Journal of Cooperatives

Volume 25 *2011* *Page 16-43*

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This research was funded in part by a grant from the former National Research Initiative Competitive Grants Program sponsored by the U.S. Department of Agriculture's National Institute of Food and Agriculture.

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Abstract

This study analyzes factors influencing farmer interest in marketing switchgrass through contracts and/or joining a cooperative that harvests, transports, stores, and markets their switchgrass. Data are from a survey of farmers in 12 southern states. A bivariate probit analysis is used to estimate the effects of farm characteristics, farmer demographics, and opinions about switchgrass on marketing alternative preferences. Interest in contracting and joining a cooperative are positively influenced by farm size, on-farm storage, moderate off-farm income, and heightened importance of job creation in decision to produce switchgrass. Negative influences include concerns about planting/harvesting conflicts and expectation of ceasing farming soon.

Key words: switchgrass, farmer opinions, cooperatives, contracts
JEL codes: Q13, Q40.

Introduction

The share of renewable energy produced from biomass in the U.S. has been growing over time, so that energy produced from biomass currently accounts for about one half of the renewable energy being consumed (EIA, 2010). Much of the increase in bioenergy can be attributed to increased production and consumption of corn grain ethanol. However, continued growth in the production of corn grain ethanol is likely to be constrained by the effects such growth has on food prices and the environment. Thus, the federal government is promoting the development of advanced biofuels produced from lignocellulosic biomass (LCB) by funding research into lignocellulosic conversion technologies and mandating that at least 16 billion gallons of the fuel ethanol being produced in the U.S. in 2022 be derived from LCB (Hoekman, 2009).

Achieving this level of production will likely require the large scale planting of dedicated energy crops that can meet the needs of commercially-sized conversion facilities. One candidate energy crop is switchgrass (*Panicum virgatum*). Switchgrass is a fast-growing, warm season, perennial grass native to much of North America which has been deemed a model bioenergy feedstock (Lewandowski et al., 2003; McLaughlin and Kszos, 2005; McLaughlin and Walsh, 1998; Wright, 2007; Wright and Turhollow, 2010).

The economics of growing switchgrass as a bioenergy feedstock have been extensively studied (e.g., Aravindhakshan et al. 2010; Brechbill, Tyner, and Ileleji, 2011; Downing and Graham, 1996; Duffy, 2008; Duffy and Nanhou, 2002; English et al. 2007; Epplin, 1996; Epplin et al., 2007; Hallam, Anderson, and Buxton, 2001; Haque and Epplin, 2010; Jain et al., 2010; James, Swinton, and Thelen, 2010; Jiang and Swinton, 2009; Khanna et al., 2008; McLaughlin et al., 2002; Monti et al., 2007; Mooney et al., 2009; Perrin et al. 2008; Popp, 2007; Thorsell et al., 2004; Vadas, Barnett, and Undersander, 2008). There are also a number of studies analyzing the influence of producer characteristics and other factors on the likelihood that a producer would be willing to convert land to the production of switchgrass (e.g., Hipple and Duffy, 2002; Jensen, et al., 2007; Jensen et al., 2010) or some other dedicated energy crop (Mattison and Norris, 2007; Roos et al., 2000; Sherrington, Bartley, and Moran, 2008; Sherrington and Moran 2010). More general discussions of the logistics and likely organization of a switchgrass-to-energy industry can be found in Altman and Johnson (2008), Carolan, Joshi, and Dale (2007), and Cundiff et al. (2009).[a] Although prior studies have made assumptions about, or proffered thoughts on, the likely organization of a switchgrass-to-energy industry, there has been little in the way of systematic inquiry into this organization. Furthermore, while previous research has examined interest in growing switchgrass and barriers to adoption, this research extends prior findings by examining farmer preferences for switchgrass marketing arrangements.What seems to be widely accepted at this point is that scale economies in biorefineries suggest that the industry will "be characterized by regionally dominant, large capacity biorefineries," (Carolan, Joshi, and Dale, 2007, p. 7). What is less clear is how these biorefineries will acquire their feedstock. A basic distinction is whether the biorefinery (i) purchases the biomass either in spot markets or through contracts with either individual growers or a group of growers organized as some form of cooperative, or (ii) grows its own biomass after obtaining either a leasehold or fee simple interest in the requisite land base (Larson, English, and He, 2008; Epplin et al., 2007). This study focuses on the first alternative, the purchase of switchgrass from farmers and the associated market arrangements.

