
▸ Do you, or other members of your household, use the Internet for non-business purposes?	0.50	
▸ Do you use the Internet as a business tool for your farm or ranch?	0.30	
In what year did you begin using the Internet as a business tool for your farm or ranch?		1997.05

(continued . . .)

Table A3. Continued

Question		Mean
Use Internet for Information:		
▸ Do you currently use the Internet to obtain information that you use in running your farm or ranch?	0.28	
How much do you currently pay in subscription fees to access Internet sites to obtain information you need to run your business?		$10.28
▸ Which of the following types of business information do you obtain over the Internet?		
1. Technical information about inputs	0.17	
2. Pricing information about inputs	0.15	
3. Information about commodity markets	0.20	
4. Financial information	0.11	
5. Weather information	0.23	
6. Information on agricultural policy	0.11	
7. Information from chat rooms	0.11	
▸ Would you say that using the Internet to acquire business information has increased the financial returns to your farm or ranch during the past year?	0.08	
What is the estimated dollar value of the increased financial returns that you received in 2000 as a result of using the Internet to acquire business information?		$3,753
Use Internet for Purchasing:		
▸ Do you use the Internet to purchase goods and services that you use in operating your farm or ranching business?	0.10	
What is the estimated dollar value of the goods and services that you purchased over the Internet in 2000 for use in operating your farm or ranch?		$7,655
In 2000, what would you estimate to be the dollar value of your cost savings from using the Internet to purchase goods and services that you use in operating your farm or ranching business?		$1,036
Use Internet for Marketing:		
▸ In 2000, did you market any of the commodities that you produce or any services using the Internet?	0.02	
What is the dollar value of the commodities and services that you marketed over the Internet in 2000?		$29,071
What was the dollar value of the extra sales revenues that you received in 2000 as a result of marketing commodities over the Internet?		$6,188
Use Internet for Own Web Page:		
▸ Do you operate a business web site for your farm operation or ranch?	0.01	
Overall Benefit:		
▸ Overall, has using the Internet improved the ability of your farm or ranch to compete in your industry?	0.16	

Notes: Total number of observations = 517. Indented entries are conditional on previous entry; e.g., average monthly access fee = $19.98 for those farmers who have Internet access. All other entries are averages over the entire sample. For yes/no questions, entries comprise the proportion of yes answers. Italicized subheadings were not part of the survey; they were added to this table for clarity.