Internet Access and Internet Purchasing Patterns of Farm Households

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The Internet is becoming an increasingly important management tool in production agriculture. Using data from the 2004 Agricultural Resource Management Survey (ARMS) and a double-hurdle estimation approach, we explore the adoption of computers with Internet access by and Internet purchasing patterns of farm households. Adoption of the Internet is positively related to age and education of the operator, off-farm work, presence of spouse, participation in government programs, farm size, and regional location of the farm. Internet purchasing patterns of farm households are positively related to the education of the operator and spouse, presence of teenagers, and regional location of the farm. Finally, farm businesses and their households are more likely to purchase a greater percentage of non-durable goods through the Internet as distances to markets increase.

Key Words: adoption of Internet, education, farm size, farm households, Internet, double-hurdle model, farm business, major household items, minor farm inputs

The Internet is a strategic technology that is used across all sectors of the economy (Cohen et al. 2001). Farming and other agriculture-related industries are no exception (Kinsey 2001). While participation in federal government programs is only one reason that America's farmers use the Internet, it is perhaps the primary reason for an increased interest in Internet use among farmers.[1] While data available from the USDA's Agricultural Resource Management Survey (ARMS) does not include information regarding farmers' electronic program participation, it does enable researchers to evaluate the ability of farmers to access the Internet from their homes and/or business locations.[2] It is important to note that the value of the Internet extends beyond its role in farming and economic activity to include the social realm as well. The Internet permits the formation of online (virtual) communities and access to cultural and social networks beyond an individual's locality (Wellman et al. 1996). As a social entity, a family farm consists of a dual organizational structure—a farm business and a household consisting of the farm operator and family members. The implication for Internet adoption is that in addition to the farm business, the Internet has many uses for the farm household.

According to the U.S. Census Bureau, approximately 62 percent of U.S. households own a computer and nearly 75 percent of U.S. households with a phone line have access to the Internet (Nielsen//NetRatings 2004). The Internet has steadily penetrated rural areas in recent years, and more than half of rural adults—52 percent—now go online (Mishra and Park 2005). Rural residents are enthusiastic users of the Internet and were early adopters of this technology—45 percent of rural residents go online daily.

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[1] The Farm Service Agency, a major provider of farm program payments to farmers, currently has 78 farm program forms available to farmers to complete and submit electronically via the Internet. Many other federal agencies that administer programs to the nation's farmers have followed suit.

[2] ARMS data includes information on whether the farm operation received farm program payments. In this study, receipt of farm program payments is used as a proxy for electronic program participation by farmers.

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Previous studies have focused on computer adoption by farmers and Internet adoption/use by farmers (Putler and Zilberman 1988, Batte, Jones, and Schnitkey 1990, Ortmann, Patrick, and Musser 1994, Mishra and Park 2005). Other studies have examined computer and/or Internet adoption and its impact on economic performance of the farm business (Lazarus and Smith 1988, Willimack 1989, Batte 2005). Internal factors such as record-keeping, decision-making, and production processes are some of the reasons for computer adoption by farmers (Holt 1985). External factors such as Internet research and marketing might also play an important role through the growth of information that has competitive value (Feder and Slade 1984). For example, farmers can use the Internet to search for input supplies and to locate potential buyers of their products, increasing their efficiency (via true market conditions). Wojan (2003) noted—but did not empirically evaluate—the potential benefits from farmers' Internet use.

The adoption of computers with Internet access may be due to several factors; for example, presence of a spouse who is working off the farm, the number of adult children who are exposed to Internet technology in schools, and off-farm businesses owned by farm operators and/or spouses that use the Internet to market and advertise their business's products to potential clients. Although a considerable amount of empirical research has addressed Internet adoption, the existing empirical literature has taken a rather narrow approach to the issue. In particular, existing empirical research has largely focused on the farm *business* as the relevant unit of analysis rather than the farm *household*. The farm *household* exerts at least some influence on the decisions made in the farm *business*, when examining the adoption of a technology that can be used by both the farm *business* and the farm *household*.

This study provides information regarding access to the Internet by farm households. In particular, the objective of this paper is twofold. First, the study identifies the factors associated with adoption of computers with Internet access. Second, the study investigates farm, operator, spouse, presence of children, regional, and household characteristics that influence Internet purchasing patterns (farming business and household usage).[3] The analysis emphasizes the roles of human capital, education, presence of spouse, educational attainment of spouse, and presence of children in various age groups on the probability of adopting Internet use. The need to analyze the contribution of the human factor in Internet adoption is due to the continuing rise in the number of U.S. farm operators with higher education, increasing productivity, and the bridging of the information gap between urban and rural populations.[4] The analysis is conducted on a national level with the unique feature of a larger sample than has been used in previous research comprising farms of different economic sizes and in different regions of the United States.

The paper assumes that decision-making processes for farming, technology adoption, and other issues involve the farm *household* (i.e., both the farm operator and spouse), not just the farm *business*. First, our data is rich enough to capture the educational level of the farm operator and spouse. Second, we have information on the work decisions (farm and off-farm) of the farm operator and spouse. Third, ARMS collects information on the composition of the family, such as the number of children in various age categories.

Literature Review

There are two strands of literature on computer adoption by farm operators and their household. The first focuses on farmers' use or adoption of computers and is based on various survey data that are mostly localized (Iowa, New York, California, Ohio, and the Great Plains) (Lazarus and Smith 1988, Putler and Zilberman 1988, Willimack 1989, Batte, Jones, and Schnitkey 1990, Huffman and Mercier 1991, Ortmann, Patrick, and Musser 1994, Batte 2005).[5] In the majority of published studies, choices are modeled in a qualitative form as a function of farm, operator, and financial characteristics (explanatory variables). More recently, Mishra and Park (2005) used count data analysis to study the number of times farmers accessed the Internet. In addition, many studies address net benefits (Batte, Jones, and Schnitkey 1990, Amponsah 1995, Hoag, Ascough, and

[3] See Figure 1.

[4] While only 10 percent of the operators had attended or graduated from college (including graduate education) in 1964, this number rose to nearly 48 percent in the 2004 ARMS survey (USDA 2004).

[5] Only Mishra and Park's (2005) study used national farm-level data from USDA.

Frasier 1999) and types and number of applications (Putler and Zilberman 1988, Batte, Jones, and Schnitkey 1990).

