Farmers' Perception of Precision Technology: The Case of Autosteer Adoption by Cotton Farmers

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Abstract

Precision agriculture and autosteer technology are, overall, profitable investments for farmers, as previous literature has established. However, what has not been investigated is whether or not farmers perceive these technologies as such. This research postulates that cotton farmers must see potential for higher profits as a result of adopting precision technologies in order to adopt it. Using the 2009 Southern Cotton Precision Farming Survey[a] and multinomial logit model, this research investigates farmers' perception of precision agriculture and how those perceptions impact adoption of the autosteer GPS guidance system. Autosteer adoption was found to be significant and positively related to the perceived future importance of precision agriculture as well as farmers' ranking of input cost savings relative to other attributes of the autosteer GPS technology. Additionally, results show that attributes of the cotton picker is another important factor in adoption of autosteer GPS technology.

***Keywords*:** Farmers' perception, precision agriculture, autosteer, multinomial logit estimation, technology adoption, input cost saving.

JEL codes: Q12, Q16

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[a] Abbreviations: Southern Cotton Precision Farming (SCPF), Multinomial Logit (MNL), Precision Agriculture (PA), Real-Time Kinematic (RTK) Autosteer

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1. Introduction

The perceived attributes of new technologies are known to condition adoption behavior. Adoption of technologies by farmers may reflect rational decision-making based on farmers' perceptions of the appropriateness of the characteristics and the value of technology to them in the coming years. Adoption of precision agriculture (PA) technologies is somewhat different from many other technologies introduced in agricultural production. A major difference is the fact that precision agriculture technologies[b] consist of a complex set of technologies, each with a specific purpose (Lowenberg-DeBoer, 1998; Khanna et al. 1999; Khanna 2001).

Gandonou et al. (2002) outline several obstacles to adoption of PA technologies. These obstacles included the high cost of adoption and a lack of perceived benefit delivered by precision agriculture. Farmers may adopt one or more technologies and evaluate those before adopting additional technologies (Byerlee and de Polanco 1986; Leathers and Smale 1991). Farmers' experience with one type of technology will likely affect their perception of future PA technologies and eventually the decision to adopt PA technology. The complexity of PA technologies and the compatibility of new technologies with current practices and existing equipment are other considerations in the decision process (Rogers, 1983). Research analyzing the impact of producers' perceptions in the agricultural sector is rare (Adesina and Baidu-Forson, 1995). Furthermore, the omission of farmers' attitudes toward the technologies studied may lead to biased results (Adesina and Zinnah, 1993).

[b] It has long been recognized that the advancement of PA management depends on the emergence and convergence of several technologies (Shibusawa, 1998), including geographic information systems (GIS), Global Positioning System (GPS), in-field remote sensing, automatic controls, miniaturized computer components, mobile computing, and telecommunications (Gibbons 2000).

Since the early 1990s, GPS-based technology has been widely used in agriculture (Larsen et al., 1994). GPS-based guidance technology can be used for many field operations such as sowing, tilling, planting, cultivating, weeding and harvesting. GPS-based navigation systems are the latest technology that has become commercially available for farm vehicles (Adidine et al., 2002). Cotton farmers primarily use two GPS navigation technologies: lightbar and autosteer. Both of these utilize GPS technology to identify the operator's location in the field; the fundamental difference between the two is that lightbar requires the operator to manually adjust steering whereas autosteer technology allows the operator to focus on monitoring the operation of the implement instead of steering. This innovation has the potential to decrease operator fatigue and increase the efficiency of farm input application. It requires minimal setup and service time, is easy to use, and allows greater accuracy when working in limited-visibility conditions.[c] The autosteer system eliminates human error, such as overlapping and skipping, which can lead to misapplication of pesticides, fertilizers and seed. Hence, autosteer technology could be helpful in reducing fuel consumption and emissions. Environmental quality is associated with farm input uses, and good environmental outcomes are assumed to be ones in which fewer inputs—like fuel—are used (Mishra et al., 2005; Chang et al., 2011).

