An Empirical Analysis of Internet Use by U.S. Farmers

Ashok K. Mishra and Timothy A. Park

The Internet may reduce constraints on a farmer's ability to receive and manage information, regardless of where the farm is located or when the information is used. Using a count data estimation procedure, this study attempts to examine the key farm, operator, regional, and household characteristics that influence the number of Internet applications used by farm households. Findings indicate that educational level of the farm operator, farm size, farm diversification, off-farm income, off-farm investments, and regional location of the farm have a significant impact on the number of Internet applications used.

Key Words: computers, count data method, education, farm households, Internet applications

The Internet has changed the world. People can now access up-to-the-minute information at the click of a mouse and can also communicate and engage in trading activities online. This electronic revolution has changed the business world, but has it affected the world of farming? A survey by USDA's National Agricultural Statistics Service (NASS) (the Agricultural Economics and Land Ownership Survey) in 1997 found that 31 percent of U.S. farmers owned or leased computers, although only 13 percent had access to the Internet (NASS 2001); by 2001, these numbers had increased to 50 percent and 43 percent (NASS 2003). Farmers are also beginning to embrace e-business and successfully trade online. As a technology, the Internet has the potential benefit of reducing constraints on a farmer's ability to receive and manage information, regardless of where the farm is located or when the information is used. Internet-provided communication and information-gathering services are generally available at substantially lower costs than conventional technology. Consequently, the commercial opportunities provided through use of the Internet may afford farmers new ways to build business partnerships, including opportunities to purchase inputs, sell farm products, and acquire new agricultural information. Many agricultural groups, researchers, farm organizations, teachers, and extension agents have taken an active interest in Internet use in agriculture.

Despite this interest, little analysis of Internet use patterns in agriculture has been done. Understanding the factors that influence farm-level Internet use will facilitate diffusion of innovations by farmers and application developers. This study attempts to examine the key farm, operator, regional, and household characteristics that influence the number of Internet applications used. Rather than estimating a likelihood of adoption (0,1) logit model, as is the case in most of the adoption literature, this study estimates the number of specific types of Internet applications that a farm operator reports using—for example, paying bills, obtaining loans, input and commodity price tracking, contact with advisory services, and obtaining information from USDA and other sources. This investigation goes beyond whether or not adoption has occurred because there is not much that has been done to document how farmers are using the Internet or why they are using it. Furthermore, because the Internet has "gradations" of adoption, one must go beyond the simple binomial logit to understand past growth and to predict future growth. The analysis is conducted on a national level with the unique feature of a larger sample than previously reported, comprising farms of different economic sizes and in different regions of the United States.

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The authors would like to thank two anonymous reviewers and the editors of the journal for their helpful comments and suggestions.

The views expressed here are not necessarily those of the Economic Research Service or the U.S. Department of Agriculture.

Previous Studies

Agricultural businesses increasingly use information as an input in the production process. Rapid development of computer and telecommunication technologies in the 1990s and corresponding reductions in their costs have increased the capability of computers to assist business managers in the collection, storage, and processing of information. Using 1987 farm costs and returns data, Willimack (1989) found that fewer than 3 percent of U.S. farmers used a computer to maintain farm records. Lazarus and Smith (1988) found that 15 percent of the New York dairy farmers who were enrolled in the Farm Business Summary and Analysis Program owned computers in 1986. A follow-up study by Lazarus, Streeter, and Jofre-Giraudo (1989) tracked a panel of record-keeping farmers over a four-year period and found an increasing cumulative adoption pattern.

Putler and Zilberman (1988) surveyed farmers in Tulare County, California, and found that over 25 percent of farmers owned computers. Batte, Jones, and Schnitkey (1990) found that 24 percent of Ohio commercial farmers had adopted a computer by 1987. On the other hand, Ortmann, Patrick, and Musser (1994) reported that 80 percent of respondents attending the 1991 Top Farmer Crop Workshop at Purdue University were using computers. A study of commercial farmers in 13 states conducted in March 1991 found computer adoption rates varied widely among the states, ranging from 14 percent to 32 percent (Batte et al. 1995).

