Determining Farmers' Willingness-To-Grow Cellulosic Biofuel Feedstocks on Agricultural Land

Melissa K. Lynes, Jason S. Bergtold, Jeffery R. Williams, and Jason E. Fewell

The authors are Graduate Research Assistant, Associate Professor, Professor, and Graduate Research Assistant, respectively, Department of Agricultural Economics, Kansas State University, Manhattan, KS, 66506.

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Abstract

The levels of cellulosic biofuel feedstocks that are being produced continue to fall short of standards set by the Environmental Protection Agency (EPA). Technical feasibility studies have been conducted to determine if the levels of production the EPA has mandated are obtainable; and breakeven farmgate studies have shown the costs of growing cellulosic feedstocks. However, very few studies have been conducted on farmers' willingness to grow these feedstocks. This study examines farmers' willingness to harvest crop residue, or grow a dedicated annual, or perennial bioenergy crop. A Heckman selection model is used to account for selection bias, estimate the probability of a farmer growing a particular feedstock, and to determine how many initial acres farmers would be willing to plant of a dedicated annual or perennial bioenergy crop. We find that, due to the variation in the type of crops and feedstocks considered different variables are significant in the farmers' decision-making process.

JEL Codes: Q12, Q15, Q16

Keywords: acreage allocation, annual bioenergy crop, cellulosic biofuel feedstock, crop residue, Heckman selection model, perennial bioenergy crops, willingness to grow

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Despite yearly standards set by the Environmental Protection Agency (EPA), the production of biofuels from cellulosic biofuel feedstocks continues to fall short of mandated levels. In 2010, the EPA revised yearly production requirements for cellulosic biofuels: biomass-based diesel, advanced biofuels, and total renewable fuels. Originally, the goal was 0.10 billion gallons of cellulosic biofuel. This was to increase to 0.25 billion in 2011 and 0.50 billion in 2012. By 2022, 16 billion gallons of cellulosic biofuel was to be produced (U.S. Environmental Protection Agency 2010). However, a 2011 study conducted by the Energy Information Administration (EIA) in conjunction with the EPA, projected that only 8.65 million gallons of cellulosic biofuel will be produced in 2012 (U.S. Environmental Protection Agency 2011). This is approximately 1/60 of the original goal of 0.50 billion gallons of biofuel production by 2012. So far, the short-fall in production has not jeopardized the goal of 16 billion gallons by 2022, but soon could. According to the "EPA Finalized 2012 Renewable Fuel Standards" it is believed that 15.2 billion gallons of renewable fuel in 2012 is still attainable (U.S. Environmental Protection Agency 2011). According to the standards set by the Energy Independence and Security Act of 2007, by 2016 any new biofuels produced must originate from cellulosic feedstocks (U.S. Congress, House of Representatives 2007).

Given the drastic short fall in cellulosic biofuel production, it is important to know if farmers are willing to produce the alternative cellulosic biofuels feedstocks needed for advanced biofuels production. The purpose of this study is to estimate the probability of and examine factors affecting farmers' willingness to produce different types of cellulosic biofuel feedstocks. In addition, the paper estimates farmers' potential initial acreage allocation decisions for dedicated annual and perennial biofuel crops. The study examines three sources of cellulosic biofuel feedstocks. The first source is agricultural residue (e.g. corn stover), which represents a value-added product for farmers. The other two types are dedicated annual bioenergy crops (e.g. energy or sweet sorghum) and perennial bioenergy crops (e.g. switchgrass or miscanthus).

Technical feasibility studies have estimated the breakeven price at which farmers should be willing to produce cellulosic biofuel feedstocks, as well as the effects on soil integrity, water quality, and water quantity of biofuel production. While these studies examine the technical conditions under which farmers may produce cellulosic energy feedstocks, there is relatively little literature that examines farmers' willingness to adopt these enterprises.

This study contributes to the existing literature by examining the effect of farm, farm manager, and socioeconomic characteristics on Kansas farmers' willingness to produce alternative cellulosic biofuel feedstocks. Using the data from the study we go a step further to analyze the potential initial acreage allocation decisions for dedicated annual and perennial feedstock production, providing an initial estimate of the potential supply at the farm level. We use a probit model to determine farmers' willingness to harvest their crop residue. We then use a two-stage Heckman selection model to examine farmers' willingness to grow dedicated bioenergy crops. The first stage examines a farm managers' willingness to produce, while the second stage determines how many acres the farm manager would be willing to initially plant of the bioenergy crop. There have been numerous studies conducted on farmers' willingness to grow perennial and herbaceous crops as bioenergy feedstocks and harvest crop residues. This paper extends these initial efforts to consider a dedicated annual bioenergy crop and how many acres they are initially willing to grow of both the annual and perennial bioenergy crops.

Literature Review

Technical Feasibility and Logistics

There has been a great deal of research conducted on the technical feasibility of growing cellulosic biofuels and farmgate pricing (Bangsund, DeVuyst, and Leistritz 2008; P. Gallagher, et al. 2003; Graham, et al. 2007; Graham 1994; Rajagopal, et al. 2007; Walsh, et al. 2003). Graham (1994) found that most of the 158.6 million hectares of land that are suitable for growing bioenergy crops are already being used to produce traditional crops.

Other studies have looked at biomass yield and production potential (Graham, et al. 2007; McLaughlin, et al. 2002; Nelson 2002; Perlack, et al. 2005; Propheter, et al. 2010). Perlack, et al. (2005) estimated that biomass production could reach one billion dry tons per year. Of this total, 75% of the biomass produced would be from agricultural land, using up to 55 million acres, assuming that dedicated perennial bioenergy crops are grown simultaneously with existing biomass sources and technology continues to increase crop yields.

With high enough prices there will likely be an increase in the amount of biomass produced, displacing agricultural land that has typically been used for traditional crop and livestock production (de la Torre Ugarte, English, and Jensen 2009; Gallagher, et al.

2003). An increase in the production of dedicated bioenergy crops will lead to a decrease in land allocated for traditional crop and livestock production, which will likely increase commodity prices, further increasing competition among dedicated energy crops (Walsh, et al. 2003).