Previous studies also include farmer age, education level of the farm operator, and farm size as explanatory variables. Some studies have included farming experience as a replacement for farmer's age (Hoag, Ascough, and Frasier 1999), while others (Lewis 1998) use age as a proxy for farm experience. It has been argued that young farmers are more familiar with computers (Putler and Zilberman 1988). Moreover, educated farmers are more likely to adopt a technology (computers with Internet access) since education represents greater capacity to learn and perhaps is an indicator of prior experience with computers. Huffman's (2001) review of human capital impact on agriculture focuses on the effects of education on technology adoption. Lewis (1998) studies adoption and use of sophisticated farm management information systems (FMIS) to reflect innovations in farm operations. Batte, Jones, and Schnitkey (1990) and Amponsah (1995) found that education had a positive effect on computer adoption, and that age had a negative impact on the number of applications and perceived benefits by farmers. Off-farm employment status of farmers is sometimes used as a proxy for experience with computers (Huffman and Mercier 1991, Hoag, Ascough, and Frasier 1999, Mishra and Park 2005). Mishra and Park (2005) argue that farmers with off-farm employment are more likely to have experience with computers and to seek information via the Internet.

To capture scale of operation effect on computer adoption, studies have included farm size, as measured in acres or volume of sales (Mishra and Park 2005), and farm income and expenditures (Amponsah 1995, Hoag, Ascough, and Frasier 1999) as explanatory variables in the models of computer adoption. Hoag, Ascough, and Frasier (1999) found a positive impact of farm size (acres) on computer adoption. Their results further indicate that size had an inverted U-shaped impact, implying that mid-sized farms were the most likely to adopt. Indicators such as the number of farm enterprises, the number of products produced, and/or a diversification index (such as Theil's Entropy Index) have been used to capture the impact of flexibility or more varied decision-making processes on the adoption of computers (Putler and Zilberman 1988, Huffman and Mercier 1991, Mishra and Park 2005). Other indicators of management intensity include tenancy or farm ownership (Batte, Jones, and Schnitkey 1990, Huffman and Mercier 1991, Hoag, Ascough, and Frasier 1999, Mishra and Park 2005) and the existence of a formal record-keeping system (Batte, Jones, and Schnitkey 1990, Amponsah 1995).

The study by Mishra and Park (2005) is unique in several ways. First, their study uses large national farm-level data from the USDA. The dataset has several desirable properties; in addition to all the farm and operator characteristics, the data also has information on the spouses, family size, financial characteristics, and work decisions of spouses. The second unique factor is the use of a count data method. Mishra and Park (2005) investigated the ways farm operators use the Internet, rather than the adoption of computers. In particular, their study investigated factors that affect the number of different types of applications that a farm operator performs using the Internet. Third, they used information on work habits of spouses on the number of Internet applications performed by the household. Finally, the authors included regional variables to capture the regional difference in number of Internet applications used by farmers in various regions of the United States.

A second strand of literature focuses on the purchasing patterns of farm households via the Internet; however, available literature in this area is thin compared to the computer adoption literature. Farm operators and their households must make two choices with regard to input purchases. First, whether to buy it locally, and second, whether to use the Internet to find the product for a cheaper price and/or the ability to have the product delivered cheaply enough to offset the time constraints of having to go to a physical location and purchase the item. Applying this concept, Foltz and Zeuli (2005), using longitudinal data from Wisconsin dairy farms, examined the factors affecting farms' propensity to purchase locally when accounting for differences in both farmer attitudes and community characteristics. They found little evidence for linkage between farm-level characteristics and local purchasing patterns. The authors, however, concluded that the number of local marketing outlets offered positively influences the decision by farms to purchase inputs locally. In a recently published article, Batte and Ernst (2007) investigated farmers' willingness to substitute online merchants or national farm input stores for local businesses. Using survey data from Ohio and conjoint analysis, they concluded that farmers are willing to purchase inputs from online or national stores outside their communities if compensated with lower prices and/or greater service.

A couple of studies highlight the importance of e-commerce in agriculture. E-commerce in agriculture could potentially tighten the supply chain and cut marketing margins and transactions costs in ways that benefit smaller, local producers as well as local agribusiness firms. Ehmke, Hopkins, and Tweeten (2001) evaluate the acceptance of e-commerce among agribusiness firms in Ohio. The authors conclude that half of agribusinesses in Ohio believe that there is no point in buying or selling products online. This resistance to implementing e-business practices, including e-commerce, stems from commitment to tradition and lack of familiarity with information technology. The authors also report that many agribusiness firms found the costs of running an e-commerce venture very expensive because they lacked the necessary human capital to make such a venture cost-effective. In another study, Henderson, Dooley, and Akridge (2004) investigated Internet and e-commerce adoption by farm input firms. Using responses from 643 agribusiness firm managers, they found that although most agricultural firms were active participants on the Internet, only a few engaged in e-commerce activities with their customers. Firms upstream in the distribution channel were much more likely to be engaged in e-commerce than their downstream counterparts were. Finally, Henderson, Dooley, and Akridge (2004) note that agricultural input firms are more likely than their farm customers to conduct e-commerce business with their suppliers. Although we cannot measure the supply side of Internet in our data directly, we do have information on distance traveled to buy household items and farm inputs. The notion is that convenience or time constraints might matter in the decision to buy via the Internet.

Empirical Framework

These types of estimation are very popular when studying time allocation decisions. Most of the previous studies in computer and Internet adoption have used either logit or multilogit models to estimate adoption. On the other hand, a traditional approach to dealing with censored dependent variables (in our case the intensity or share of farm business and household items purchased through the Internet) has been to use the standard Tobit model. Specifically, the model permits incorporation of all observations, including those censored at zero. Cragg (1971) modified the Tobit model to overcome the restrictive assumption inherent in it. He suggests the "double-hurdle" model to overcome the problem of too many zeros in the survey data by means of estimating a participation decision model first. In particular, the model assumes two hurdles to be overcome in order to observe positive values (Baum 2006). For example, in our study an individual has to overcome two hurdles in order to report Internet use for farm input purchases or household purchases. The first hurdle relates to whether or not the individual or household has access to the Internet, and the second to the percentage of farm business conducted or household purchases made through the Internet. In general, the first hurdle refers to the participation or ownership decisions, and the second hurdle to the level or intensity of use. The model permits the possibility of estimating the first and the second stage using a different set of explanatory variables. Further, in contrast to Heckman's (1979) procedure, the double-hurdle model[6] considers the possibility of zero realizations (outcomes) in the second hurdle arising from the individuals' deliberate choices or random circumstances. The difference between Heckman's procedure and the double-hurdle procedure is the following. In Heckman's procedure, only non–Internet-owning respondents can report zero percentage of purchase (either farm business or household items). Further, the model assumes that households owning a computer with Internet access do not report zero values at all (Woolridge 2002, Cameron and Trivedi 2005). In the case of the double-hurdle model, zero values can be reported in both decision stages. The zero value reported in the first stage (participation decision) arises from non-adoption of computers with Internet, and those in the second stage (intensity of