Computer adoption rates by farmers vary with operator and business characteristics. Survey results by Willimack (1989), Lazarus and Smith (1988), Batte, Jones, and Schnitkey (1990), and the publication *Farm Futures* (1998) found an inverse relationship between adoption rates and farmer age. Consistent with Putler and Zilberman (1986), these studies found that higher education and larger business sizes were positively related to computer adoption rates. Willimack (1989) found higher adoption rates for crop farmers than livestock farmers. However, Putler and Zilberman (1986) and Batte, Jones, and Schnitkey (1990) found a positive relationship between adoption and livestock producers and a negative relationship between adoption and crop farmers. Willimack (1989) also found regional differences in adoption rates. Updating his earlier study, Batte (2004) reported that computer adoption by Ohio farmers increased from 32 percent in 1991 to over 44 percent in 2004. However, the adoption rate varied by size of farm, age of operator, and level of education, and with off-farm employment.

Farm operators use computers for different activities. For example, the majority of farmers use computers for financial accounting, preparation of financial statements, production record-keeping, and word processing. In a recent study of computer adoption by Ohio farmers, Batte (2004) found that nearly 77 percent of computer-adopting farmers indicated that financial record-keeping was one of the three most important tasks completed using computers. This was followed by production record-keeping (47 percent), accessing the Internet for other information (38 percent), e-mail (about 32 percent), commodity price tracking on the Internet (30 percent), and word processing/correspondence (28 percent). Even before access to the Internet became widespread, some farmers used electronic sources (Batte, Jones, and Schnitkey 1990). Using a multinomial logit approach, the authors examined the farm and farmer characteristics related to number of applications (using three categories: single application, two or three applications, and four or more applications).

This study, unlike prior studies, focuses on how farm operators use the Internet rather than on the adoption of computers. Using a count data approach, this study investigates those factors that affect the number of (different types of) applications that a farm operator performs using the Internet.

Estimation Procedure

The specification of count data for technology adoption is consistent with a number of previous studies of small businesses and agricultural decision makers. McWilliams et al. (1998) developed count data models for technology adoption and examined the link between the economic behavior that drives adoption decisions and the appropriate statistical models used to estimate these decisions. This study builds on previous work, which accounts for the intensity of technology adoption by using count measures. Using a count specification, Liu, Tsou, and Hammitt (2001) examined the factors that influence adoption of advanced technology (such as mainframe computers, robots, flexible manufacturing systems, computer-aided design machines). Gale (1998) also used a count data model to estimate the adoption of technology use in rural manufacturing.

The negative binomial distribution is consistent with the following adoption scenario for an economic agent. When considering the adoption process for a new Internet application, the farmer goes through a sequence of mental decisions (or hurdles) in learning about relative advantages of the computer application, which may lead to a final cumulative decision to adopt the application. The series of hurdles represents the updating of knowledge about the technology in each period, bringing the farmer closer to actual adoption, which occurs after the θth success. The Poisson model represents the limiting case when θ approaches ∞. McWilliams et al. (1998) note that this model implies an adoption decision in which agents continuously evaluate and update information about the technology.

Greenstein (2004) commented on measures to construct a census of adoption of Internet technologies by individual business establishments. The survey measured the dispersion of Internet use based on indicators of participation and enhancement or intensity of use in using Internet applications. To identify intensity of use, Greenstein developed a count measure based on adoption of two or more applications by the business from a set of applications that included Internet-based enterprise resource planning, TCP-IP–based applications in customer service, education, extranet, publications, purchasing, or technical support. Specification of the count data model for farmer use of Internet applications is consistent with methods to assess Internet use for business establishments.

In order to analyze the effects of various farm, operator, and regional characteristics on the number of Internet applications used (the Internet could be used for a number of purposes such as paying bills, obtaining loans, online banking, input or output tracking, record-keeping, etc.), this study adopts the method employed in patent literature (see Hausman, Hall, and Griliches 1984, Cameron and Trivedi 1986, Cincer 1997, and others). The number of Internet uses is a function of a set of independent variables ($\mathbf{X}_i$) outlined in the previous section:

$$\text{Ln}\left(\lambda_i\right) = \alpha_0 + \mathbf{X}_i\beta \,, \tag{1}$$

where λ_i is the number of Internet uses or applications by farm operator i. Data on the number of Internet applications/uses constitute a nonnegative integer valued random variable. The classical linear model fails to recognize this feature and hence is not appropriate. However, several authors (Hausman, Hall, and Griliches 1984, Cameron and Trivedi 1986, and Cincer 1997) have presented and discussed count data models as an alternative method.[1] In the count data model the primary variables of interest are event counts. In this analysis, Poisson and negative binomial models, which are within the linear exponential family, are considered in analyzing the number of Internet applications/uses by farm operators. Before presenting the estimated model, the Poisson and negative binomial models will be described briefly.