Other studies have projected what biorefineries or other immediate processors will have to pay farmers to supply biomass. A farmgate study in South Central North Dakota found that costs, including opportunity costs, for producing switchgrass were $47.14, $67.02, and $76.16 per ton on poor, average and high productivity soil, respectively (Bangsund, DeVuyst and Leistritz 2008). A study by Perrin, et al. (2008) found that between 2001 and 2005 the average total production cost of switchgrass was $70 per ton on ten different plots ranging from North Dakota to Nebraska. Other studies include P. Gallagher, et al. (2003), Larson, English and He (2008), Mapemba and Epplin (2004), and Turhollow (1994).

It is important to keep in mind that biorefineries and farmers will value bioenergy crops differently. Biorefineries consider biomass as an input and value it according to the price they receive for selling biofuel produced from it. Famers view the biomass as an output and consider returns from other crops, machinery requirements, input costs, labor, commodity market, prices, and government policy, to determine the profitability and risk of growing a bioenergy crop (Mapemba and Epplin 2004; Paine, et al. 1996). According to Mapemba and Epplin (2004) there are 19 different types of machinery required to harvest biomass. This plays a significant role in determining farm level breakeven prices. Breakeven pricing for switchgrass can be thought of as the price that covers production costs as well as replacing the returns from traditional crops which include returns to operator labor, management, equity, and land (Babcock, et al. 2007; Bangsund, DeVuyst and Leistritz 2008).

Mapemba and Epplin (2004) found that harvest time constraints are another important factor when determining breakeven biomass prices. Optimal harvest of different types of biomass occurs at various times during the year. Epplin et al. (2007) report that an eight-month harvest system costs $36.88 per dry ton to harvest switchgrass compared to using a two-month harvest system, which costs $52.75 per dry ton, ignoring transportation costs. This implies that farmers would be able to supply the biomass in a less costly way to biorefineries if they could supply it when labor for harvesting was available and weather was suitable. If biorefineries utilize multiple feedstocks for a year round supply (e.g. switchgrass and crop residues), this situation may allow farmers a choice to produce feedstocks that provide a better fit for their on-farm production systems, potentially reducing costs for both parties and increasing supplies (Epplin, et al. 2007).

Other costs need to be considered as well. Due to the bulky nature of biomass produced from bioenergy crops, transportation costs are high. Biomass should be grown close to the processing plant to reduce costs (Epplin, et al. 2007; P. Gallagher, et al. 2003; Larson, et al. 2005; Paine, et al. 1996). Furthermore, the potential value of carbon sequestration credits gained from perennial bioenergy crop production should be considered. Such information would be needed to help determine the optimal prices that farmers may receive for growing these crops. However, there is still much that needs to be determined before relying on these types of credits (Bangsund, DeVuyst and Leistritz 2008).

Bioenergy Crop Production

There have been several studies that have examined the opportunity costs of growing bioenergy crops or removing residue for biomass as an alternative to traditional cropping practices. Leaving corn residue on the soil as opposed to harvesting it has several values. It can be valued as organic matter, because it can add to the nitrogen, phosphorous, and potassium in the soil, which means less need for commercial fertilizers (Hess, et al. 2009). Leaving the residue on the ground can also retain and recycle nutrients, improve soil structure, and help maintain soil water levels (Wilhelm, et al. 2007). Several issues arise when crop residue is removed including increased soil erosion, increased levels of chemical run off, reduced efficiency of water absorption, and reduced levels of soil organic matter (Blanco-Canqui and Lal 2009). The cost of harvesting the residue also needs to be considered (P. Gallagher, et al. 2003). An advantage gained from removing the residue before planting is that herbicides will work more effectively due to more direct contact with the soil resulting in a reduction in the amount of herbicides needed (Hess, et al. 2009).

There are several environmental concerns associated with increased bioenergy crop production. Farmers may consider removing marginal land from Conservation Reserve Program (CRP) acres, using them for biomass production to make a higher profit (Paine, et al. 1996). McLaughlin et al. (2002) found that if feedstock prices reached $47.50 per ton for switchgrass, 13.3 million acres would be removed from the CRP and used for switchgrass production instead. If these acres are removed from CRP and put into perennial bioenergy crop production the conservation benefits that were present with CRP production will likely be reduced (Baker and Galik 2009).

Planting of perennial bioenergy crops (e.g. switchgrass and miscanthus) can provide environmental and production benefits. McLaughlin and Walsh (1998) found that planting switchgrass decreases soil erosion, uses half as much fertilizer as corn, only requires one herbicide application during its establishment year, and is more flood and drought tolerant than traditional crops, making it a viable and potentially attractive bioenergy crop option. Perennial crops also encourage wildlife proliferation and improve water quality over traditional annual crops due to their natural filtration system (Paine, et al. 1996). Research has shown net energy gains of 343% from producing a perennial crop which far exceeds the 21% energy gained when using corn grain for ethanol (McLaughlin and Walsh, 1996). However, due to production risks and high establishment costs, many farmers are disinclined to plant perennial crops (Pannell, et al. 2006).

Farmers' Willingness to Grow

Despite the significant value these previous studies have provided for farmgate pricing, opportunity costs, and feasibility, these studies may be of little relevance if farmers are not willing to grow bioenergy crops or harvest crop residues for biofuel production. There have only been a few studies that have examined the willingness of farmers to grow cellulosic biofuels. Via survey methods, Jensen, et al. (2006) found among Tennessee farmers, those farms that are smaller in size, plant soybeans, have younger and more highly educated operators, and utilize conservation practices (e.g.no-till) were more willing to grow bioenergy crops. They found that farmers who own or have access to equipment for hay production were more willing to plant switchgrass, indicating they have the capability to cut, bale, and handle switchgrass without additional capital investment. However, livestock operators were less likely to adopt switchgrass

(Jensen, et al. 2006), potentially given the opportunity cost of converting land from pasture or hay production to bioenergy crop production.

Sherrington, Bartley and Moran (2008) used focus groups of farmers in the United Kingdom to determine whether or not farmers are willing to grow an energy crop. They found the main factors affecting adoption are perception of financial returns and uncertainty in financial returns (at least) in the short-run. The study also found that farmers, especially older farmers, would be willing to contract out bioenergy crop production on their operation to a third party.

A choice experiment conducted by Paulrud and Laitila (2010) examined farm and farmer characteristics that may have significant influence on farmers' willingness to grow bioenergy crops, especially herbaceous and perennial crop options. The study found that production on leased or rented land, share of land set-aside for production, and the type of farming had no significant effect on farmers' willingness to grow. The age of the farmer, farm size, income, cultivating on set-aside land, and geographical location had negative effects on farmers' willingness to grow.