This study seeks to determine whether perceived opportunities of autosteer technology increase the probability that farmers will adopt it. First, we determine whether farmers who have a greater preference for cost savings relative to other attributes of autosteer technology are more likely to adopt. Secondly, we assess the impact of farmers' perceptions regarding the future of precision agriculture technology and the attributes of autosteer technology. Lastly, we delineate

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[c] When asked about autosteer technology, a farmer in Douglas County, Washington replied, "It's the biggest thing that has come along in agriculture in Douglas County in years." The farmer also told the reporter, "I can do more work more efficiently, with less input of fuel, seed, fertilizer and chemicals, and that means lower costs." http://www.wa.nrcs.usda.gov/news/Footprints/Fall07/bareither.html

the characteristics of cotton farmers and cotton operations in the southern United States that adopt autosteer technology. Omission of such variables may bias the results of other studies investigating adoption of technology. This study utilizes the 2009 Southern Cotton Precision Farming (SCPF) Survey and a multinomial logit (MNL) model to accomplish the above objective. Extending the analysis to cover farmers' perceptions and the attributes of the technology may help in better understanding adoption behavior since farmers likely perceive technologies differently than do researchers, educators, and extension agents. Additionally, from an industry perspective, ex-post adoption studies could help technology manufacturers' direct resources to the most advantageous technology development strategies. Autosteer technology may help optimize resources and inputs for crop production, thereby reducing expenditures and making agriculture more profitable for the producer and better for the environment.

2. Literature Review

Several studies regarding the severity of the problem of technology adoption assess farmers' perceptions (see Gould et al., 1989; Norris and Batie, 1987; Lynne et al., 1988). However, in the context of developed countries, the literature on farmers' perception of technology and the resulting impact on adoption thereof is scarce; only two studies have focused on how producers' perceptions of conservation, environment and risks affected their intentions to adopt PA technologies (Napier et al., 2000; Batte and Arnholt, 2003). In one, Batte and Arnholt (2003) used six case studies to find that profitability was the biggest motivating factor in using PA tools. In another, Adesina and Zinnah (1993) found that farmers' perceptions of technology-specific attributes had a significant impact in the adoption of new varieties of mangrove swamp rice varieties in Sierra Leone. These studies, however, primarily investigate the severity of the problem as it relates to perception, and/or report on farmers' perceptions about the quality of specific technology, as investigated in the study by Adesina and Zinnah (1993).

PA equipment includes information-gathering tools such as yield monitors, targeted soil sampling and remote sensing tools; variable rate technology; and guidance systems, such as lightbar and autosteer equipment (Paxton et al., 2011). Auto guidance systems assist equipment operators in navigating equipment through the fields. Considerable attention in economics literature has been devoted to adoption of PA technologies, but little or no empirical study has been specifically conducted on autosteer adoption. One study has addressed the impact of autosteer on net returns, risk, and production practices using a whole farm simulation approach (Shockley et al., 2011). Additionally, in 2005, the economic feasibility of autosteer and lightbar GPS guidance systems was evaluated via a linear programming approach (Griffin et al., 2005). Our research contributes to the literature by analyzing the impact of operator characteristics and their perceptions of PA on the probability of adopting autosteer. This work is necessary because if farmers do not recognize potential benefits of the technology, then adoption of autosteer is unlikely even if it is truly beneficial.

The development of PA technologies like autosteer is important in light of several issues faced by farmers. First, these innovations benefit aging farm operators by reducing the physical demand required to continue farming (Feder et al., 1985). Secondly, technologies like autosteer reduce the skill level required to operate farm machinery (Griffin et al., 2005), which broadens the potential for greater substitutability of farm labor (D'Antoni et al., 2011). With employment in the farming sector decreasing (United States Department of Labor 2010), it is important to standardize processes so those without much experience may be quickly and cheaply trained to work on-farm. Finally, rising fuel costs and heightened attention to environmental conservation accentuate the need for efficiency of input use, which autosteer offers. However, despite this advantage, economic constraints ranked highest among reasons given for rejection of PA technologies, according to the SCPF Survey. The large up-front expenditures required for GPS or margin of inaccuracy (which limits efficiency gains) may cause these concerns.

Other limitations to GPS technologies have been noted as well. For example, according to Reid (1998), Reid et al., (2000), and Li et al., (2009) successful PA technology development depended on creation of a component enabling GPS-guided vehicles to automatically adjust to obstacles. This technology is now available; however, the price proves prohibitive for many farmers. Though lightbar GPS systems have the ability to adjust the track of the farm vehicle to changes in roll, pitch, and yaw, lightbar is generally considered the entry-level technology while Real-Time Kinematic (RTK) autosteer systems are the more advanced, and therefore higher cost, technology. Many tractor manufacturing companies now offer RTK GPS-based auto steering system as an option on their tractors. Position information from RTK GPS can be used for guidance as well as other applications such as seed mapping, traffic control, and tillage control. The development of RTK autosteer improves the accuracy of GPS systems to within an inch, which, to some extent, addresses concerns of efficiency gains; however, the high cost of RTK leaves the perceived profitability of this technology questionable. Still, as evidenced in the most recent SCPF Survey, autosteer adoption by cotton farmers outnumbers lightbar adoption three to one. Griffin et al. (2005) found that farms of a fixed size benefit more from lightbar than autosteer technology, and autosteer only becomes profitable with the increase of a farmer’s ability to expand operations. Unfortunately, in recent years, a growing percentage of cotton acreage in the Southeast has been diverted to corn. The adoption of autosteer may help in reversing this trend. Perhaps an increase in cotton acreage would improve potential profitability of autosteer technology.