As the ethanol conversion industry has developed, large players have entered the market, with the three largest holding over 30% of the market (Renewable Fuels Association, 2011). Producers and local citizens are concerned about the exercise of this market power and how local farmers and economies will fare (Rossi and Hinrichs, 2010). Membership in a cooperative that harvests, stores, and markets switchgrass provides an alternative to either a spot market or contracts with individual farmers. The capital costs of such a cooperative venture would be significantly lower than investment in a biorefinery, but could still allow producers to capture some of the value added associated with getting the feedstock to the biorefinery at the time and condition needed by the bioerefinery (Carolan, Joshi, and Dale, 2007).

Thus, the purpose of this study is to examine the preferences of farmers interested in growing switchgrass for different switchgrass marketing arrangements for switchgrass. These preferences were elicited in a mail survey of farmers in twelve southeastern U.S. states. Farmers who indicated interest in growing switchgrass were asked separately about their willingness to enter into a long-term contract for producing switchgrass and/or join a farmer-based cooperative that would harvest, store, and market the switchgrass. A bivariate probit model is used to analyze the effects of farmer demographics, farm characteristics, farmer attitudes toward risk and switchgrass markets on willingness to enter into a contract and/or join a marketing cooperative.

Previous Research

An extensive literature examines the rationale for why an agricultural producer might prefer vertical coordination in the form of either a cooperative or a marketing or production contract to a spot market. Much of this literature relies on Williamson's (1979) transaction cost economics for its theoretical underpinnings. A key implication of this literature is that asset specificity and uncertainty are important motivators for vertical coordination. Asset specificity is the degree to which an asset is specialized to a particular use. The greater the asset specificity, the greater the distinction between the value of an asset in its current use and its value in alternative uses, or salvage value. Asset specificity promotes vertical coordination because it gives rise to "hold-up problems and opportunistic pursuit of quasi-rents by the contracting parties" (Laijili et al., 1997, p. 265). In other words, ownership of a highly specialized asset can leave a party vulnerable in negotiations.

Asset specialization can result from a number of different factors, including the physical or intellectual nature of the asset, the location of the asset, or some form of time constraint related to the asset (Altman and Johnson, 2008). Participants in the ag-bioenergy industry could subject themselves to hold-up problems associated with asset specificity by investing the physical resources needed to grow, harvest, store, transport or process biomass feedstock (Altman and Johnson, 2008). In addition, the planting of a perennial feedstock could also constitute investment in a specialized asset and, thus, promote, vertical coordination (Carolan, Joshi, and Dale, 2007).

Uncertainty is also widely cited as a rationale for vertical coordination (David and Han, 2004). Greater price uncertainty implies greater risk and greater opportunity for hold-up or opportunistic behavior. Thus, "[c]ontracts and vertical ownership of the marketing channel may limit exposure to environmental uncertainty (i.e., supply, demand, price, and revenue uncertainty) and may counteract behavioral uncertainty (i.e., performance ambiguity in positive agency theory) by facilitating performance evaluation." Franken et al., 2009, p. 299.