The Poisson Model

Let $\mathbf{Y}_i$ be the observed event (number of Internet uses) count for the ith farm operator. The $\mathbf{Y}_i$ is assumed to be independent and to have a Poisson distribution with parameters λ_i. The parameters λ_i depend on a set of explanatory variables ($\mathbf{X}_i$), which are in this case the factors affecting the number of Internet applications/uses by a farm operator:

$$\lambda_i = \exp\left(\mathbf{X}_i\beta\right), \tag{2}$$

where $\mathbf{X}_i$ represents the set of explanatory variables, and β is the vector of parameters to be estimated. The basic probability density function for the Poisson model is given by

$$\Pr(\mathbf{Y}_i) = f(\mathbf{Y}_i) = \left[\frac{e^{-\lambda_i}\lambda_i^{\mathbf{Y}_i}}{\mathbf{Y}_i!}\right]. \tag{3}$$

[1] See Winkelmann and Zimmermann (1995) for a recent overview of count data models.

The Poisson specification assumes that the mean of $\mathbf{Y}_i$ is equal to its variance.

The Negative Binomial Model

The negative binomial model, which is more flexible than the Poisson, assumes that λ_i follows a gamma distribution with parameters (γ, δ), where $\gamma = \exp(\mathbf{X}_i \beta)$ and δ is common across time. Then, the gamma distribution for λ_i is integrated by parts to obtain a negative binomial distribution with parameters (γ_i, δ). Specifically,

$$\text{(4)} \qquad \Pr(\mathbf{Y}_i) = \int_0^\infty \frac{1}{\mathbf{Y}_i} e^{-\lambda_i} \lambda_i^{\mathbf{Y}_i} f(\lambda_i) d\lambda_i \,.$$

Under the above framework, the number of Internet uses by a farm operator is expressed as a function of various farm, operator, household, and regional characteristics. Specifically, $\lambda_i = \exp(\mathbf{X}_i \beta)$, where $\mathbf{X}_i$ is a set of explanatory variables such as age and education of the operator, farm size, diversification, contracting, regional dummies, etc.

A subsequent question then arises as to which model (Poisson or negative binomial) is more appropriate. Cameron and Trivedi (1986) have proposed a number of tests for the over- or underdispersion in the Poisson regression model. They basically test for the underlying assumption—mean-variance equality—of the Poisson model. Under the null hypothesis, $H_0 : \text{var}(\mathbf{Y}_i) = \mu_i$. The specific alternative hypothesis is that $H_1 : \text{var}(\mathbf{Y}_i) = \mu_i + \alpha^* g(\mu_i)$, where $g(.)$ is a specified function that maps from R^- to R^+. Tests for overdispersion or underdispersion are tests of whether $\alpha = 0$. A similar test is used in this study.

Conceptual Model

Using standard multinomial logit models, studies have investigated the factors influencing the adoption of computers or any technology, or diffusion of innovations. The limited economic literature on farmers' adoption of computers stems from the random profit model. In these models it is assumed that farmers adopt computers if the expected incremental profit from computer use is positive (Huffman and Mercier 1991). This study employs a similar underlying economic model even though the expression (or equation) of farmer computer use is more complex than the binary formulation used in previous studies. Consequently, the model analyzes the influence of a similar set of factors, as dictated by reviewing the literature, that appear to influence computer use by farmers.