We can surmise from Griffin et al. (2005), then, that the lower cost system is economically superior. This supposition is supported by the whole farm analysis of Kentucky grain farmers by Shockley et al. (2011); it found that adding only a bolt-on, sub-meter autosteer system to the sprayer was economically superior to adding only the RTK system to the sprayer. However, the type of crop grown may play a significant role in whether the lower cost sub-meter system is truly preferable to the RTK system. Lowenberg-DeBoer (2003) found that the adoption of PA technologies was more feasible in high value crops, such as cotton, than bulk commodities like corn; therefore, the notion that lower cost is strictly preferable to higher cost GPS guidance system technology may not hold across crop type.

Our research seeks to evaluate whether farmers are more likely to adopt autosteer as the relative value placed on input cost savings increases. Shockley et al. (2011) found that autosteer technology becomes more profitable as input prices increases and the efficiency of chemical application declines. As the price of inputs rise, farmers will be increasingly aware of how efficiently the resource is used and will look for ways to maximize efficiency. Autosteer technology is assumed to provide greater potential efficiency gains than lightbar.

3. Methods

3.1 Theoretical Model

Farmers' decisions regarding adoption of autosteer are assumed to be based upon utility maximization. Specifically, the individual chooses the outcome that maximizes the utility gained from that choice (in our case, GPS guidance system technology—autosteer, lightbar). The utility[d] derived from choice *q* for individual *i* equals

$$U_{iq} = \mu_{iq} + \varepsilon_{iq} \qquad (1)$$

[d] The underlying non-observable utility function which ranks preferences of the *i*th farmers is given by $U\left(M_{ji}, A_{ji}\right)$. Thus, the utility derived from the GPS technology depends on a vector (*Z*) of farm and farm operator specific attributes of adopters and a vector (A) of attributes associated with GPS technology.

where μ_{iq} is the average utility associated with choice *q* for individual *i*, and ε_{iq} is the random error associated with that choice. The probability of choosing alternative 1 is the probability that the utility from alternative 1 exceeds the utility from alternative 2:

$$\Pr(y_i = 1) = \Pr(\mathrm{U_{i1}} > \mathrm{U_{i2}}) \tag{2}$$

$$= \Pr(\mu_{i1} + \varepsilon_{i1} > \mu_{i2} + \varepsilon_{i2})$$

$$= \Pr(\varepsilon_{i1} - \varepsilon_{i2} > \mu_{i2} - \mu_{i1})$$

When there are *J* choices, as in our case (autosteer, lightbar, and none), the probability of choice *m* is

$$\Pr(y_i = q) = \Pr(\mathrm{U_q} > \mathrm{U_j} \ \ \forall\, j \neq q) \tag{3}$$

The specific form of the discrete choice model is determined by the assumed distribution of ε and the relationship of how μ_q, the average utility for choice q, to measured variables. To obtain the MNL model let the average utility be a linear combination of the attributes of the individual (farm operator), farm, and technology:

$$\mu_{iq} = Z_i \vartheta_q \tag{4}$$

where *Z* is *a n* x *k* matrix of the explanatory variables, and ϑ is a k x 1 vector of parameters to be estimated. Equation 4 serves as a basis for the maximum likelihood estimator. Let $\Pr(Y_i = q|Z_i, \vartheta_2, \dots \dots .., \vartheta_J)$ be the probability of observing $Y_i = q$ given Z_i with parameters ϑ_2 through ϑ_J. Let p_i be the probability of observing the value of *y* that was actually observed for the *i*th observation. Therefore, the likelihood function, if the observations are independent, is:

$$\mathrm{L}\left(\vartheta_2, \dots \dots .., \vartheta_J \middle| Y, Z\right) = \prod_{i=1}^{N} p_i \tag{5a}$$

Substituting p_i in the above equation yields:

$$\mathrm{L}\left(\vartheta_2, \dots \dots .., \vartheta_J \middle| Y, Z\right) = \prod_{i=1}^{N} \prod_{y_i = q} \frac{\exp(Z_i \vartheta_q)}{\sum_{j=1}^{J} \exp(Z_i \vartheta_j)} \tag{5b}$$

Taking logs, we obtain the log likelihood equation which can be maximized with numerical methods to estimate the ϑ's. The resulting estimates are consistent, asymptotically normal, and asymptotically efficient (Amemiya, 1981).