[6] The double-hurdle model has been widely applied in household consumption and labor supply decisions.

use) come from non-computer with Internet use due to respondents' deliberate decisions or random circumstances. In this regard, both Woolridge (2002) and Cameron and Trivedi (2005) conclude that the double-hurdle model can be considered as an improvement both on the standard Tobit and Heckman type of models. Further, the likelihood ratio test reveals the double-hurdle model to be the appropriate methodology in modeling the Internet purchasing patterns of farm households.[7]

For the purpose of this study, the underlying assumption of the double-hurdle model is that farm households make two decisions with respect to Internet purchases in an effort to maximize utility: whether to adopt a computer with Internet access in the farm household (participation decision), and how many (percentage) business and household items to purchase via the Internet. The participation and percentage of purchases (business and household) are determined by a set of independent variables (Cragg 1971). Therefore, in order to observe a positive level of purchases, two separate hurdles must be passed. Two latent variables are used to model each decision process with a binary choice model determining participation and a censored model determining the purchasing level (Blundell and Meghir 1987):

(1) $y_{1i}^{*} = X_{1i}'\beta_1 + \nu_i$ having Internet,

$y_{2i}^{*} = X_{2i}'\beta + \mu_i$ percentage of business and household items purchased through Internet.

Using Blundell and Meghir's (1987) formulation, the decision to have Internet access and the share of business and household purchases made through the Internet can be modeled as

$$(2)\qquad E_i = x_i'\beta + \mu_i \quad \text{if } y_{1i}^{*} > 0 \text{ and } y_{2i}^{*} > 0$$
$$E_i = 0 \qquad \text{otherwise,}$$

where y_{i1}^{*} is a latent variable describing the household's access to Internet; y_{i2}^{*} is the observed level (percentage) of farm business and household items purchased through the Internet; X_{1i} is a vector of explanatory variables accounting for the decision to have Internet access; X_{2i} is a vector of explanatory variables accounting for the percentage of business and household purchases made via the Internet; E_i is the share of farm business and household items purchased through the Internet; and ν_i and μ_i are respective error terms assumed to be independent and distributed as $\nu_i \sim N(0,1)$ and $\mu_i \sim N(0, \sigma^2)$.[8] The likelihood ratio test (test statistics of 7.26 and critical value $\chi^2_{2,0.01} = 9.21$) fails to reject the restricted model of homoscedasticity in favor of the alternative variance specification. The model assumes that both access to Internet and purchasing decision equations are linear in their parameters α and β. Consistent estimates of the double-hurdle model can be obtained by estimating (maximizing) the following likelihood equation:

$$(3)\quad LL = \sum_0 \ln\left[1 - \Phi\left(X_{1i}'\beta_1\right)\pi\left(\frac{X_{2i}'\beta_2}{\sigma}\right)\right] + \sum_+ \ln\left[\Phi\left(X_{1i}'\beta_1\right)\frac{1}{\sigma}\varphi\left(\frac{E_i - X_{2i}'\beta_2}{\sigma}\right)\right].$$

The first term in equation (3) corresponds to the contribution of all the observations with observed zero (Woolridge 2002). In this case, the zero observations are coming not only from having computers with Internet access but also from the percentage of farm business and household items purchased through the Internet. This contrasts with Heckman's (1979) model, which assumes that all the zeros are generated only by not having computers with Internet access. Specifically, the two-stage Heckman's model can be written as

$$(4)\quad LL = \sum_0 \ln\left[1 - \Phi\left(X_{1i}'\beta_1\right)\right] + \sum_+ \ln\left[\Phi\left(X_{1i}'\beta_1\right)\frac{1}{\sigma}\varphi\left(\frac{E_i - X_{2i}'\beta_2}{\sigma}\right)\right].$$

Comparing equations (3) and (4) reveals that the additional term

[7] The test statistics, 15.68 (critical value, $\chi^2_{24,0.01}$ = 10.86), indicate that the null hypothesis of Tobit specification is rejected in favor of double-hurdle specification.

[8] We assume that these two error terms are independent, since this assumption is commonly utilized in the double-hurdle model (Su and Yen 1996) and because there is evidence that the double-hurdle model contains too little statistical information to support the estimation of dependency (Smith 2003).

$$\pi\left(\frac{X_{2i}'\beta_2}{\sigma}\right)$$

depicts the contribution of the double-hurdle model, and this term captures the possibility of observing zero values in the second stage. Finally, the second term in equation (3) accounts for all the observations with non-zero usage of computers for Internet purchases. The probability in the second term is the product of the conditional probability distribution and density function coming from the censoring rule and observing non-zero values, respectively (Cameron and Trivedi 2005). In our model, the former denotes the probability of the hurdle of having a computer with Internet access, and the latter indicates the density of observing Internet purchases (farm business and household items).

Furthermore, under the assumption of independence between the two error terms, the log-likelihood function of the double hurdle is equivalent to the sum of the log-likelihoods of a truncated regression model and a univariate probit model (McDowell 2003, Martinez-Espineira 2006, Aristei and Pieroni 2008).[9] Hence, the log-likelihood functions of the double-hurdle model can be maximized without loss of information, by maximizing the two components separately: the probit model (overall observations) followed by a truncated regression on the non-zero observations (Jones 1989, McDowell 2003, Shrestha et al. 2007).

Data and Methods

Data for the analysis is from the Agricultural Resources Management Survey (ARMS) for 2004. The survey is conducted annually by the Economic Research Service and the National Agricultural Statistics Service. The survey collects data to measure the financial condition (farm income, expenses, assets, and debts) and operating characteristics of farm businesses, the cost of producing agricultural commodities, and the well-being of farm operator households.