Most studies in the literature include farmer age and education and farm size as explanatory variables. However, all studies include at least some other characteristics. Studies by Nelson and Phelps (1966), Khaldi (1975), and Wozniak (1989) use education as a measure of human capital to reflect the ability to adopt innovation (either technology or insurance). Huffman's (2001) review of human capital impacts on agriculture focuses on the effects of education on technology adoption. Huffman conjectures that when technology is new and widely profitable, education plays a significant role in the adoption decision. By contrast, the adoption patterns for technologies that have been available for an extended period will generally not be driven by education. The results from this suggest that this conjecture may not be valid for adoption of computer and Internet applications. Huffman and Mercier (1991) showed that adoption or purchase of microcomputer applications for Iowa farmers in the 1982–84 period was influenced by schooling. Schooling remains a significant variable in the adoption decision for Internet applications even in the ARMS data from 2000. The implication is that the producer's education level continues to play a significant role in the adoption of Internet applications related to operations of the farm enterprise. Evolving computer technologies, new software developments, and upgrades to current applications require a minimum level of human capital in terms of education and commitment to continued learning.

Off-farm employment is included as a proxy for experience with computers or as an indicator of the farmer splitting time across different activities (Hoag, Ascough, and Frasier 1991, Huffman and Mercier 1991). In this study, information was included on whether the household (which could refer to either the operator, the operator's spouse, or both) receives income from off-farm employment in the form of wages and salaries (a proxy for having a permanent off-farm job), the justification being that households that do receive such income have a better understanding of computers and software applications through their off-farm jobs and are familiar with ways to search for information online, both regarding farming and other activities. In addition, one would expect that if the farmer has an off-farm job, then because of time pressure he or she is more likely to use a computer or the Internet for gathering (obtaining) information on either issues related to farming or other issues. Alternatively, as one reviewer noted, a farmer with an off-farm job may have less interest in farm information and therefore have fewer Internet uses. Farm size, as measured by value of agricultural production, is used as an indicator of the scale of farm operations. In addition, several studies have included types and number of products produced by or number of enterprises in the farm business as an indicator of complexity associated with farming and a need to make a greater number of or different information decisions. For example, Amponsah (1995) uses acreage under specialty crop, and Hoag, Ascough, and Frasier (1991) included crop versus livestock production as indicators of farming complexity and need for information. In this study, degree of farm diversification (entropy measure) is used as an indicator for the number of different enterprises in the farm business.

Diversification, as measured by an entropy index, which was popularized by Theil (1972), is used as a explanatory variable in the model because of several desirable properties it possesses (see Hackbart and Anderson 1978). The index takes a value of 1 when a farm is highly diversified and 0 when a farm is specialized (Theil 1972). Specifically, an entropy measure of farm diversification considers the number of enterprises a farm participates in and the relative importance of each enterprise to the farm. An operation with many enterprises, but with one predominant enterprise, would have a lower number on the diversification index. Higher index numbers go to the operations that distribute their production more equally among several enterprises. It is assumed that diversification may lead to economies of scope, which lower costs and increase profits. Since operators of diversified farms require more information for both producing and marketing their products, it is a reasonable assumption that operators of such farms will use the Internet far more than others.

Farmers have a variety of ways to reduce or cope with agricultural income risk (Harwood et al. 1999). Contracting, both production and marketing contracts, can be a risk management strategy. While several risk factors likely influence decisions to contract, surveys of contracting farmers indicate that risk reduction plays an important role. Production contracts shift production and input price risk from growers to contractors. Under production contracts, growers (farmers) provide labor and facilities and are paid a fee for raising the animals. Under marketing contracts, on the other hand, producers usually bear all yield risk and frequently all input price risk. Additionally, Mishra and Perry (1999) show that farmers who contract sales of crops and livestock (marketing contract) are more likely to use input contracting. Hence the assumption is that farmers using marketing contracts are more likely to search for information—from various sources, including the Internet—on ways to further reduce risks associated with farming.

Geographic location of farms determines cropping patterns, rainfall amounts, and soil productivity. Nine regional dummies, created by the U.S. Department of Agriculture's Economic Research Service, were used in the analysis (Figure 1). Regional location of farms may also capture the impact of transportation, market accessibility, and other infrastructure on the availability of information and use of information technology.

The State New Economy Index (Atkinson, Court, and Ward 1999) is used as an indicator of high technology, Internet, and new economy characteristics of states. The 1999 Index is based on 17 indicators in five broad categories relating to knowledge jobs, globalization, economic dynamism and competition, digital economy measures, and technological innovation capacity. The digital economy sub-index measures factors such as the percentage of adults online, commercial Internet domain names per firm, the deployment and use of information technology in K–12 public schools, and the use of digital technologies to deliver state government services.