3.2 Empirical Model

Based on the discussion so far, an MNL model is used to estimate the probability of autosteer adoption conditional on a vector of explanatory variables. Farm operators who adopt autosteer are classified among three distinguished groups (*q*) based on their adoption status. The first, I_1, includes only the operator who adopts autosteer technology; the second, I_2, includes only the operator who adopts lightbar and/or other GPS guidance system technology; and the third, I_3, includes the operator who adopts neither autosteer nor lightbar GPS guidance system technology. Let Y_j takes the value 1 if the j^{th} farm operator chooses the q^{th} technology; 0 otherwise. The relative odds (*P*) of GPS guidance system technology choices are expressed using the following MNL model:

$$\log\left(\frac{P_{jq}}{P_{jM}}\right) = Z_j'\vartheta_q + \varepsilon_j, \qquad j = (1, \ldots\ldots, n), q = (1, \ldots\ldots, M-1) \tag{6}$$

where *log* is the natural logarithm, *Z* is an exogenous explanatory vector, ϑ is a vector of parameters to be estimated, and ε is a random disturbance term. The means of explanatory variables as defined by vector *Z* and based on the distinct *M* GPS guidance system technology choices is presented in Table 2. The conditional probability for the choice *q* is derived as in the following [for more detail, see Greene (2002), p. 721]:

$$\mathrm{P}_{jq} = \mathrm{Prob}\left(Y_{jq} = 1\right) = \frac{\exp\left(Z_{ji}'\vartheta_q\right)}{\sum_{k=1}^{M}\exp\left(Z_{ji}'\vartheta_q\right)}, \quad q = (1, \ldots\ldots, M-1) \tag{7}$$

which, alternatively, can be written as:

$$\mathrm{P}_{jq} = \frac{\exp\left(Z_j'\vartheta_q\right)}{1+\sum_{k=1}^{M-1}\exp\left(Z_j'\vartheta_q\right)}, \quad q = (1, \ldots\ldots, M-1) \tag{8}$$

$$\mathrm{P}_{jM} = \frac{1}{1+\sum_{k=1}^{M-1}\exp\left(Z_j'\vartheta_k\right)}$$

Table 1 lists the explanatory variables that are included in vector Z. The expected sign for the corresponding parameter ϑ is also included in the table. Age has an indeterminate sign because younger farmers may be more familiar with new technologies and therefore be more willing to adopt, while on the other hand, older farmers may be more willing to adopt autosteer technology due to lower physical demands required of the operator. Similarly, less experienced farmers may reap the greatest benefits from technology due to their relatively lower skill in operating farm machinery, whereas farmers with greater experience may be more likely to understand the need for and benefits of autosteer technology and be more willing to adopt. The final explanatory variable with an ambiguous sign is for the importance of input cost savings. There is no *a priori* reason to expect farmers who place a greater value on input cost savings than time/effort savings to be more willing to adopt autosteer (or vice versa).

Several factors do increase likelihood that cotton farmers will adopt autosteer. First, as their educational attainment, income range, and confidence in the future importance of PA increase, so does the probability that they will be open to adopting it. Additionally, those attending more extension events are expected to be more knowledgeable about PA technologies and therefore more likely to adopt. Furthermore, farmers currently using computers for farm management are expected to be more likely to adopt autosteer technology specifically. Lastly, the larger the cotton picker used on the farm, the higher is the expected probability of a farmer adopting autosteer technology. Presumably, purchase of a larger picker indicates heightened concern over maximizing efficiency through capital investment, and therefore, increased likelihood of investment in further technology that will enhance operational efficiency.