The target population of the survey is operators of farm businesses representing agricultural production in the 48 contiguous states. A farm is defined as an establishment that sold or normally would have sold at least $1,000 in agricultural products during the year. Farms can be organized as proprietorships, partnerships, family corporations, nonfamily corporations, or cooperatives. Data is collected from one operator per farm, i.e., the individual who is responsible for making most of the day-to-day management decisions. It is likely that when completing the survey, the managing operator seeks assistance from others who are involved in daily decision-making of the farm business and the farm household. For the purpose of this study, those operator households organized as nonfamily corporations or cooperatives and farms run by hired managers were excluded.

The 2004 ARMS also queried farmers on two issues related to computers and their use. First, the questionnaire asked farmers if the farm had access to a computer with Internet access. Second, the questionnaire asked about the percentage of business and household purchases made via the Internet. Given this information, we use a double-hurdle model to estimate the empirical model mentioned above [equation (1)]. To assess the demand side of Internet, we have information on the distance to markets for household goods and farm inputs. Specifically, farm operators were queried on distances they or their family had traveled to (i) buy groceries, clothing, and household supplies, (ii) buy items like cars, trucks, furniture, and household appliances, (iii) buy most farm machineries and implements, and (iv) purchase most of the farm-related business items (seeds, chemical, parts, and supplies). Anecdotal evidence would suggest that if the farm operator and/or his family members have to travel long distances to purchase goods then they might be more inclined to buy via the Internet. The pattern of computer adoption and general Internet use of farm households is different from that of other, non-farm households (Ferreira 1999). Farm households use computers for their farm businesses as well as for household purposes (Ferreira 1999). In 2004, approximately 67 percent of all family farms had Internet access (USDA 2004). However, the majority of the family farms with Internet access did not make any Internet purchases. Table 1 presents the description and summary statistics of the variables used in the analysis.

Finally, following Goodwin and Mishra (2004), we adopt a bootstrapping approach that accounts

[9] In this study we use the double-hurdle model with the assumptions of Internet access and purchase decisions and homoskedastic and normally distributed error terms.

Table 1. Description of Variables and Summary Statistics of Variables Used in the Analysis

Variables	Description	Mean [a]
OPERATOR CHARACTERISTICS		
OP_AGE	Age of the farm operator	54.85 (12.64)
OP_AGESQ	Operator age squared	3168.41 (1434.03)
OP_EDUC	Operator's educational level	13.51 (2.13)
OP_OCUP	= 1 if operator's main occupation is farming, 0 otherwise	0.65
HOUSEHOLD CHARACTERISTICS		
HH_SIZE13	Number of persons living in the household between ages of 6–13	0.30
HH_SIZE17	Number of persons living in the household between ages of 14–17	0.23
HH_SIZE65	Number of persons living in the household who are 65 years or older	0.37
SPOUSE	= 1 if spouse was present in the household, 0 otherwise	0.86
Spouse's Education		
S_COMHS	= 1 if spouse completed high school	0.33
S_SOMECOLL	= 1 if spouse attended college	0.23
S_COMCOLLGE	= 1 if spouse completed college	0.19
S_GRADUATE	= 1 if spouse attended/completed graduate school	0.06
Spouse Age Group		
SAGE_YOUNG1	= 1 if the age of the spouse is less than 35	0.18
SAGE_YOUNG2	= 1 if the age of the spouse is between 35–44	0.13
SAGE_YOUNG3	= 1 if the age of the spouse is between 45–54	0.43
SAGE_YOUNG4	= 1 if the age of the spouse is between 55–64	0.15
FARM CHARACTERISTICS		
FARM_SIZE	Value of agricultural commodities sold by the farm ($10,000)	54.62 (170.43)
F_PRODUCT	= 1 if the farm had production contract, 0 otherwise	0.13
F_MARKET	= 1 if the farm had marketing contract, 0 otherwise	0.23
GOVT_PMT	= 1 if farm received farm program and conservation reserve payments, 0 otherwise	0.52 (0.64)
OFF-FARM WORK AND INCOME ATTRIBUTES		
OFF_WORK	= 1 if household derives income from wages and salaried job off the farm, 0 otherwise	0.66
ADWAGE_SP	Wage and salaries earned from off-farm work by spouse	13,682 (39,680)

cont'd.

Table 1. Description of Variables and Summary Statistics of Variables Used in the Analysis (cont'd.)

OFF-FARM WORK AND INCOME ATTRIBUTES (CONT'D.)		
OFF_BUSINC	Off-farm business income of the household	11,355 (66,149)
M_MHOUHOLD	Miles to shopping for groceries, clothes, household supplies	14.4 (14.55)
M_MAJHOLD	Miles to shopping for cars, trucks, furniture, and household appliances	23.0 (23.9)
M_FARMMACHI	Miles to shop for most farm machinery and equipment	24.2 (30.1)
M_FARMRELAT	Miles to shop for farm-related business (seeds, chemicals, parts, and supplies)	17.0 (25.64)
REGIONAL LOCATION OF THE FARM		
REG_HEART	= 1 if the farm is located in the Heartland region of the U.S., 0 otherwise	0.14
REG_NORTHC	= 1 if the farm is located in the Northern Crescent region of the U.S., 0 otherwise	0.16
REG_NORTHGP	= 1 if the farm is located in the Northern Great Plain region of the U.S., 0 otherwise	0.05
REG_PGATE	= 1 if the farm is located in the Prairie Gateway region of the U.S., 0 otherwise	0.09
REG_EUPLAND	= 1 if the farm is located in the Eastern Upland region of the U.S., 0 otherwise	0.13
REG_SSBOARD	= 1 if the farm is located in the Southern Seaboard region of the U.S., 0 otherwise	0.15
REG_FRIM	= 1 if the farm is located in the Fruitful Rim region of the U.S., 0 otherwise	0.15
INT_ACCESS	= 1 if the farm/ranch has a computer with Internet access (dependent variable)	0.67
HH_COMPUSE	Percentage of Internet use for purchasing household items	2.37 (7.87)
HH_FARMUSE	Percentage of Internet use for purchasing farm equipment and inputs	2.15 (8.64)
SAMPLE SIZE		6,481

[a] Standard deviation of continuous variables is reported.

Source: USDA (2004).

consistently for the stratification inherent in the survey design.[10] The ARMS database contains a population-weighting factor that indicates the number of farms in the population (i.e., all U.S. farms) represented by each individual observation. We utilize the weighting (population-weighting) factor in a probability-weighted bootstrapping procedure. Specifically, the data (selecting N observations from the sample data) are sampled with replacement. The models are estimated using the pseudo sample of data. This process is repeated a large number of times, and estimates of the parameters and their variances are given by sample means and variance of the replicated estimates. We utilize 2,000 replications in the application that follows.