Contracting

The results of a mail survey of 60 U.S. ethanol production facilities indicate that feedstock procurement practices in the ethanol industry involve a mixture of spot markets and contracting (Schmidgall et al., 2010). Most of the facilities surveyed procured their feedstock in-house, while only about one-fourth conducted their business using a marketing firm. The most common procurement arrangement was cash sale, used by 50 facilities (83.3%), and the second most common arrangement was basis contracts, used by 47 respondents (78.3%). Cash forward contracts were used by 39 facilities (65.0%), delayed price contracts were used by 27 facilities (45.0%), and minimum price contracts were used by 15 facilities (25.0%). Six facilities (10.0%) used "other" procurement arrangements, including two that utilized hedge-to-arrive contracts. Altman and Johnson (2008) and Altman and Johnson (2009) report the results of a mail survey of 53 facilities actively producing bioenergy. The results indicate a high degree of vertical integration with 28 of the 53 relying exclusively on internally-generated biomass. In general, these facilities were biomass producers that had chosen to utilize their residues for biopower rather than dispose of these residues in some other manner. Thirteen of the remaining 25 facilities relied exclusively on biomass procured from others, with three using sport markets and 10 using contracts ranging in length from three months to 20 years. These facilities were primarily traditional power companies that were producing some energy from biomass. The final 12 facilities were wood and agricultural manufacturing companies that relied on both internally- and externally-generated biomass. Three of the 12 acquired the externally-generated biomass on a spot market while the other nine utilized contracts.

As for potential suppliers of biomass feedstock, Paulrud and Laitila (2010) use two different choice experiments in a mail survey of Swedish farmers to analyze farmer preferences. In the first choice experiment, respondents were asked to select their most preferred alternative from two different bioenergy crops that were defined by six attributes, including whether the crop was to be grown "independently" or under contract. On average, the respondents preferred to grow the crop under contract and were willing to accept €29 less in net income per hectare per year to grow the crop under contract instead of independently. The choice experiment asked respondents to indicate the number of hectares they would be willing to devote to a number of different energy crops. The authors use the results of both choice experiments to project the number of hectares that would be converted to energy crop production under four different scenarios. While this study did examine selling bioenergy crops independently or under contract, the study did not examine the market alternative of farmers joining a cooperative, for example that could harvest, store, and transport the bioenergy crop.

Various studies have found differences in farm characteristics and farmer demographics between farmers who use contracting and those who do not, suggesting that farmers who are interested in selling switchgrass through contracts might differ in these characteristics and demographics from those who are not interested. For example, several studies have found that larger farm size has a positive influence on contracting (Dong, Hennessy, and Jensen, 2008; Edleman, 2006; Katchova and Miranda, 2004; Key and McBride, 2003; Sartwelle, O'Brien, Tierney, and Eggers, 2000; and Velandia et al., 2009). Paulson, Katchova, and Lence (2010) found differences in contracting across commodities produced, while other studies have found that diversification of the farm is inversely correlated with contracting (Davis and Gillespie, 2007; Dong, Hennessy, and Jensen, 2008; Katchova and Miranda, 2004; Sartwelle et al., 2000). The latter result may be due to the role diversification can play in managing risk. Thus, highly diversified firms may be less likely to need vertical coordination to manage risk. Sartwelle et al. (2000) found that having on-farm storage is positively correlated with contracting.

Asset specificity and uncertainty imply that credit-constrained farmers are more likely to be interested in contracting, as a contract can ameliorate lender concerns over asset specificity and uncertainty. Thus, more highly leveraged firms and those facing credit constraints have been found to be more interested in contracting (Bocquého and Jacquet, 2010; Davis and Gillespie, 2007; Katchova and Miranda, 2004; Lajili et al., 1997; Paulson, Katchova, and Lence, 2010). Credit constraints could be particularly relevant for the production of a long-lived perennial that can take a number of years to mature, such as switchgrass. On the other hand, the proportion of acres owned has been found to be negatively correlated with contracting (Velandia, Rejesus, Knight, and Sherrick, 2009).