Pannell et al. (2006) found that the level of education has less to do with adoption than training courses related to the particular technology being adopted. They found that crops with long time lags between planting and harvesting have increased production risk which could act as a disincentive for farmers to plant perennial bioenergy crops.

Data and Methods

Probit and Heckman selection models are used with survey data collected from farm mangers by enumerators to examine factors that affect farmers' willingness to supply bioenergy crops and to determine the minimum initial acres they will plant of annual or perennial bioenergy crops.

Survey Data

A survey was administered from November 2010 to February 2011 by Kansas State University and the USDA, National Agricultural Statistics Service (NASS) to assess Kansas farmers' willingness to produce alternative cellulosic biomass feedstocks for bioenergy production under different contractual arrangements. A total of 485 farmers where contacted in northeastern, central, and western Kansas to participate in the survey. These regions of Kansas were selected based on the number of farms growing corn and/or sorghum; mix of irrigated and dryland production; geographical and climate differences; and proximity to existing grain-based and future cellulosic-based biorefineries. The particular locations were chosen because western Kansas has the most irrigation out of the three areas in the study, providing a means to capture behavior by farmers who irrigate crops, especially corn. The central part of the state has less irrigation than the west, but is the largest producer of sorghum in the state. A significant dedicated annual bioenergy crop suited to Kansas is energy sorghum. The northeastern part of the state is on the boundary of the western corn belt. This area relies less on irrigation than the other two areas, but has more rainfall. The main crops produced in the northeastern part of the state are corn and soybeans.

For each region of Kansas surveyed, a random sample of approximately 160 farms with more than 260 acres and $50,000 in annual gross farm sales were obtained from the USDA-NASS farmer list. In addition, the percentage of dryland versus irrigated farms surveyed was selected to match the existing distribution of the percentage of dryland versus irrigated farms for each region. Farmers already participating in USDA-NASS enumerated surveys (e.g. ARMS) were removed from the sample and replaced with another randomly drawn farmer. The survey was tested using face-to-face interviews with farmers in the targeted study areas of the state. The survey consisted of seven sections. The sections were farm characteristics; a stated choice section on farmers willingness to grow biofuel crops and contracting; bioenergy crop contracting conditions; conservation practices; marketing strategies; risk perceptions; and demographics.

Potential participants were mailed a four page flier asking for their participation in the survey and providing information about cellulosic biofuel feedstock production one week prior to being contacted by USDA-NASS enumerators. USDA-NASS enumerators then scheduled one hour interviews with the farmers to complete the survey and stated choice experiments. Interviews, on average took 57 minutes to complete. Upon completion of the survey and receipt at the USDA-NASS office in Topeka, farmers were compensated for their time with a $15 gift card. Of the 485 farmers contacted, 290 completed the survey and 38 were out-of-business, did not farm, or could not be located. Thus, the final survey response rate was 65%. Of the 290 respondents who completed the survey 238, 215, and 216 responses were usable for analysis examining value-added, annual crops, and perennial crops respectively. The lower numbers of responses for this analysis was due to a lack of response or refusal to answer all relevant questions.

Farmer demographics taken from the 2007 U.S. Census of Agriculture (NASS, 2009) were used to determine whether the survey respondents are representative of Kansas farmers. Table 1 compares some of the demographics as reported by farmers in the survey to statewide numbers as recorded in the 2007 Census of Agriculture. A slightly lower average age is reasonable given our survey sampled larger farms that are likely operated by younger farmers. Average farm size, amount of land leased, amount of permanent pasture, and amount of land owned are considerably larger for our survey. The larger farm sizes we found stems from the fact that we chose farms over 260 acres in our sample, which eliminates many small, or hobby farms. The survey asked respondents to choose a category in which their value of agricultural product sales occurred, and the Census of Agriculture figure of $219,944 fell within the most often selected category of $200,000 to $399,999.

The survey was used to find out if farmers are willing to produce any combination of three different bioenergy crops: crop residues (e.g. corn stover) as a value-added product; a dedicated annual bioenergy crop option (e.g. sweet sorghum); and a dedicated perennial bioenergy crop (e.g. switchgrass). Figure 1 contains the question asked in the survey. It should be noted that several assumptions were made to assist respondents in answering the questions. The first was that respondents were to answer as if a favorable contract would be offered. The second assumption was made in regards to the initial acreage component of the question. Respondents were to assume that the annual or perennial bioenergy crop (found in table 2) could be planted on leased or rented land.

Table 2 provides descriptions of the variables from the survey that are used in our analysis. The dependent variables are: would a farmer be willing to harvest their value-added crop residue (VA); would a farmer be willing to plant a dedicated annual bioenergy crop (AC); would a farmer be willing to plant a dedicated perennial bioenergy crop bioenergy crop (PC); and how many initial acres of the annual (ACIA) and perennial

(PCIA) bioenergy crops would a farmer be willing to plant. The independent variables are described by categories. These are farm characteristics, farm practices, bioenergy custom farming and land use options, and farmer characteristics. The factors in each of these categories are the hypothesized variables that would affect a farmers adoption and initial acreage allocation decision for each type of cellulosic biofuel feedstock being considered based on previous studies examined in the literature and economic theory.

Model

An expected utility model framework is used to determine the factors affecting farmers' willingness to harvest crop residue and/or grow a dedicated annual or perennial bioenergy crop. Let $V_{c,j,i}(X_{c,i})$ be an expected utility function for farmer i where $c = r, a, p$ and $j = 1,0$. The index *c* represents the cellulosic biofuel feedstock being adopted, where *r* is harvesting of crop residue; *a* is a dedicated annual bioenergy crop; and *p* is a dedicated perennial energy crop. $X_{c,i}$ is the set of explanatory variables associated with the decision to harvest cellulosic biofuel feedstock *c* for individual *i*. The index *j* represents two different states and is equal to "1" if crop residue is harvested or a dedicated energy crop is grown, and "0" otherwise. For the remainder of this section, the index i representing the individual under consideration is suppressed to ease notational burden.