[10] Goodwin, Mishra, and Ortalo-Magne (2003) point out that the jackknife procedure may suffer from some limitations, and so they propose a bootstrapping procedure as an alternative.

Empirical Findings

Results for Adoption of Computers with Internet Access

The results of the double-hurdle model, estimated by maximizing the log-likelihood function [equation (3)], are reported in Tables 2 and 3. We will

Table 2. Probit Estimates of Adoption of Internet by Farm Households, Farm Use, 2004

	Probit	
Variables	Parameter Estimates	Marginal [a] Effect
Intercept	-2.8766 (0.311)[b]	--
Age of farm operator	0.0251 (0.011)	0.009**
Age of farm operator, squared	-0.0004 (0.000)	-0.0001***
Education of farm operator	0.1620 (0.0089)	0.057***
Farming as main occupation of the farm operator	0. 2782 (0.043)	0.099***
Value of agricultural commodities sold by the farm ($10,000)	0.0009 (0.0004)	0.0003**
If farm receives government payments	0.123 (0.032)	0.043***
Farm has production contract	0.0366 (0.0697)	0.013
Farm has marketing contract	0.1279 (0.048)	0.044***
Off-farm work	0.0768 (0.042)	0.027*
Off-farm business income of the household ($10,000)	0.018 (0.005)	0.007***
If spouse is present in the household	0.561 (0.0516)	0.210***
Number of persons living in the household between ages of 6–13	-0.0598 (0.050)	-0.021
Number of persons living in the household between ages of 14–17	0.1463 (0.0378)	0.051***
Farm is located in the Heartland region	0.298 (0.074)	0.098***
Farm is located in the Northern Crescent region	0.173 (0.102)	0.059**
Farm is located in the Northern Great Plains region	0.235 (0.4326)	0.077**
Farm is located in the Prairie Gateway region	0.016 (0.083)	0.021
Farm is located in the Eastern Upland region	-0.150 (0.789)	-0.054
Farm is located in the Southern Seaboard region	0.094 (0.078)	0.032
Farm is located in the Fruitful Rim region	0.318 (0.098)	0.104***
Farm is located in the Basin Range region	0.219 (0.310)	0.072**
Pseudo-R^2	0.34	
Log Likelihood	-3413.627***	
Sample size	6,481	

[a] Marginal effects are calculated at the sample mean.

[b] Numbers in parentheses are standard errors. Single, double, and triple asterisks indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

Table 3. Double-Hurdle Estimates of Choice of Internet Purchasing Patterns by Farm Households, 2004

	Truncated Regression			
	Percentage of Farm Inputs Purchased		Percentage of Household Item Purchased	
Variables	*Parameter Estimates*	Marginal Effect[a]	*Parameter Estimates*	Marginal Effect
Intercept	-62.671 (7.762)[b]	--	-58.675 (6.395)	--
Age of farm operator	-0.237 (0.066)	-0.044***	-0.244 (0.055)	-0.050***
Education of farm operator	1.802 (0.322)	0.338***	1.999 (0.1229)	0.409***
Share of farming income in total household income	0.001 (0.078)	0.0001	0.0277 (0.078)	0.006
Number of persons living in the household between ages of 6–13	0.108 (0.929)	0.020	0.271 (0.570)	0.055
Number of persons living in the household between ages of 14–17	2.407 (1.003)	0.451***	2.126 (0.612)	0.435***
Spouse completed high school	8.588 (2.622)	1.659***	8.836 (1.961)	1.887***
Spouse attended college	13.592 (2.446)	2.746***	13.160 (2.075)	2.977***
Spouse completed college	14.600 (2.876)	3.005***	12.652 (2.074)	2.893***
Spouse attended/completed graduate school	16.421 (3.139)	3.564***	16.962 (2.346)	4.276***
Spouse age less than 35 years	8.963 (3.528)	1.780***	7.571 (2.803)	1.656**
Spouse age 35–44 year	5.158 (3.299)	1.000	6.788 (2.268)	1.488**
Spouse age 45–54 years	2.969 (2.308)	0.559	6.494 (2.023)	1.347***
Spouse age 55–64 years	5.932 (2.443)	1.158	7.878 (2.105)	1.237***
Wage and salaries received by spouse from off-farm work	-0.008 (0.009)	-0.001	0.004 (0.004)	0.001
Distance to where household buys groceries, clothes, and household supplies	--	--	0.062 (0.028)	0.013***
Distance to where household buys major items like cars, trucks, furniture, and household appliances	--	--	0.022 (0.020)	0.005
Distance to where operator/household buys farm machinery and implements	0.035 (0.030)	0.007	--	--
Distance to where operator/household buys other farm-related business (seeds, chemicals, parts, supplies)	0.032 (0.011)	0.006**	--	--

cont'd.

Table 3. Double-Hurdle Estimates of Choice of Internet Purchasing Patterns by Farm Households, 2004 (cont'd.)

Variables	Truncated Regression Percentage of Farm Inputs Purchased *Parameter Estimates*	Variables	Truncated Regression Percentage of Farm Inputs Purchased *Parameter Estimates*	Variables
Farm is located in the Heartland region	0.866 (2.364)	0.164	7.683 (1.802)	1.697***
Farm is located in the Northern Crescent region	5.079 (2.097)	0.985**	8.977 (1.882)	1.999***
Farm is located in the Northern Great Plains region	-7.186 (3.212)	-1.266**	2.423 (2.588)	0.511
Farm is located in the Prairie Gateway region	-0.502 (2.464)	-0.093	4.696 (1.899)	1.012**
Farm is located in the Eastern Upland region	-0.879 (2.416)	0.164	1.555 (1.955)	0.323
Farm is located in the Southern Seaboard region	1.859 (2.030)	0.353	5.878 (1.863)	1.273***
Farm is located in the Fruitful Rim region	9.147 (2.724)	1.828***	10.714 (1.879)	2.432***
Farm is located in the Basin Range region	2.983 3.469)	0.574	6.714 (2.367)	1.491***
Pseudo-R^2	0.22		0.32	
Log Likelihood	-7667.421***		-6353.684***	
Sample size	6,437		6,437	

[a] The marginal effect for the expected value of the dependent variable (percentage of items purchased) is conditional on being uncensored.
[b] Numbers in parentheses are standard errors. Single, double, and triple asterisks indicate statistical significance at the 10 percent, 5 percent, and 1 percent level, respectively.

first describe the results of factors affecting adoption of the Internet (Table 2). The log-likelihood ratio χ^2 statistics [-2 log L], which tests the joint significance for the independent variables included in the model, are significant at the 1 percent level. Table 2 shows that pseudo-R^2 is 0.34 for the estimated model, indicating reasonable explanatory power.