3.3 Data

The *Importance of Cost Savings* variable was created to determine the importance of the input cost savings attributes relative to time/energy saving attributes accrued directly to the operator of precision agriculture. In the SCPF Survey, farmers ranked the relative importance of fuel cost savings, labor cost savings, input cost savings, more time to do other things, and reduced operator fatigue/longer operating hours. The average rankings of the cost savings were calculated as:

$$R_1 = \frac{1}{3}\,(Fuel\ Cost\ Savings + Labor\ Cost\ Savings + Input\ Cost\ Savings) \qquad (9)$$

The average ranking of savings directly accrued to the operator:

$$R_2 = \frac{1}{2}(More\ Time\ for\ other\ Activites + Reduced\ Fatigue) \qquad (10)$$

The *Importance of Cost Savings* variable is defined as

$$\textit{Importance of Cost Savings} = \begin{cases} 1 \ \ if\ R_1 > R_2 \\ 0\ if\ \ R_1 \leq R_2 \end{cases} \qquad (11)$$

When the average ranking of cost savings (R_1) is greater than the average ranking of benefits accrued directly to the operator(R_2), then the *Importance of Cost Savings* variable is equal to one (zero otherwise). Also of interest is the explanatory variable *Importance of Precision Agriculture*. Farmers responded yes or no to the question, "Will precision farming be important five years from now?" Farmers that responded yes were assigned a value of one (zero otherwise). This variable addresses our primary objective by eliciting farmers' perceptions of the future importance of precision agriculture.

In this study, we examine cotton farmers in 12 southern states (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, and Virginia). In 2009, cotton farmers from these states were asked to complete the Southern Cotton Precision Farming Survey to determine their use of PA technologies during 2007 and 2008. This survey was produced by Mooney et al. (2010) to address the need to evaluate producers' experiences with a variety of PA technologies and to determine which benefits they received or expected to receive from the technology. The need for this information was established in light of work by Griffin et al. (2004) which stated that the future of precision farming depended on how favorably producers viewed PA technologies.

The survey was developed according to the procedures of Dillman (1978). The questionnaire was mailed to participants along with a postage-paid return envelope and cover letter explaining the purpose of the survey. The initial mail date was February 20, 2009 and a reminder was sent two weeks later on March 5, 2009. A follow-up mailing was sent to producers that had not responded three weeks later on March 27, 2009. The Cotton Board in Memphis, TN supplied a mailing list of 14,089 potential cotton producers for the 2007-2008 marketing year. Surveys were mailed to all addresses on the list with 309 being returned as undeliverable and 204 stating they had retired or did not farm cotton. This resulted in a total number of 13,579 surveyed cotton farmers with a total of 1,692 surveys returned, for a response rate of 12.5%. While slightly fewer cotton farmers were surveyed than are listed in the USDA's 2007 Agricultural Census (USDA, 2007), the distribution of these farmers across states corresponds closely with the distribution of farmers from the Census.

Because of such a low response rate, this sample may not accurately represent the population. Post-stratified survey weights were estimated to align the survey sample with the number of cotton farmers enumerated by the Census. While the survey weights do not adjust for non-response, post-stratified weights are useful for calibrating the survey data such that the response pattern of respondents closely approximates the distribution of the population of cotton producers (Lohr, 1999). The weights used in this study are “raking” weights suggested by Brackstone and Rao (1976), which are estimated by iteratively normalizing cell weights by the Cartesian product of the marginal row (cotton acres) and column (state cotton farm numbers) totals from the Agricultural Census cotton farm population (Lambert, 2010). The observations were grouped into 72 classes corresponding to the 12 states and 6 acreage classes. The acreage classes were based on the area planted in cotton during 2007 and the classes were 1-99, 100-249, 250-499, 500-999, 1000-1999, and 2000 or more. Therefore, a weighted regression model was estimated in this study (Lambert, 2010).

For purposes of this research the usable observations were reduced to 469, which is about 3.45% of total survey (28% of the returned sample). This sample represents about 18,600 cotton farms as a result of post-stratification survey weights. Table 2 provides summary statistics for the variables used in this paper. The dependent variable takes a value of one if the farmer adopts autosteer technology, a value of two if the farmer adopts lightbar GPS guidance system technology, and a value of three if the farmer has no GPS guidance system technology.