A farmer will harvest crop residue or grow a dedicated energy crop if $\Delta V_c = V_{c,1}(X_c) - V_{c,0}(X_c) > 0$. That is, if the expected utility from producing a cellulosic biofuel feedstock is greater than if it is not grown. Given the nature of utility, ΔV_c cannot actually be observed. Instead, the binary response from a farmer willing to harvest crop residue or grow a dedicated bioenergy crop is. Let $j_c = 1$ if $\Delta V_c > 0$ and "0" otherwise. The model for a particular farmer willing to produce a given cellulosic biofuel feedstock is given by:

$$\Delta \mathrm{V_c} = \boldsymbol{\alpha}'_{\mathbf{c}}\mathbf{X_c} + \varepsilon_\mathrm{c} \text{ with } \varepsilon_\mathrm{c} \sim \mathrm{NI}(0, \sigma_\varepsilon^2) \text{ and} \tag{1}$$

$$j_c = \begin{cases} 1 & if\ \Delta \mathrm{V}_c > 0 \\ 0 & otherwise \end{cases} \tag{2}$$

where $\boldsymbol{\alpha}_\mathbf{c}$ is a vector of parameters. Given that ε_c is normally distributed and j_c is observed, the model given in equations (1) and (2) can be estimated as a probit model. The probit models in this paper are estimated with STATA® version 11.2 using the "probit" command. Marginal effects were calculated at the means of the explanatory variables and the associated asymptotic standard errors were estimated using the delta method (Greene 2008) with the "mfx" command in STATA®.

Many of the same variables are used to estimate farm managers' willingness to harvest crop residue or grow a dedicated annual or perennial bioenergy crop. The variables that are used in all three models are the farm characteristics including *West*, *Central, Total Acres, Percent Lease*, and *Percent CRP*. A majority of the farm practices' variables are also included in all three models. The farm practice variables include *Graze Residue, Bale Reside, Use Baler*, have livestock (*Livestock*), and have a conservation plan (*Plan*). Two of the bioenergy custom farming and land use variables are included in all three models: *Custom Harvester* and *Store Biomass*. All of the demographic variables are included in all three models. These variables include *Off-Farm, Experience, Age, College, Risk Avoider*, and *Rely on Market*. The value-added crop residue model also includes the following additional covariates: *Remove Biomass*, *Rotate Crops*, and *CV Till. Rotate*

Crops and *Lease AC* are included in the dedicated annual bioenergy crop model and *Lease PC* is included in the dedicated perennial bioenergy crop model.

The three types of cellulosic feedstocks examined are fundamentally different, given the differences in production practices and investments needed to produce them. When crop residue is harvested following grain harvest a value-added enterprise is created. An annual bioenergy crop can replace a traditional crop in a rotation. A perennial bioenergy crop requires replacing a traditional annual crop or hay crop for five to ten years and it takes two to three years to establish. This is the reason why some variables are included in some models but not others.

Based on previous studies (Jensen, et al. 2006; Pannell, et al. 2006; Paulrud and Laitila 2010; Sherrington, Bartley and Moran 2008), farmers who are willing to lease their land for the production of a bioenergy crop, farmers with more acres, younger farmers, famers with a college education, farmers who currently practice conservation tillage, and farmers who have used a baler will be more likely to grow a cellulosic feedstock. Farmers who have livestock, already harvest biomass for other uses, and are risk avoiders will be less likely to grow a bioenergy feedstock. It is hypothesized that farmers who are willing to allow a custom harvester to harvest their bioenergy crop, willing to store biomass for six months or more, and who have a conservation plan will be more willing to harvest their crop residue and/or grow a dedicated bioenergy crop. Furthermore, it is hypothesized that farmers who already bale or graze their crop residue will be less likely to harvest their crop residue and/or grow a dedicated bioenergy crop. Finally, it is conjectured that farmers who currently have CRP land will be more willing to grow a dedicated perennial bioenergy crop, if allowed under the current CRP regulations. We assume here that the perennial crop for bioenergy production would be a value-added enterprise on top of the CRP rental payment received (even if reduced).

A two-part question was asked for the dedicated annual and perennial bioenergy crop options. A farmer was asked if they would be willing to produce a bioenergy crop assuming favorable contractual terms, and if so, how many initial acres would they be willing to plant, assuming they could plant the crop on leased and/or rented acres (figure 1). As a result, the model used to examine the initial acreage allocation for each dedicated bioenergy crop in question must take into account possible self-selection bias given the conditional two-part nature of the question asked. That is, respondents are self-selecting themselves into the group of respondents who are willing to grow dedicated bioenergy crops, which could bias parameter estimates and inference if not taken into account (Heckman 1979; Maddala 1983). To accommodate this, a Heckman selection model is used to jointly examine the adoption and initial acreage allocation decisions.

The first stage of the model examines farmers' willingness to grow a dedicated bioenergy crop, which is given by equations (1) and (2) and can be estimated as a probit model. The second stage of the model examines a farmers initial acreage allocation for each crop type conditional on their willingness to produce a dedicated annual or perennial bioenergy crop. The set-up for the two bioenergy crop options examined follows the set-up in Fuglie and Bosch (1995). Let Y_c represent the initial number of acres a farm manager will be willing to plant of a dedicated annual or perennial bioenergy crop. Then, let the initial acreage allocation decision be represented by the following equation:

$$(3) \qquad Y_c = \boldsymbol{\beta'}_{\boldsymbol{c}}\boldsymbol{X_b} + u_c \text{ with } u_c \sim \mathrm{NI}(0, \sigma_u^2)$$

where $\boldsymbol{\beta}_c$ is a vector of parameters and X_b is the vector of variables associated with producing feedstock c. Remember, that Y_c will only occur if $j_c = 1$, which means that a farm manager has to be willing to grow a dedicated bioenergy crop in order to allocate acreage to the planting of the crop. Thus, the conditional mean of Y_c is $E(Y_c|\boldsymbol{X}_b, j_c = 1) = \boldsymbol{\beta'}_c\boldsymbol{X}_b + E(u_c|\boldsymbol{X}_b, j_c = 1)$ (Heckman 1979). This means that the conditional mean represented by the model equation (3) must be adjusted for potential self-selection bias by taking into account the adoption decision given by equations (1) and (2).

The vector of explanatory variables X_b in the initial allocation model given by equation (3) are similar to those included in the probit models for the dedicated annual and perennial bioenergy crops. The variables removed from the initial acreage allocation model are the bioenergy custom farming and land use variables which includes *Custom Harvester, Store Biomass, Lease AC,* and *Lease PC*. The variable *Rotate Crops* is removed from the dedicated annual bioenergy crop model as well. It is assumed that these factors influence a farmers' willingness to produce, but not necessarily how many initial acres they are willing to allocate for production.