Columns 2 and 3 in Table 2 report the parameter estimates and predicted marginal effects (evaluated at their sample means) of the factors that influence adoption of the Internet. Findings are, in general, consistent with *a priori* expectations based on theoretical grounds and findings in previous studies on computer adoption. Variables *OP_AGE* and *OP_AGESQ*, for example, are found to be statistically significant with the expected opposite signs, indicating an inverted U-shaped relationship between the age of the operator and the likelihood of adopting a computer with Internet access. This means that, all other things being equal, the likelihood of adoption of the Internet increases throughout the life of the operator until it reaches a maximum at 32 years of age based on point estimates, then declines as the operator grows older. The findings pertaining to the nonlinear effect of age on computer with Internet access are consistent with those of Putler and Zilberman (1988) and Mishra and Park (2005).

The educational attainment of the farm operator has a positive impact on Internet adoption. The estimated coefficient for *OP_EDUC* is positive and significant at the 1 percent level. Increased education is expected to improve the understanding of the complexities of production and financial relationships and therefore increase demand for information. Additionally, increased education corresponds to an increased ability to judge the usefulness of the Internet to gather information for the farm business. These findings are consistent with Putler and Zilberman (1988), Willimack (1989), Lazarus and Smith (1988), and Batte (2004, 2005), who studied computer adoption using data from a survey that covered a small geographic area, usually farm-level data in a specified county. Results indicate that a marginal change in schooling from the average of 14 years is associated with a 6 percent increase in Internet adoption by farm households.[11] Results indicate that farm operators reporting farming as their main occupation (*OP_OCUP*) are more likely to adopt the Internet than are their counterparts. A possible explanation is that operators of large farms generally indicate farming as their main occupation, and large farms are likely to adopt technology for productivity and efficiency reasons (Internet technology may help them with GPS and precision farming). Our finding is reinforced by a significant relationship between farm size (value of agricultural commodities sold) and adoption of the Internet, indicating that a marginal change in farm size from the average of $550,000 (value of agricultural product sold) is associated with a 0.03 percent increase in Internet adoption. Further, Mishra and Park (2005) indicate that large farms are constantly searching for information regarding marketing and production activities that can increase their profitability. Operators of large farms are likely seeking information regarding new technology, extension-related information, and communication with other farmers in their region or across the country, and the Internet is one of the best vehicles for doing this. The farm operator does not have to worry about location and time when acquiring this information from the Internet, as the computer is in his house and the information is always available.

Findings reported in Table 2 also show a significant relationship between farms receiving government program payments and adoption of computers with Internet access, indicating that farms receiving government payments have an approximately 4 percent higher probability of adopting computers with Internet access. This finding lends support to the argument that farmers who are receiving government payments may be encouraged to adopt computers with Internet access to facilitate their connection with federal agencies and to get instant access to information regarding farm programs, production, and price information. In fact, anecdotal evidence suggests that farmers are encouraged to use the Internet to contact the Farm Service Agency and other USDA officials in order to reduce paperwork and receive information in a timelier manner. Using the Internet to conduct business with federal and state agencies should increase efficiency and ease time constraints. The presence of a spouse (*SPOUSE*) in a farm household is positively correlated with Internet adoption. Results indicate that farm households with a spouse have a 21 percent higher probability of adopting the Internet than those without. In most cases, spouses tend to work off the farm, where they acquire experience and proficiency in using the Internet to do research related to their off-farm job, to obtain information regarding consumer products, to buy products on the Internet, and for social interactions with friends and relatives.

The presence of off-farm income and ownership of nonfarm business increases the likelihood of adopting computers with Internet access. Results indicate that farm households that receive income from off-farm jobs (*OFF_WORK*) have an approximately 3 percent higher probability of adopting computers with Internet access. The coefficient of off-farm business income (*OFF_BUSINC*), a proxy for nonfarm business/farm related business ownership, is positive and statistically significant at the 1 percent level. Results indicate that a marginal change in off-farm business income from the average of $11,000 is associated with a 0.7 percent increase in Internet adoption by farm households. Perhaps this is due to exposure to computers in a different environment where they are more commonly used. Another plausible explanation is that, in the information age, many businesses post their important and timely information on the Internet, either displaying their

[11] See Baum (2006) for a complete discussion and interpretations of marginal effects using STATA.

products or information about the business, or using the Internet to do transactions. Farm operators who have prior knowledge of the advantages of the Internet are more likely to use it in their farm business and in their households. Putler and Zilberman (1988), in their study of farms in Tulare County, California, found a positive and significant correlation between non-farming business income and probability of computer adoption.

Regional dummies were included in the regression to assess the regional impact of farm households' adoption of the Internet. The coefficients for the Heartland (*REG_HEART*), Northern Crescent (*REG_NORTHC*), Northern Great Plains (*REG_NORTHGP*), Fruitful Rim (*REG_RFRIM*), and Basin and Range (*REG_BASINR*) regions are positive and statistically significant at at least the 5 percent level. Farms located in the above regions are more likely to adopt computers with Internet access compared to farms in the benchmark region (Mississippi Portal). Farms in these regions are large and tend to grow cash grains, cattle, and some dairy. It is likely that the regional variables represent the effects of omitted variables that are correlated with regional location (e.g., the intensity of advertising by Internet providers, number of Internet providers, transactions costs) of farm households. Marginal effects in column 3 (Table 2) indicate that farm households located in the Fruitful Rim and Heartland regions have an approximately 10 percent higher probability of adopting computers with Internet access, followed by the Basin and Range region (7 percent), and then the Northern Great Plains region (6 percent).

Results for Choice of Internet Purchasing Patterns

In the second stage, we investigate the choice of Internet purchasing patterns (farm and household items) once the farm household has adopted the Internet. Table 3 reports estimation results for the double-hurdle model, which were also reached based on the maximum likelihood and Huber-White sandwich robust variance estimation method. Further, Table 3 shows that pseudo-R^2 is 0.22 and 0.32 for the estimated models (share of farm business purchases and share of household items purchases), indicating reasonable explanatory power.