Data

Data for the analysis are from the 2000 Agricultural Resources Management Survey (ARMS). ARMS is conducted annually by the Economic

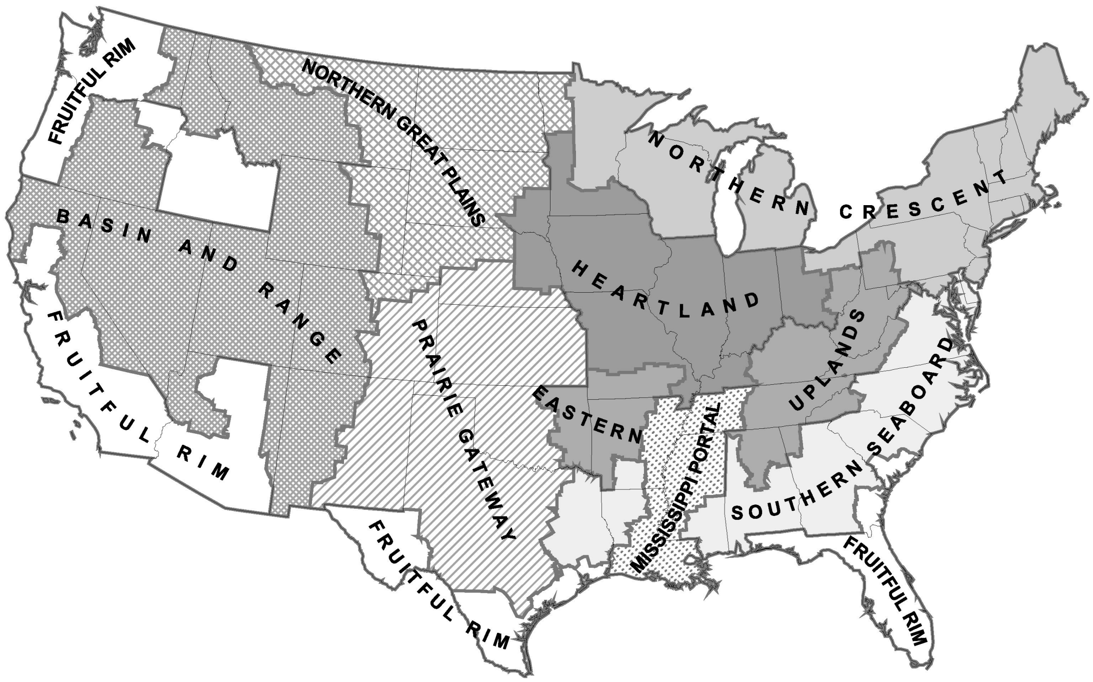

Figure 1. ERS Resource Regions

Source: Lipton (1999).

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 of agricultural products during the year. Farms can be organized as proprietorships, partnerships, family corporations, nonfamily corporations, or cooperatives. Data are collected from one operator per farm, the senior farm operator. A senior farm operator is the operator who makes most of the day-to-day management decisions. For the purpose of this study, those operator households organized as nonfamily corporations or cooperatives and farms run by hired managers were excluded.

The 2000 ARMS survey queried farmers on all types of financial, communication, and information-gathering activities, as well as on their online buying and selling of crops and livestock. Table 1 shows the percentage of farms reporting various uses of Internet. In this case a farm operator could have indicated having used the Internet, but may not have used any of the applications on which the survey queried. Farms using the Internet reported implementing the technology for a number of different reasons: price tracking (83 percent), agricultural information services (56 percent), accessing information from USDA (33 percent), and online record-keeping and data transmission to clients. The dependent variable (number of Internet uses/applications) was obtained by summing the number of Internet applications or operations that the farmer reported using or doing from a list of nine activities. These include paying bills, obtaining loans, online banking, input or commodity price tracking, record-keeping operations, contact with advisory services, contact with other farmers, obtaining information or other services from USDA, and obtaining information or other services from sources other than USDA.