There is a lack of research (to the authors' knowledge) examining how many acres farmers may be willing to commit to the production of a dedicated annual bioenergy crops. Farms in the western or central part of the state are more willing to allocate more acres to bioenergy crop production than farms in the northeast. Recall, much of the sorghum produced in Kansas is done in the central part of the state. We hypothesize that larger farms and farms with a high percent of leased land and/or CRP land are willing to grow more acres initially. *Graze Residue* and *Bale Residue* should decrease the amount of initial acres a farmer is willing to plant.

The Heckman Selection models of dedicated bioenergy crop adoption and initial acreage allocation are estimated with STATA® using the "heckman" command. The procedure estimates both the binary choice model given by equations (1) and (2) and the acreage allocation model given by equation (3) simultaneously to account for the self selection bias (Puhani 2000). The approach adjusts for any potential self-selection by taking account of the fact that $E(u_c|X_b, j_c = 1) = \rho\sigma_u \frac{\phi(a_c' X_c)}{\Phi(a_c' X_c)}$ where ρ is the correlation between ε_c and u_c; σ_u is the standard deviation of u_c and ϕ and Φ are the standard normal probability and cumulative density functions, respectively. If the parameter ρ is equal to zero, then no selectivity bias exists (Gourieroux 2000).

Results

Results for each model are presented by each cellulosic biofuel feedstock examined.

Crop Residues

Table 3 reports the results from the probit model used to estimate the effects of willingness to harvest crop residue. The McFadden pseudo R2 indicated a relatively good fit of the model to the observed data. The results indicate, with statistical significance, that farmers who reside in western Kansas (*West*), who raise livestock (*Livestock*), have already removed biomass (*Remove Biomass*), and practice conservation tillage (*CV Till*) are less likely to remove crop residue than other farmers. These results make intuitive sense. Farmers who raise livestock may already graze their livestock on crop residues making them less likely to sell the residue. The crop residue may be a cheaper source of feed compared to buying other feed rations for their livestock. Similar logic applies to farmers who already remove biomass. They may be harvesting the biomass for livestock feed for their use or for sale to other producers. In either case, since they have already established a use for their crop biomass they are less likely to seek an alternative unless it pays substantially more, which can be uncertain in a market that does not exist.

Farmers in western Kansas on average receive less rain fall than farmers in central and northeastern Kansas. Leaving crop residue on the soil surface through the use of conservative tillage practices can help to capture additional moisture in the soil that is needed for future cash crops. Conservation tillage also reduces soil erosion, maintains soil quality, and reduces the amount of fertilizer needed (Reicosky 2008). If farm managers are accustomed to leaving their crop residue on the ground for one of these reasons, they are likely less inclined to remove their residue. Finding conservation tillage to have a negative impact on a farmers' willingness to switch is contradictory to what Jensen et al. (2006) found. This is probably due to the fact that their study focused on growing switchgrass, not harvesting crop residue.

Other factors are found to be positive and statistically significant on farmers' decisions to harvest crop residue (table 3). These include irrigation of crops (*Irrigate*), allowing a custom harvester access to harvest crop residue (*Custom Harvest*), storing biomass on-farm (*Store Biomass*), and off-farm employment (*Off-Farm*). Irrigation increases soil moisture, but significant amounts of reside reduces irrigation efficiency. Thus, the manager may want to remove some biomass from irrigated land. If a farmer is willing to allow a custom harvester to remove the crop residue (e.g. per a contract with a biorefinery or intermediate processor), then the farmer may be more willing to have their crop residue removed. This implies that farmers are interested in selling the residue, but would like someone else to harvest their crop residue to reduce critical on-farm time or machinery constraints. Farmers who are willing to hold biomass on their farm for longer than six months are more likely to harvest their crop residue, as well. These farmers are willing to allocate some of their land to the storage of biomass as long as they know the biorefinery is going to purchase the residue, which will most likely occur under some form of contract (Rajagopal, et al. 2007).

Two interesting, yet insignificant variables are worth discussing. We find as Paulrud and Laitila (2010) did that leased land (*Percent Leased*) is insignificant in determining whether farmers are willing to harvest crop residue. This implies that farmers are indifferent between using owned or leased land for biomass removal for bioenergy feedstocks. In addition, being risk adverse (*Risk Avoider*) is also insignificant. This may imply that farmers do not see removing crop residue, under an optimal contractual agreement, as a risk increasing or decreasing activity.

Table 3 also contains some interesting marginal effects. The marginal effects for *Livestock, Remove Biomass*, and *CV Till* are all negative and statistically significant. This means that if a farmer owns livestock, removes biomass for other reasons, or uses conservation tillage, then they would be 11%, 13%, and 15% less likely to harvest crop residue and sell it to a biorefinery, respectively. However, if a farmer decides they would allow a custom harvester to harvest the crop residue (*Custom Harvester*), are willing to store biomass on farm (*Store Biomass*), or rely on market information (*Rely on Market*) they would be 28%, 16%, and 8% more likely to harvest their crop residue and sell it to a biorefinery, respectively.

Dedicated Annual Bioenergy Crop

Table 4 reports the results from the Heckman selection model for a dedicated annual bioenergy crop used to examine the effects of different factors on the likelihood of producing an annual bioenergy crop and a farmers initial land allocation if they decided to do so.

The probit model results show that if farmers are willing to grow an annual bioenergy crop, there are several variables that are statistically significant and positive. These variables include farm size (*Total Acres),* percent of land leased (*Percent Leased*), grazing of crop residue (*Graze Residue*), baling of crop residue (*Bale Residue*), willing to use a custom harvester (*Custom Harvester*), willing to store biomass (*Store Biomass*), and willing to lease land to grow an annual crop (*Lease AC*). The more land a farmer manages, the more willing and able the farmer may be to diversify his or her crop portfolio. The positive effect of *Total Acres* on the farmers' willingness to grow a dedicated bioenergy crop conflicts with the findings of Jensen et al. (2006) and Paulard and Laitila (2010). *Percent Leased* indicates farmers are more likely to produce annual bioenergy crops if they lease land. This may occur because landlords might show less resistance to an annual bioenergy crop option that can be grown in rotation with other cash crops. It is also worth noting that summary statistics show that farms, on average, typically rent more than half the acres. *Graze Residue* is positive,
indicating farm managers who have livestock and graze residue are still willing to produce an annual bioenergy crop because it does not interfere with their grazing regime.