Results in Table 3 reveal a consistent theme with regard to Internet purchasing patterns once a decision to adopt a computer with Internet access has been made. For example, results in Table 3 show that an additional year in farmer age decreases the percentage of farm business inputs purchased through the Internet by 0.04 percent, while the percentage of household items purchased decreases by approximately 0.05 percent. On the other hand, educational attainment of the operator has a positive and significant impact on Internet purchasing patterns. Our results show that the percentage of farm business inputs purchased through the Internet increases by about 0.33 percent, while the percentage of household items purchased increases by approximately 0.41 percent (Table 3). The number of teenagers (between 14–17 years of age) has a positive and significant impact on Internet purchasing patterns. A plausible explanation is that younger people are more interested in technology and may be more likely to take full advantage of the possibilities that the Internet provides (such as browsing for information for school, buying goods over the Internet, and communicating with other friends and family members). Through the Internet, consumer goods and services may be purchased at a lower price, and household members may have access to a wider array of goods and services, some of which may not be available from local merchants and service providers.

A couple of spousal attributes play a significant role in Internet purchasing patterns. We categorized spouse's age and educational attainment to assess their effect on Internet purchasing patterns and found that all eight variables were significant in explaining the percentage of household items purchased through the Internet. Of the eight variables used to characterize age and education, five were significant in explaining the percentage of farm business purchases performed via the Internet. The marginal effect in each case (farm businesses and household items) increases with educational level as well as with age of the spouse. For example, farm business purchases increase by 3.5 percent for spouses with a college degree, and by only 1.7 percent for spouses with only a high school degree. Moreover, this impact is higher when the Internet is used to purchase household items—4.3 percent and 1.9 percent, respectively. With regard to age of the spouse and Internet purchasing patterns, we see an interesting trend. Results in Table 3 show that the young spouses (under the age of 35), compared to older spouses (65 or older), have significant impact on the purchase of farm inputs via the Internet. On the other hand, results indicate that the percentage of household items purchased via the Internet decreases with the age of the spouse. For example, the percentage of household items purchased via the Internet decreases from 1.7 percent for spouses who are under 35 years of age to 1.3 percent for spouses between 45 and 54 years.

Shaffer (1989) and Henderson, Tweeten, and Schreiner (1989) have noted that, in the past, farmers who live in small towns with fewer goods and services offered by businesses may have to drive to larger communities for goods and services. Furthermore, it is likely that retail consolidation has led to higher prices, making goods and services less competitive in small towns and communities across rural America (Shaffer 1989). In this regard, the Internet may help lower search costs for products and information and perhaps offer competitive prices for goods and services to farm households located in small rural communities. We included two variables that potentially capture the impact of shopping distances on the choice of Internet purchasing among farm households. The first is the distance traveled for the purchase of minor farm inputs (such as seeds, chemicals, parts, and supplies—"minor farm business inputs") and major inputs (such as farm machinery and implements—"major farm business inputs") as a percentage of farm business inputs secured through the Internet. The second is the distance traveled for the purchase of minor households items (such as groceries, clothing, household supplies—"minor household items") and major items (such as cars, trucks, furniture, and household appliances—"major household items") as a percentage of household items purchased through the Internet. Results in Table 3 are interesting. In both cases, both minor farm business inputs and household items show a significant impact on the share purchased via the Internet as the distance traveled increases. For example, results in Table 3 indicate that an additional mile increases the percentage of "minor farm business inputs" purchased through the Internet by approximately 0.01 percent. Moreover, an additional mile increases the percentage of "minor household items" purchased through the Internet by a similar percentage. Potential explanations for these results are as follows: first, it is likely that the farm business and the farm household do not need to evaluate these "minor" purchases, as they have considerable experience with these products; second, the attributes of these minor purchases are such that they do not change rapidly—the products are often non-durable (they will be consumed in less than a year) and therefore purchased frequently; and finally, there is little or no perceived risk associated with purchasing via the Internet. The combination of the aforementioned factors makes it conducive for the farm operation and farm household to purchase these items using the Internet as opposed to traveling to town to purchase them. Results in Table 3 show that farms located in several regions—such as the Heartland, Northern Crescent, Northern Great Plains, Southern Seaboard, Fruitful Rim, and Basin and Range regions—significantly influence Internet purchasing patterns. For example, compared to the Mississippi Portal region (see Figure 1), farms located in the Northern Crescent and Fruitful Rim regions purchase a higher percentage of farm inputs through the Internet. A possible explanation is that farms in these regions are more diverse (fruits, vegetable, nursery, and cotton in the Fruitful Rim region; dairy, general crop, and cash grains in the Northern Crescent region) and may require various inputs that could be easily purchased through the Internet. On the other hand, farms located in the Northern Great Plains region (wheat and cattle farms) show a decrease in the percentage of farm inputs purchased through the Internet. With regard to choice of Internet purchase for household items, results in Table 3 indicate that farm households located in six of eight regions buy a higher percentage of household items through the Internet than do households in the Mississippi Portal (benchmark) region. Further, the magnitude of the share of Internet purchases ranges from 2.4 percent in the Fruitful Rim region to about 1.0 percent in the Prairie Gateway region. It is likely that the regional variables are correlated with other variables such as number of Internet providers and transaction costs in the region. Further, the regions identified above tend to grow high-valued products such as fruits, vegetables, nursery, and cotton, and are mostly diversified farms, which could be indicators of management intensity and hence increased likelihood of Internet use.