The overall State New Economy Index scores for the states reveal that Massachusetts, California, and Colorado (with scores above 70) rank the

Table 1. Farmers' Use of Internet Technology for Various Activities

Activities	Percentage of farmers
Paying bills	7
Obtaining loans	2
Online banking	10
Input or commodity price tracking	83
Record-keeping operations	31
Contacting advisory services	28
Contacting other farmers	31
Obtaining information or other services from USDA	33
Obtaining information or other services from sources other than USDA	56

Source: 2000 Agricultural Resource Management Survey (ARMS), U.S. Department of Agriculture.

highest on the new economy measures. States that score lower on the index have historically lagged behind in industrialization patterns and include a group of ten states (Mississippi, Arkansas, West Virginia, Louisiana, Montana, North Dakota, Alabama, South Dakota, Iowa, and Wyoming) with scores below 35. Summary statistics for each of the variables utilized in the analysis are presented in Table 2.

Results

The adequacy of the Poisson regressions depends on the equality of the mean and variance of the dependent variable. If this restriction is not appropriate, and the variance exceeds the mean, there is overdispersion. The estimate of the overdispersion parameter (3.251) corresponds to a significance level of 0.001, hence concludes that the mean and variance are not equal and the Poisson distribution assumption has to be abandoned. Tests, not reported here, show evidence of overdispersion in the data used. Further, the results indicate that a negative binomial specification is appropriate (Cameron and Trivedi 1986). Estimated model parameters for the negative binomial model are presented in Table 3. The overall fit of the model is good, as indicated by the number of significant variables. The correlation between observed and predicted values is in the range of 67 percent. Caution is emphasized in using these statistics. Computing measures similar to R^2 can be complex and misleading in count data models.

The State New Economy Index (*SCORE1999*) has little explanatory power among factors influencing the number of Internet applications adopted by farmers. Atkinson, Court, and Ward (1999) acknowledge the difficulty in measuring the new economy at the state level, as the most useful data are typically available at the national level. In addition, a main feature of the information technology revolution is the emergence of regional clusters of innovations that may not be closely correlated with state economic activity.

Unlike in previous studies of computer adoption, age of operator was not found to be significant; however, the coefficients for both age (*OP_AGE*) and age squared have the expected sign. The estimated coefficient for *OP_EDUC* is positive and significant at the 5 percent level of significance. Increased education is expected to improve understanding of the complexities of production and financial relationships and therefore to increase demand for information. This is consistent with the arguments suggested by Welch (1970) and Rahm and Huffman (1984). Additionally, increased education corresponds to an increased capability to judge the usefulness to the business of computers and of the information obtained using them. Results suggest that an additional year of education increases the number of Internet uses by farm operators by 2.6 percent, holding all other variables constant. These findings are consistent with Willimack (1989), Putler and Zilberman (1988), Lazarus and Smith (1988), and Batte (2004, 2005), who studied the adoption of computers by farmers. Batte, Jones, and Schnitkey (1990) and Amponsah (1995) also found that education had a positive effect on the number of applications used.

The coefficient for farm size, measured by the value of agricultural commodities sold by the farm (*F_VALPROD*), is positive and significant at the one percent level of significance. One argument for this is that large farms face more complex decisions and so the value of information required is greater. Also, large farms that produce a majority of the products are on the cutting edge of adopting new ways in production and marketing to increase farm profitability. Also, operators

Table 2. Variable Definitions and Summary Statistics

Variable Name	Description	Mean[a]
SCORE1999	Internet access score	45.17 (11.19)
OP_AGE	Age of the farm operator (years)	48.0 (10.41)
OP_EDUC	Education level of farm operator	13.89 (0.49)
F_VALPROD	Value of agricultural commodities sold by the farm *($0,000)*	59.79 (15.75)
F_DIVERS	Entropy measure of farm diversification	0.20 (0.03)
OF_WAGE	= 1 if household reports off-farm income through wages and salaries, 0 otherwise	0.64
F_INVEST	= 1 if the farm household received interest and dividends, 0 otherwise	0.68
M_CONTRACT	= 1 if the farm had marketing contract, 0 otherwise.	0.32
P_CONTRACT	= 1 if the farm had production contract, 0 otherwise	0.14
R_HEART	= 1 if the farm is located in the Heartland region of the U.S., 0 otherwise	0.21
R_NORTHC	= 1 if the farm is located in the Northern Crescent region of the U.S., 0 otherwise	0.15
R_NORTHGP	= 1 if the farm is located in the Northern Great Plains region of the U.S., 0 otherwise	0.08
R_PGATE	= 1 if the farm is located in the Prairie Gateway region of the U.S., 0 otherwise	0.14
R_EUPLAND	= 1 if the farm is located in the Eastern Uplands region of the U.S., 0 otherwise	0.08
R_SSBOARD	= 1 if the farm is located in the Southern Seaboard region of the U.S., 0 otherwise	0.13
R_FRIM	= 1 if the farm is located in the Fruitful Rim region of the U.S., 0 otherwise	0.10
R_BASINR	= 1 if the farm is located in the Basin and Range region of the U.S., 0 otherwise	0.06
INT_APPL	Number of Internet applications used by farmers (*dependent variable*)	3.26 (1.71)
	Sample	2,138