Farmers who currently bale their residue have more experience using the equipment required to harvest an annual bioenergy crop, which implies that they do not have to invest in new equipment for crop harvest. A positive sign on *Lease AC* follows what Sherrington, Bartley, and Moran (2008) found, farmers are willing to lease land to someone else to grow a bioenergy crop.

The only negative and significant variable is *Risk Avoider* (table 4). This implies that growing an annual crop has risk involved and someone who is a risk avoider is less likely to grow the bioenergy crop. No markets for dedicated bioenergy crops currently exist, making it a highly uncertain and risky decision for farmers, who may be less likely to adopt an enterprise that increases on-farm risk (Pannell, et al. 2006; Rajagopal, et al. 2007). According to the marginal effects in table 4, if someone is a risk avoider they are 16% less likely to grow a dedicated annual crop.

Percent Leased, Graze Residue, Bale Residue, and *Lease AC* all have statistically significant and positive marginal effects (table 4). If the percentage of land leased increases by 1%, then a farmer would be 0.26% more likely to grow a dedicated annual bioenergy crop. If a farmer started grazing or baling their residue (*Graze Residue* and *Bale Residue*) they would be 14% and 17% more likely to grow an annual bioenergy crop, respectively. If a farmer decides they are willing to lease land to someone else for production of an annual bioenergy crop they are 24% more likely to allow a third party to grow an annual bioenergy crop.

The mean number of acres farmers are initially willing to plant of a dedicated annual bioenergy crop is 121.22 acres. This initial allocation is positively and significantly affected by the variables *West, Total Acres, Irrigate,* and *Off-Farm* income (table 4). Farmers located in the western part of the state are willing to plant 75.55 more acres then farmers in the Northeast. This is expected given farms in the western part of the state are typically larger than farms in the other regions studied. A positive relationship with *Total Acres* is also expected. As acreage increases, farmers can reduce on-farm risk by diversifying their enterprises, which would include growing a bioenergy crop. As farmers increase their farm size by one acre, they are willing to plant 1.95 more acres of a dedicated annual bioenergy crop. Farms with irrigation will plant 52.74 more acres initially than farms that are non-irrigated. Having off-farm income is another way that farmers are able to reduce their financial risk and buffer any potential loss from planting an annual bioenergy crop. Farmers with a source of off-farm income, are likely to plant 39.89 more acres initially than farmers who have no source of off-farm income.

Dedicated Perennial Bioenergy Crop

The Heckman selection model results for farmers' willingness to grow a dedicated perennial bioenergy crop (e.g. switchgrass) and the initial acreage they are willing to plant is reported in table 5.

The variables *Central, Percent Leased, Percent CRP, Use Baler, Custom Harvester, Lease PC,* and *College* all have positive effects on willingness to grow and are statistically significant. Perennial crops, like switchgrass, are viable crops for growing on marginal land, similar to CRP land. Managers with larger amounts of acres in CRP may be able to increase their income by growing a perennial bioenergy crop on marginal land rather than leaving it idle or putting it into CRP. Of course, this will be influenced by CRP rental rates. Farmers who have used a baler before have the skill set and access to the equipment that would be required to harvest the biomass from a perennial bioenergy crop, implying they would not have to spend the time or money investing in or learning about new equipment. The positive impact of previously using a baler supports what Jensen et al. (2006) reported. Jensen et al. (2006) found that college was positive, as well. Relying on market information has a negative effect on farmers' willingness to grow a perennial bioenergy crop option. This implies that market information is currently informing farmers that growing a perennial bioenergy crop is not advantageous and may be highly uncertain.

Marginal effects reported in table 5, indicate that if a farmer increases the percentage of CRP land by 1% the marginal effect of this increase would be that the farmer is 2.66% more likely to be willing to grow a dedicated perennial bioenergy crop (table 5). The marginal effects for *Use Baler, Custom Harvester, Lease PC*, and *College* are all positive and statistically significant, as well. If a manager begins using a baler, is willing to use a custom harvester, is willing to lease their land for production, or if they are a college graduate, then the farmer would be more likely to grow a dedicated perennial bioenergy crop by 30%, 32%, 42%, and 18% respectively. However if a farmer relies heavily on market information to make decisions (*Rely on Market*), then they are 18% less likely to grow a dedicated perennial bioenergy crop.

The mean number of acres a farmer is willing to plant of a dedicated perennial bioenergy crop is 97.04. The initial allocation of land a farmer is willing to commit for the production of a perennial bioenergy crop is positively affected by a number of variables, including: *West, Central, Irrigate*, and *Risk Avoider* (table 5). Farmers located in the western region are willing to plant 96.77 more acres initially than farmers located in the northeast region. Farmers in the central part of the state are willing to plant 42.69 more initial acres than those located in the northeast. A dedicated perennial bioenergy crop will not likely be planted on irrigated land unless the returns are expected to be higher than traditionally irrigated crops. An increase of 53.97 acres for farms that have irrigation could be based on the fact that a perennial crop is an easy crop to plant on the corners of an irrigated field, which may be marginal land. Risk aversion has an interesting effect. If a manager is a risk avoider, they are willing to plant 55.91 more acres initially than someone who is not. This may imply that farmers perceive having more acres of a perennial crop on marginal lands will reduce their exposure to risk by providing an economically viable alternative for less productive or marginal lands.

Summary and Conclusions

This paper examines Kansas' farmers' willingness to harvest crop residue and grow dedicated bioenergy crops. Three different types of cellulosic bioenergy crops were considered. The first type was harvesting of crop residue like corn stover, a value-added enterprise. The second type was a dedicated annual bioenergy crop like energy or sweet sorghum. The third type was a dedicated perennial bioenergy crop like switchgrass. The study data came from in-person interviews conducted in three regions of Kansas. An expected utility framework was utilized to examine farmers willingness to harvest a crop residue or grow a bioenergy crop. The corresponding empirical model was estimated as a probit model. For the two bioenergy crop options, an initial acreage allocation model was estimated as well. In order to account for the self-selection bias, a Heckman selection model was used to simultaneously estimate the binary adoption decision and the initial acreage allocation model.

The study found that 77% of survey respondents were willing to harvest crop residue, while 61% were willing to grow an annual bioenergy crop, and 44% of respondents were willing to grow a perennial bioenergy crop. The survey also revealed that the average number of initial acres a farmer would be willing to devote to growing an annual bioenergy crop was 121 acres while they were only willing to devote 97 acres to growing a perennial bioenergy crop.