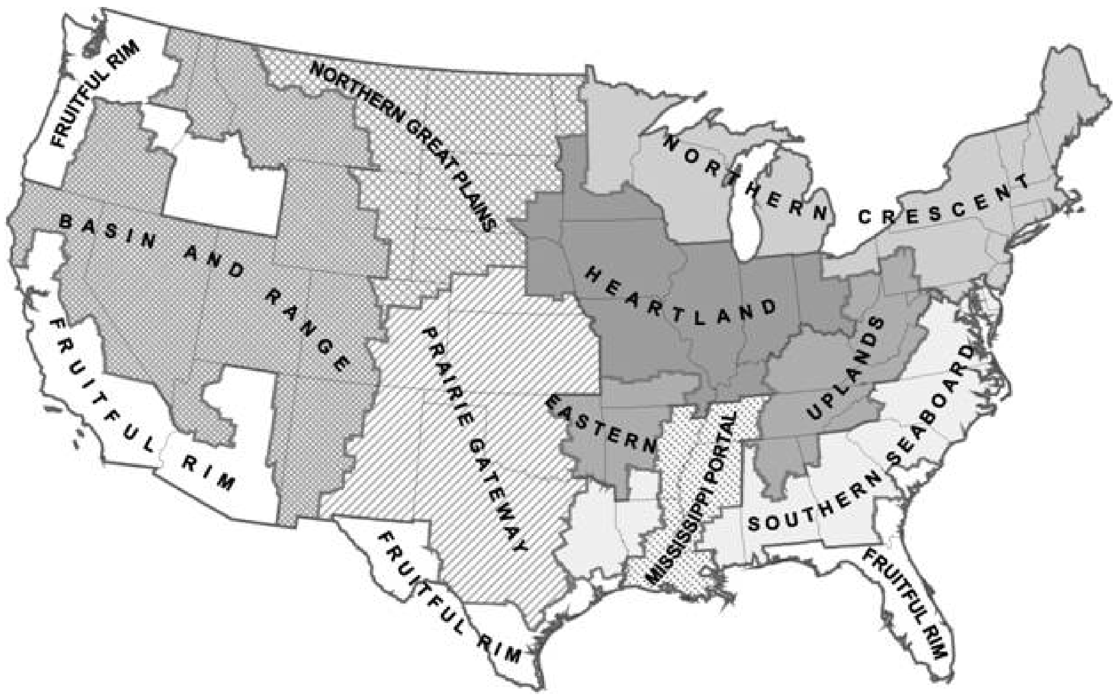

Figure 1. Farm Resource Regions of the United States

Summary and Conclusions

In the past eight decades, several new technologies have emerged and benefited both the farm sector and farm households in the United States. The Internet is a yet another but slightly different technology that is making an imprint on farm businesses and farm households. The Internet permits persons to engage in a wide range of activities to satisfy the needs of their farm businesses and households. The Internet has the ability to deliver large quantities of information and provide new opportunities for networking to enable farm operations and households to gain access to a world far beyond their rural communities. According to ARMS, only 67 percent of farms have computers with Internet access; consequently, the full potential of the Internet has not been realized by farm businesses and farm households. The objective of this study was twofold: first, to examine the key farm, operator, regional, and household characteristics that influence the adoption of computers with Internet access by farm households; second, to investigate Internet purchasing patterns of farm households in the United States.

Using 2004 ARMS data and a double-hurdle estimation procedure, the study reveals several interesting findings. Participation in government programs increases the probability of Internet adoption. This finding may provide indirect evidence that perhaps government strongly encourages farmers to adopt Internet filing in order to reduce paperwork. Of the demographic variables considered, age of the farm operator showed the typical inverted U-shaped relationship involving the likelihood of Internet adoption. Thus, older farmers are less likely to adopt computers with Internet access. Results from this study show that the presence of a spouse increases the likelihood of Internet adoption. This may reflect the ease and familiarity with computers that spouses may have while working off-farm jobs. Furthermore, increasing familiarity with computers and Internet use associated with off-farm work or off-farm business activity increases adoption of the Internet. Results from this study also show that there are regional differences in the adoption of the

Internet. Thus, younger farmers who have a college education, a spouse, and teenage children in the household represent the majority of the 67 percent of farm households that have a computer with Internet access. On the other hand, elderly farmers who have no spouse or teenage children in the household and no college education represent the subgroup of farmers who have not adopted a computer with Internet access. These results provide strong evidence for the need to tailor extension and outreach activities to educate farm households on Internet adoption and on how to utilize the Internet in both the farm business and farm households to increase the efficiency and profitability of the operation. For the subgroup of farm households that have not adopted a computer with Internet access, the extension programs will likely focus on providing information on how to purchase, where to purchase, and how to set up a computer with Internet access. Extension and outreach activities designed for the aforementioned subgroups should also teach those farm households where to search for and obtain information related to their farm business and farm household and how to utilize the Internet to complete governmental documentation. Given that the Internet age has lowered the cost of obtaining, producing, and delivering information, while increasing the quantity and rate at which information flows, it is essential that those farm households without a computer with Internet access adopt one.

Furthermore, the adoption of computers with Internet access by a majority of younger college-educated farmers means that the need for electronic extension is going to continue to rise. These farmers will seek solutions to technical problems, enhancing agricultural marketing strategies, and improving possibilities for farm profitability, and will seek assistance in interpreting data and applying information to their farming operations, via the Internet, so it is essential that the electronic extension offerings of land grant universities provide this information in a clear and concise manner. Furthermore, it is likely that these farm households will consider using the Internet as a low-cost method for marketing their products to a much broader set of consumers, i.e., they will no longer be bound by advertising and selling in the rural area where their physical operation is located. Consequently, additional extension activities will assist farm households in all aspects of website development for an e-based agricultural business. With regard to Internet purchasing patterns (either purchasing farm inputs or household items), the study finds that educational attainment of farm operator and spouses and number of teenagers in the household all increase the share of purchase of farm inputs and household items through the Internet. Results from this study also indicate that a higher share of farm inputs and household items bought by farm households are minor purchases such as seeds, chemicals, fertilizers, parts and supplies, groceries, household supplies, and clothes.

The Internet should allow farm households to purchase goods more conveniently and often at lower prices. The Internet also offers access to an endless selection of merchandise that was previously unavailable to the farm household. Consequently, extension and outreach focused on employing the Internet as a method for purchasing farm business and farm household supplies should be geared toward younger farmers who have a college education, a spouse, and children in the household, i.e., those households that have already adopted computers with Internet access. Outreach activities should focus on the pros and cons of using the Internet to purchase these goods, including but not limited to identity protection, payment methods, selection of retailers, and shipping and returns of online purchases, and purchasing on the Internet to minimize farm and household expenditures.

Future research should seek to explore specific product attributes of both major (large ticket items) and minor purchases that make a farm household more or less likely to buy these products via the Internet. For example, do large ticket items—which are sources of both production and financial risk to the farm household and farm business—have product features that change rapidly, and are they durable (i.e., do they last longer than a year, which means purchases occur infrequently), making them non-conducive to Internet purchase? Other attributes that might influence the purchasing of items via the Internet include the need to personally inspect the item, financing of the purchase, and other obligations that can be completed only by being physically present at the purchasing site. An additional area of research that is beyond the scope of this paper is what effect Internet purchases by rural residents will have on rural businesses that once were the sole suppliers of farm and/or household goods.

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