[a] Standard deviation of continuous variables are reported.

of large farms tend to make greater use of non-equity capital, thus face greater financial risk and may be more focused on information as a risk management tool. Operators of large farms also tend to make greater use of leased land. Lease contracts add complexity, and thus likely heighten information needs of the manager or the farm operator. Our results are consistent with the findings of Ortmann, Patrick, and Musser (1994), Putler and Zilberman (1988), Batte (2004, 2005), and Hoag, Ascough, and Frasier (1991). The coefficient for *F_DIVERS* is positive and statistically significant at the one percent level of significance. A plausible explanation for this is that diversified farms may be using the Internet to track input and output prices, and information related to enterprises (crops and livestock), production management, and marketing. This result suggests that farmers are likely to use more Internet applications the greater the number of individual enterprises on the farm, since a large number of enterprises are associated with greater

Table 3. Effect of Farm, Operator, and Regional Characteristics on Number of Internet Uses (negative binomial model)

Variable Names	Parameter Estimates
Intercept	0.557**
	(0.262)
SCORE1999	0.001
	(0.001)
OP_AGE	0.006
	(0.009)
OP_EDUC	0.026**
	(0.008)
OP_AGESQ	-0.000
	(0.000)
F_VALPROD	0.600E-03***
	(0.165E-03)
F_VALPRODSQ	-0.138E-06
	(0.168E-06)
F_DIVERS	0.232***
	(0.115)
OF_WAGE	-0.071***
	(0.034)
F_INVEST	0.077***
	(0.029)
M_CONTRACT	0.066***
	(0.030)
P_CONTRACT	0.046
	(0.044)
R_HEART	0.149*
	(0.088)
R_NORTHC	0.069
	(0.091)
R_NORTHGP	0.135
	(0.096)
R_PGATE	0.123
	(0.091)
R_EUPLAND	0.349***
	(0.087)
R_SSBOARD	0.028
	(0.094)
R_FRIM	0.319***
	(0.095)
R_BASINR	0.134
	(0.106)
Log-likelihood correlation	-3500.34
between observed and predicted	0.67

Notes: Numbers in parentheses are standard errors. Single, double, and triple asterisks show statistical significance at 10 percent, 5 percent, and 1 percent levels, respectively.

complexity for a whole range of farm management issues. Additionally, diversified farms also tend to be larger in economic size. Our findings are in contrast with Putler and Zilberman (1988), who found that more diversified farms were less likely to have a computer but that farm-related business increased the probability of computer adoption.

One of the interesting findings is the negative and statistically significant relationship between off-farm income (*OF_WAGE*) and number of Internet applications by farm operators. Results suggest that farm households that receive off-farm income in the form of wages and salaries (a proxy for a permanent off-farm job) are likely to use the Internet in fewer applications. A possible explanation for this is that many of the operations (or uses) that the farm-operator household was asked about relate to farming and information-gathering about farming. Additionally, as one reviewer pointed out, wage and salary income is most likely earned by small and intermediate size farms, where the farming activities might not be as important to total household income. Likewise, these smaller operations tend to focus on less complex enterprises, like raising beef cattle. Operators of large farms have more sources of off-farm income including other self-employment sources. Under such circumstances, one can conceive of there being a negative relationship between off-farm income and number of Internet uses by farm operators. These results are opposite to the findings of Hoag, Ascough, and Frasier (1991) and Batte (2004, 2005), who found direct correlation between off-farm employment and computer adoption.