We found little consistency between what variables were significant in the three willingness to produce models. One variable that was consistently positive and statistically significant between all three models was *Custom Harvester*. This implies that in every model if a farmer would allow a custom harvester to harvest their biomass, they would be more likely to harvest their crop residue or grow a dedicated bioenergy crop. Storage of biomass (*Store Biomass)* on-farm was positive in all three models, but only statistically significant in two of the models. *Lease AC* and *Lease PC* were also positive and statically significant in their respective models. Except for *Store Biomass* in the annual crop model, all of the bioenergy custom farming and land use variables were positive and statistically significant. To our knowledge, these variables have not been previously examined. They are important variables to consider when considering farmers willingness to produce bioenergy crops in other parts of the country in conjunction with favorable contracting options.

In the models that estimated factors affecting the initial acres of bioenergy crop production, *West* and *Irrigate* were positive and statistically significant in both models.

Inconsistencies between which variables are significant and which are not implies that farmers are taking into account different things when they are trying to decide if they would be willing to grow a particular type of cellulosic bioenergy crop. This paper reveals that farmers are willing to grow cellulosic bioenergy crops under favorable contract conditions. However, more research needs to be done to determine what those favorable contract conditions are.

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Figure 1. Table Asking Farmers to Indicated Whether They Would be Willing to Produce a Bioenergy Crop Under Favorable Contracting Situations, and if so, How Many Acres They Would Commit to Grow Initially

In the following table, indicate if you would be willing to produce the following types of biofuel feedstocks and how much you would be willing to harvest/plant of that feedstock.

Cellulosic Biofuel Feedstock Type	**Considering you enter into a favorable contract with a refinery, would you produce this biofuel feedstock on your farm?** (*Choose one*)	**If Yes, what is the minimum acreage you would initially be willing to plant of this bioenergy crop/feedstock?** (*Assume the crop can be planted on rented lands*)
a. Value Added (e.g. crop residue, such as corn stover, wheat straw, etc.)	___ Yes ___ No	
b. Annual Crop (e.g. sweet sorghum)	___ Yes ___ No	
c. Perennial (e.g. switchgrass, miscanthus, prairie grasses, etc.)	___ Yes ___ No	

Table 1. Comparison of Kansas Farmer Demographics to Survey Respondents

	2007 Census of Agriculture[a]	Survey
Age	57.7 years	55.1 years
Average size of farm	707 acres	2172 acres
Average amount of rented land on farm	863 acres	1271 acres
Average amount of owned land on farm	381 acres	900 acres
Average amount of permanent pasture land on farm	398 acres	594 acres
Average market value of agricultural products	$219,944	$200,000 to $399,999[b]

[a] *Source*: USDA, National Agricultural Statistics Service, 2007

[b] Category represents the one chosen with the highest frequency by respondents.

Table 2. Variable Definitions and Summary Statistics

Variable	Description	Mean (Standard Error)^a (N=242)
Dependent Variables		
VA	Equal to "1" if the farmer would be willing to harvest residue from a value added crop, "0" otherwise	.77
AC	Equal to "1" if the farmer would be willing to grow an annual bioenergy crop, "0" otherwise	.61
ACIA	The initial acreage a farmer would be willing to plant for an annual bioenergy crop (truncated at 0)	121.22 (141.48)
PC	Equal to "1" is the farmer would be willing to grow a perennial bioenergy crop, "0" otherwise	.44
PCIA	The initial acreage a farmer would be willing to plant for a perennial bioenergy crop (truncated at 0)	97.04 (112.29)
Farm Characteristics		
West	Equal to "1" if the farm is located in the western region of Kansas, "0" otherwise	.33
Central	Equal to "1" if the farm is located in the central region of Kansas, "0" otherwise	.33
Total Acres	Total number of acres the farmer operates (000s of acres)	21.72 (16.97)
Percent Leased	Fraction of total acreage that is leased	.58 (.32)
Percent CRP	Fraction of total acreage that is enrolled in CRP	.01 (.03)
Farm Practices		
Graze Residue	Equal to "1" if the farmer grazes the residue, "0" otherwise	.50
Bale Residue	Equal to "1" if the farmer bales the residue, "0" otherwise	.30
Use Baler	Equal to "1" if the farmer currently uses a baler, "0" otherwise	.59
Livestock	Equal to "1" if the farmer owns livestock, "0" otherwise	.60
Irrigate	Equal to "1" if any crop is irrigated, "0" otherwise	.33
Plan	Equal to "1" if the farm has a conservation plan, "0" otherwise	.82
Remove Biomass	Equal to "1" if the farmer removes any biomass, "0" otherwise	.87
Rotate Crops	Equal to "1" if the farmer rotates the crops, "0" otherwise	.98
CV Till	Equal to "1" if the farmer uses conservation tillage practices on corn, sorghum and/or wheat, "0" otherwise	.92

Table 2. Variable Definitions and Summary Statistics (continued)

Variable	Description	Mean (Standard Error)[a] (N=242)
	Bioenergy Custom Farming and Land Use	
Custom Harvester	Equal to "1" if the farmer would allow a biorefinery to hire a custom harvester to harvest the biomass, "0" otherwise	.83
Store Biomass	Equal to "1" if the farmer would be willing to store biomass bales on farm for more than 6 months, "0" otherwise	.59
Lease AC	Equal to "1" if the farmer would be willing to lease their land to someone to grow an annual bioenergy crop, "0" otherwise	.17
Lease PC	Equal to "1" if the farmer would be willing to lease their land to someone to grow a perennial bioenergy crop, "0" otherwise	.15
	Farm Manager Characteristics	
Off-Farm	Equal to "1" if any member of the household brings home off-farm income, "0" otherwise	.53
Experience	The number of years the farmer has operated the farm	33.77 (12.65)
Age	Famers age	55.12 (11.72)
College	Equal to "1" if the farmer graduated from college, "0" otherwise	.31
Risk Avoider	Equal to "1" if farmer avoids taking risks, "0" otherwise	.38
Rely on Market	Equal to "1" is the farmer relies on market information to make decisions, "0" otherwise	.82

[a] Standard Errors are only provided for continuous variates. The standard error for a binary is equal to the square root of *p(1-p)*, where *p* is the mean of the response or probability that the varaite is equal to 1.