Autosteer adoption is estimated as a function of demographic variables such as age, experience, level of schooling, use of computer for farm management, and income. The average age of the farm operator in the sample is about 56, with 31 years of farming experience. The survey queried on number of years of formal education to establish educational attainment, and found the average farm operator in the sample had about 15 years of formal education. To assess the impact of computer use on precision technology adoption by cotton farmers, we used a dummy variable—whether or not the farmer used computers for farm management. Farm household income was measured by respondents choosing their appropriate income range. Specifically, farmers were asked to identify their estimated taxable household income from both farming and non-farm sources within 6 income ranges. These ranges included: (1) less than

$50,000; (2) $50,000-$99,999; (3) $100,000-$149,999; (4) $150,000-$199,999; (5) $200,000-$499,999; (6) $500,000 or greater. The number of extension events cotton farmers attended each year was also included in the model. Farm size is an important determinant of the adoption of technology (Feder, Just, and Zilberman, 1985). Based on the data, farm size for this study is based on total acres operated (owned and rented); farms were categorized into three categories, namely: (1) small sized cotton farm (less than 1,000 acres in cotton); (2) medium sized cotton farm (1,000-2,099 acres in cotton); and large sized cotton farm (2,100 or more acres in cotton). In the regression model, farm size is included as a dummy variable. The large farm dummy variable is used as the benchmark category in the regression analysis.

Another significant aspect of the empirical model is the characteristics of farm machinery. In particular, cotton farmers were queried whether the type of picker they owned, if any, had four rows, five rows, or six rows. If the farmer did not own a picker, the value assigned to the size of the picker was zero; a four-row picker was assigned a value of one, a five-row picker was assigned a value of two, and a six-row picker was assigned a value of three. Cotton farmers were also queried on the age of the picker (in years) and this is included in the empirical model.

4. Results and Discussion

A cursory look at the results points to the importance of the farmer's age, use of computers, age of the picker, size of the picker, and perceived importance of precision farming. First, the result of the Wald chi-squared test shows that the coefficients of the succession regression model, when considered jointly, are all significantly different from zero. Another indicator of the model's overall fit is the estimated value of McFadden pseudo-R^2 of 0.37, which considering the cross-sectional nature of the data points to the model's fair predictive power.

Table 3 reports weighted estimation results for the MNL model based on the maximum likelihood estimation method. The reference GPS guidance system technology category for the MNL model is I_3 reflecting no GPS guidance system technology category. The test for independence of irrelevant alternatives (IIA) was found to be insignificant (for further details see Hausman and McFadden, 1984; Long, 1997). Accordingly, as mentioned earlier, the estimated coefficients ϑ_q (q=1, …, M-1) measure the correlation of the regressors in vector Z_j (see equation (6)) on the likelihood of farm operator adopting a GPS guidance system in category I_1, or I_2, relative to I_3. A positive regression coefficient means that an increase in the explanatory variable is associated with increased probability of category q (i.e., I_1, or I_2) relative to category M (i.e., I_3). Before expounding on the results, it is worth mentioning that the estimated model demonstrated a fairly superior predictive capability as indicated by a McFadden pseudo-R^2 value of 0.37.

Column 2 in Table 3 presents the parameter estimates of the model depicting the likelihood of occurrence of the autosteer adoption relative to the strategy where no GPS guidance system is undertaken; Column 3 in Table 3 presents the marginal effects. Findings are, in general, consistent with expectations based on theoretical expectations and findings from previous studies in adoption literature. The perceptions of farmers regarding the importance of PA and the potential input cost savings of autosteer adoption are significantly associated with the likelihood of adoption of autosteer GPS guidance system. Regarding the importance of PA over the next five years, an incremental increase in perceived importance increases the likelihood of autosteer adoption by 0.103 (Table 3). Additionally, an incremental increase in the ranking of input cost savings as a potential benefit to autosteer adoption, relative to non-adopters of GPS guidance systems, increases the likelihood of adoption by 0.193. Therefore, a positive outlook for PA and the perception of greater cost savings from this technology increase the likelihood of autosteer adoption by cotton farmers. However, it is interesting to note that potential input cost savings is a significant factor in the adoption of lightbar GPS guidance technology compared to autosteer technology (Table 3). Results here confirm the maintained hypothesis that farmers' perceptions of attributes of precision agricultural technologies and potential input cost savings determine observed adoption choices.

Size and age of the cotton picker are also significantly associated with the probability of adopting autosteer. As the size of the cotton picker increases from four to five rows, the likelihood of adopting autosteer technology, relative to non-adopters of GPS guidance system, increases by 0.061. On the other hand, an additional year in the age of the cotton picker decreases the likelihood of adopting autosteer GPS guidance system, relative to non-adopters of GPS guidance system, by 0.019. One can argue that as equipment ages the incentive for greater capital investment in that machinery declines, and, hence, likelihood of a farmer to invest in autosteer technology decreases. Alternatively, bolt-on autosteer systems allow farmers to retrofit older machinery and are available at lower costs than RTK systems, requiring smaller capital investment to potentially increase the efficiency of older machinery. This in turn is expected to increase the likelihood of a farmer adopting autosteer technology. This notion is supported by a positive and significant coefficient on the age of the picker in the adoption of lightbar GPS guidance technology. Results indicate that an additional year increases the likelihood of adoption of lightbar GPS guidance technology by 0.007 (Table 3, last column).