The coefficient for *F_INVEST* is positive and statistically significant at the one percent level of significance. Results suggest that farm households that receive interest and dividends engage in more Internet applications. This finding is in contrast to that obtained by Ortmann, Patrick, and Musser (1994). This may be reflecting the fact that households receiving interest and dividends are more sophisticated in their investments, more likely to be educated, and have higher household income, and hence have the ability to use different Internet applications (such as searching the Internet for loans and for information on products or marketing options). It may also reflect the stronger financial position of the farm family. Further, as one reviewer pointed out, people with more off-farm investments are more likely to access the Internet to track investments, research potential investments, and perhaps make online transactions or purchases, communicate with brokers, etc.

Farm operators who have marketing contracts (*M_CONTRACT*) for sales of their crops, livestock, and other commodities are also likely to use more Internet applications. One possible explanation is that farmers who engage in production or marketing contracts are risk-averse and are constantly seeking ways to reduce their exposure to risk factors. Farmers using a marketing contract may face the risk of not having enough (quantity) of a commodity (for example, as the result of an unexpectedly low yield) to meet the contractual obligation and may have to purchase the shortfall amount in the spot market. Farmers would then use the Internet to search for information on the availability and price of the commodity. On the other hand, if the grower has a bumper harvest (more than the contractual obligation), he or she may search the Internet for information on selling the product through Internet marketing or may seek information on price and other potential buyers. Various Internet applications can provide a farmer with information about prices of outputs and inputs, discounted prices for inputs, production agriculture, and new technology.

The Mississippi Portal region was used as the benchmark; therefore, any significance of coefficients for regional dummies is relative to this region. The coefficient for the Heartland region (*R_HEART*) is positive and statistically significant at the 10 percent level of significance. Results indicate that farms located in the Heartland region are using more Internet applications than farms in the benchmark region. Farms in the Heartland region produce 23 percent of U.S. farm output and have the most cropland (27 percent), and tend to be larger farms. These farms tend to grow cash grains, raise cattle, and have some dairy. The coefficients for the Eastern Uplands (*R_EUPLAND*) and Fruitful Rim (*R_FRIM*) regions are positive and statistically significant at the one percent level of significance. Results indicate that farms located in the Eastern Uplands and Fruitful Rim regions are using more Internet applications. The Eastern Uplands region has the highest number of small farms of any region, and these farms are diversified with tobacco, poultry, cattle, and some cash grains. On the other hand, farms in the Fruitful Rim region tend to grow high-value products such as fruits, vegetables, nursery, and cotton, and are mostly diversified farms. It is likely that the region variables represent the effects of omitted variables that are correlated with regional location (e.g., the intensity of advertising by Internet providers, transaction costs) of farm households.

Concluding Comments

The Internet may reduce constraints on a farmer's ability to receive and manage information, regardless of where the farm is located or when the information is accessed. Many agricultural groups, researchers, farm organizations, teachers, and extension agents have taken an active interest in Internet use in agriculture. This study examined the key farm, operator, regional, and household characteristics that influence the number of Internet applications used by farm households. This study is unique in two aspects. First, it uses national farm-level data comprised of different farm types and farm locations. Second, it is among the first studies to use the count data estimation method to investigate the impact of various factors affecting the number of Internet applications employed by farm operators.

Results from this study indicate that the number of Internet applications used is directly and significantly correlated with the educational level of the farm operator, farm size, farm diversification, presence of marketing contracts, and location of farms. In some ways the factors affecting the number of Internet applications used by farmers are similar to those obtained from various adoption studies. Overall, the results indicate that a large number of Internet applications are associated with more educated and larger farm operators. If the benefits of the Internet are to be enjoyed more widely, this suggests that special efforts focused on enhancing knowledge about computer use may be needed and targeted at smaller farmers and less-educated farmers. Further, emphasis might need to be directed at smaller operators in different groups, such as those who are in the beginning stages of farming, producers who would like to learn more about and become more proficient in examining marketing data and trends for commodities, or households that might not be operating a large farm and might be more interested in nonfarm activities including the tracking of off-farm investments.

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