Table 3. Probit Model Estimation Results for Crop Residue

	Parameters		Marginal Effects	
Variable	Estimate	Standard Error	Estimate	Standard Error
Intercept	0.79	1.24	–	–
West	-1.15***	0.32	-0.33*	0.001
Central	-0.28	0.31	-0.07*	0.39
Total Acres	0.01	0.01	0.001***	0.42
Percent Leased	-0.08	0.39	-0.02*	0.84
Percent CRP	4.68	3.74	1.17	0.21
Graze Residue	0.12	0.25	0.03*	0.64
Bale Residue	0.34	0.29	0.08*	0.21
Use Baler	0.14	0.30	0.04*	0.63
Livestock	-0.45*	0.28	-0.11*	0.08
Irrigate	0.47*	0.25	0.11**	0.04
Plan	-0.07	0.32	-0.02*	0.83
Remove Biomass	-0.66*	0.39	-0.13*	0.02
Custom Harvester	0.89***	0.27	0.28*	0.004
Store Biomass	0.59***	0.22	0.16*	0.01
Rotate Crops	0.94	0.67	0.32	0.23
CV Till	-0.94*	0.59	-0.15**	0.003
Off-Farm	0.50**	0.22	0.13*	0.03
Experience	0.01	0.01	0.003***	0.35
Age	-0.02	0.01	-0.005***	0.19
College	-0.09	0.24	-0.02*	0.70
Risk Avoider	0.06	0.24	0.01*	0.82
Rely on Market	0.29	0.28	0.08*	0.35
		Fit Statistics		
Log likelihood		-96.80943		
McFadden R-Squared		.2404		
Number of Observations		238		

Note: The marginal effects are calculated at the means of the explanatory variables. '*' denotes statistical significance at the 10% level, '**' denotes statistical significance at the 5% level, and '***' denotes statistical significance at the 1% level.

Table 4. Heckman Selection Model Estimation Results for Willingness to Produce a Dedicated Annual Bioenergy Crop

	Probit Model				Selection	
	Parameter Estimate		Marginal Effect		Parameter Estimate	
Variable	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error
Intercept	-0.81	1.05	–	–	-96.02	93.43
West	0.04	0.28	0.02	0.10	75.55**	33.33
Central	0.27	0.25	0.10	0.09	14.62	27.10
Total Acres	0.01**	0.01	0.01**	0.003	1.95***	0.71
Percent Leased	0.70**	0.36	0.26**	0.14	38.46	38.82
Percent CRP	-3.19	3.45	-1.22	1.30	358.46	380.28
Graze Residue	0.39*	0.22	0.14*	0.08	-10.39	24.36
Bale Residue	0.45*	0.26	0.17*	0.09	-10.19	26.29
Use Baler	0.42	0.27	0.16	0.10	-40.19	33.63
Livestock	-0.32	0.26	-0.11	0.09	4.013	29.31
Irrigate	0.005	0.23	0.004	0.08	52.74**	23.85
Plan	0.20	0.26	0.07	0.10	-21.08	29.11
Custom Harvester	0.72***	0.27	0.29***	0.10	–	–
Store Biomass	0.42*	0.23	0.14*	0.08	–	–
Rotate Crops	0.11	0.71	0.05	0.28	–	–
Lease AC	0.72***	0.29	0.24***	0.08	–	–
Off-Farm	0.30	0.21	0.11	0.08	39.89*	23.54
Experience	0.002	0.01	0.0008	0.01	0.78	1.56
Age	-0.02	0.02	-0.01	0.01	2.01	1.84
College	0.25	0.24	0.09	0.09	-19.52	25.26
Risk Avoider	-0.43**	0.22	-0.16**	0.08	38.82	26.13
Rely on Market	-0.19	0.27	-0.07	0.10	-6.67	29.38
ρ					-0.13	
Fit Statistics						
Log Likelihood			-929.314			
Wald Chi-Square			61.299***			
Number of Observations			215			

Note: The marginal effects are calculated at the means of the explanatory variables. '*' denotes statistical significance at the 10% level, '**' denotes statistical significance at the 5% level, and '***' denotes statistical significance at the 1% level.

Table 5. Heckman Selection Model Estimation Results for Willingness to Produce a Dedicated Perennial Bioenergy Crop

	Probit Model				Selection	
	Parameter Estimate		Marginal Effect		Parameter Estimate	
Variable	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error
Intercept	-2.04**	0.85	–	–	-80.10	96.56
West	-0.003	0.28	-0.01	0.11	96.77***	30.25
Central	0.43*	0.25	0.17*	0.10	42.69*	24.63
Total Acres	0.003	0.01	0.001	0.003	0.67	0.70
Percent Leased	0.87**	0.37	0.33**	0.14	14.72	42.69
Percent CRP	6.78**	3.24	2.66**	1.26	-86.26	342.25
Graze Residue	0.35	0.22	0.14	0.09	-18.98	23.89
Bale Residue	-0.22	0.24	-0.08	0.09	-17.43	24.12
Use Baler	0.83***	0.26	0.30***	0.09	-32.92	30.80
Livestock	-0.28	0.25	-0.11	0.10	20.80	27.54
Irrigate	-0.17	0.22	-0.07	0.09	53.97**	24.19
Plan	0.41	0.27	0.15	0.10	11.26	33.28
Custom Harvester	0.89***	0.31	0.32***	0.08	–	–
Store Biomass	0.27	0.21	0.09	0.08	–	–
Lease PC	1.16***	0.29	0.42***	0.09	–	–
Off-Farm	0.12	0.21	0.05	0.08	-18.30	22.04
Experience	0.02	0.01	0.01	0.01	1.62	1.65
Age	-0.02	0.01	-0.01	0.01	0.81	1.71
College	0.47**	0.24	0.18**	0.09	-3.10	25.52
Risk Avoider	-0.15	0.22	-0.06	0.08	55.91**	23.88
Rely on Market	-0.47*	0.27	-0.18*	0.11	28.64	28.10
ρ					-0.23	
			Fit Statistics			
Log Likelihood			-673.0183			
Wald Chi-Square			42.68***			
Number of Observations			216			

Note: The marginal effects are calculated at the means of the explanatory variables. '*' denotes statistical significance at the 10% level, '**' denotes statistical significance at the 5% level, and '***' denotes statistical significance at the 1% level.