Age of the farm operator is negatively associated with the probability of autosteer and lightbar technology adoption. The marginal effect indicates that compared to younger operators with no GPS guidance system, likelihood of adoption of autosteer and lightbar technology decreases with age by 0.001 and 0.004, respectively. Although we do observe an inverted-U shaped relationship between age and adoption pattern (positive coefficient on age-squared term), the coefficient is not significantly different from zero. A possible explanation for this result is that younger farmers may be more educated and more inclined to use information technology to manage farming systems, but may not have the necessary income/wealth to purchase a costly technology like autosteer and lightbar GPS guidance system. Interestingly, the marginal effect on adoption of lightbar technology, compared to that of having no GPS guidance system, is higher—indicating that as farmers age, adoption of lightbar GPS technology decreases at a higher rate than adoption of autosteer. This may have to do with the bulkiness of the lightbar technology and manual labor requirements of the lightbar GPS technology. Our results are consistent with the findings of Batte et al. (1990); and Batte (2004 and 2005).

Results in Table 3 indicate a positive and significant correlation between farmers using computers for farm management and the likelihood of adopting autosteer GPS guidance system. This is to be expected because farmers familiar with computers are more likely to be comfortable in using GPS technology. Mishra et al. (1999) concluded that cash grain farmers who kept computerized financial records were more likely to be successful. Additionally, farmers with computer access have greater access to information on new technology such as autosteer, and are likely to be better educated about the technology. Our results are consistent with the findings of Paxton et al. (2011); Batte (2004 and 2005); and Walburger and Davidson (1999). Finally, results in Table 3 show a positive and significant relationship between farm size and likelihood of adopting autosteer GPS guidance system. In particular, compared to large farms (benchmark group), medium sized cotton farms (1,000-2,099 operated acres) are more likely to adopt autosteer GPS guidance systems.

5. Conclusions

GPS-based guidance technology, such as autosteer, can be used for many field operations including sowing, tilling, planting, cultivating, weeding, and harvesting. Autosteer technology allows the farmer to focus on monitoring the operation of the implement instead of the task of steering the equipment. Although a plethora of research has investigated the adoption of various PA technologies, none has focused on the adoption of GPS guidance technologies (such as autosteer and lightbar). In particular, research has failed to investigate two important factors in determining the adoption of autosteer technology: one, farmers' perceptions of PA technologies and two, the importance of cost savings. The literature has previously addressed whether PA and autosteer are actually profitable investments, but not whether, if so, farmers recognize the opportunity. The objective of this study was to examine the factors affecting farmers' adoption decision of PA and autosteer technology among cotton farmers in southern United States. Particular attention is given to the role of farmers' perceptions of PA technologies and the importance of cost savings in the adoption decision of PA and autosteer technology.

Using the Southern Cotton Precision Farming Survey (2009) and multinomial logit model estimation procedure, the study found that farmers who have a greater preference for cost savings than for other beneficial attributes of autosteer technology are more likely to adopt autosteer technology. Further, farmers who feel precision agriculture will be important over the following years have a higher likelihood of adopting autosteer technology.

Though other factors, such as characteristics of farm operators and equipment, play a role in the likelihood of autosteer adoption, they are not significant enough to shape how autosteer and lightbar technology should be introduced and marketed to cotton farmers. Autosteer appears to be more highly valued than lightbar technology, which is understandable given its capability to remove the burden of equipment manipulation from the operator. Its more advanced technological capabilities provide several benefits to the farmer, including reduced fatigue, increased accuracy in sowing, tilling, cultivating, weeding, and harvesting, and a broader sphere of possible laborers who could operate the machinery with less technical knowledge and training.

Despite these perceived benefits, however, it has yet to reach the input cost savings of lightbar technology, even though lightbar has reduced accuracy and requires more operator energy and aptitude than autosteer. This implies that farmers may perceive cost savings using autosteer technology as greater than they actually are. It also leads to the conclusion that farmers who adopt precision technology are future-focused, leading them to choose more advanced technology that will render larger dividends over a longer period of time.

6. References

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Table 1: Explanatory Variables and the Expected Effect on Autosteer Adoption

Explanatory Variable	**Expected Sign**
Age of the operator (years)	+/-
Educational level of the farm operator (years)	+
Computer	+
Occupation of the farm operator (farming)	+
Farm household income	+
Extension Attendance	+
Importance of Precision Agriculture	+
Importance of Input Cost Saving	+/-
Size of Picker	+
Small farm (less than 1,000 acres in cotton)	-
Medium Cotton farm (1,000-2,099 acres in cotton)	+/-
Large cotton farms (2,100 or more acres in cotton)	+
Age of Picker	-

Table 2: Summary Statistics of Dependent and Independent Variables

Variable	**Mean**	**Std. Dev.**
Autosteer (=1 if using autosteer GPS guidance system; 0 otherwise)	0.447	0.498
Lightbar (=1 if using lightbar GPS guidance system; 0 otherwise)	0.211	0.800
Age of the operator (years)	55.914	11.518
Occupation (=1 if 100% of the income is derived from farming)	0.166	0.372
Educational level of the farm operator (years)	14.698	2.167
Use of computer (=1 if using computers for farm management; 0 otherwise)	0.641	0.480
Farm household income[1]	3.100	1.553
Extension Attendance (number of times farmer attend University educational events)	3.660	7.555
Importance of Precision Agriculture	0.873	0.333
Importance of Input Cost Saving	0.171	0.377
Size of Picker	1.302	1.179
Age of Picker	6.428	6.657
Farm size (small)[2]	0.22	0.114
Farm size (medium)	0.28	0.163
Farm size (large)	0.50	0.198

Source: 2009 Southern Cotton Precision Farming Survey.

[1] Farmers were asked to identify their estimated taxable household income from both farming and non-farm sources within 6 income ranges. These ranges included: (1) less than $50,000; (2) $50,000-$99,999; (3) $100,000-$149,999; (4) $150,000-$199,999; (5) $200,000-$499,999; (6) $500,000 or greater.

[2] Based on the data farm size for this study is based on total acres operated (owned and rented). The categories of farm include: (1) small sized cotton farm (less than 1,000 acres in cotton); (2) medium sized cotton farm (1,000-2,099 acres in cotton); large sized cotton farm (2,100 or more acres in cotton).

Table 3: Weighted Multinomial logit estimates of factors affecting adoption of GPS guidance systems technology by cotton farm operators, 2009

Variable	**GPS guidance system adoption**			
	Parameter estimate for Only autosteer technology: *log* (P_1 / P_3)	Marginal Effect Only autosteer technology	Parameter estimate for Lightbar GPS technology: *log* (P_2 / P_3)	Marginal Effect lightbar GPS technology
Constant	0.552		1.086	
	(1.639)		(2.913)	
Importance of Precision Agriculture	1.263	0.103***	0.886	0.049
	(0.603)		(0.573)	
Importance of Input Cost Savings	2.553	0.193***	2.132	0.170***
	(0.506)		(0.482)	
Extension Attendance	-0.019	-0.005	0.017	0.006
	(0.033)		(0.027)	
Size of Picker	0.774	0.061***	0.565	0.034*
	(0.148)		(0.139)	
Age of Picker	-0.147	-0.019***	0.041	0.008**
	(0.032)		(0.021)	
Farm household income	-0.065	-0.004	-0.058	-0.005
	(0.105)		(0.091)	
Age of operator	-0.111	-0.001***	-0.078	-0.004***
	(0.036)		(0.024)	
Age of operator squared	0.001	0.000	0.000	0.000
	(0.001)		(0.001)	
Farming as main occupation	0.522	0.002	0.511	0.051
	(0.378)		(0.328)	
Educational level	0.040	0.027	0.010	0.001
	(0.077)		(0.067)	
Use of computer	1.112	0.072***	0.954	0.080
	(0.372)		(0.305)	
Farm size (small)	-0.079	0.010	-0.214	-0.036
	(1.109)		(1.034)	
Farm size (medium)	1.756	0.141**	1.264	0.074
	(0.643)		(0.941)	
N	469			
Log Likelihood	-348.248			
LR(χ^2)	185.15***			
Pseudo R^2	0.37			

***, **,** *** indicate statistical significance at the 10, 5, and 1 percent level of significance.
P_1 = only autosteer technology; P_2 = only lightbar GPS guidance system technology; P_3 = none.