The likelihood of contracting has also been found to differ across farmer characteristics although not generally in a clear fashion. With respect to correlation between the age of the farmer and the likelihood of contracting, the literature seems split as Davis and Gillespie (2007) Dong, Hennessy, and Jensen (2008), Edleman (2006), Paulson, Katchova, and Lence (2010), and Velandia, Rejesus, Knight, and Sherrick (2009) find that younger farmers are more likely to contract, while Katchova and Miranda (2004) and Uematsu and Mishra (2011) find the opposite. Likewise, findings regarding the relationship between education and contracting have been mixed, with Dong, Hennessy, and Jensen (2008), Key (2005), and Key and McBride (2003) finding a negative effect, and Edleman (2006), Velandia, Rejesus, Knight, and Sherrick (2009), and Uematsu and Mishra (2011) finding a positive effect. Off-farm income has been found to be negatively correlated with contracting in several studies **(**Edleman, 2006; Uematsu and Mishra, 2011) and positively correlated in others (Key, 2005; Key and McBride, 2003). Finally, even though contracting has been widely cited as a way to reduce risk[b], at least one study, Uematsu and Mishra (2011), has found that risk-loving attitudes were positively correlated with contracting. However, a more common finding is that risk aversion is positively associated with contracting (Franken, Pennings, and Garcia, 2009; Key, 2005; Lajili et al., 1997; Zheng et al. (2008).

Cooperative Membership

In general, the underlying economic rationales for contracting also apply to participating in a cooperative (Staatz, 1987). For example, a cooperative is another way for a farmer to avoid hold-up problems associated with investment in a perennial such as switchgrass. In instances characterized by a great deal of uncertainty, a cooperative could have an advantage over a contract since it will be difficult, if not impossible for contracts to satisfactorily address "all relevant future contingencies" (Hendrikse and Bijman, 2002, p. 105). In addition, having a single contract between a cooperative and a biorefinery, as opposed to multiple contracts between individual farmers and a biorefinery, can reduce administrative costs since they allow for a single contract between the cooperative and the biorefinery (Altman and Johnson, 2008; Carolan, Joshi, and Dale, 2007).

Prior research has linked cooperative membership to several farm characteristics and farmer demographics. Farm size has been found to be positively related to cooperative membership in some studies (Wachenheim, deHillerin, and Dumler, 2001; Wadsworth, 1990) and negatively related in others (Kilmer, Lee, and Carley,1994). Specialization of the farming operation has been found to be positively related with cooperative membership (Kilmer, Lee, and Carley, 1994; Wachenheim, deHillerin, and Dumler, 2001). However, Kilmer, Lee, and Carley (1994) found farm equity to be negatively related. Cooperative membership also appears to differ by age. Wachenheim, deHillerin, and Dumler (2001) and Wadsworth (1990) found cooperative members to be younger, while Kilmer, Lee, and Carley (1994) found that the likelihood of membership in a milk marketing cooperative increased as years of dairy farming increased. Wachenheim, deHillerin, and Dumler (2001) also found cooperative members to have higher levels of educational attainment.

Olson, Kibbe, and Goreham (1998) compared the characteristics of members of large crop New Generation Cooperatives (NGC), non-members, and members of small livestock NGC's in North Dakota. The NGC members were younger than nonmembers and tended to have higher levels of educational attainment than nonmembers. Crop NGC members farmed more acres, had more net income from farming, and had a lower debt/asset ratio than nonmembers and livestock NGC members. Both crop and livestock NGC members had more off-farm income than nonmembers. Crop NGC members were also members of more other farm supply, elevator, and sugar beet cooperatives than livestock members or nonmembers.

While the aforementioned studies provide insights into how demographics and farm characteristics may impact cooperative membership, these studies did not examine membership in a cooperative to store and handle a dedicated energy crop such as switchgrass. Hence, this research will extend prior research into determinants of cooperative membership.

Methods

Economic Model

Producers are assumed to be profit maximizing and to select the market arrangement or set of arrangements that provide them with the highest expected utility of wealth. Let the expected utility of wealth from contracting (y_1) and cooperative membership (y_2) be represented as (Lancaster et al, 2007):

$$y_1^* = \boldsymbol{\beta}_1{}'\boldsymbol{X} + \epsilon_1,\ y_1=1 \text{ if } y_1^*>0, 0 \text{ otherwise} \quad (1)$$

$$y_2^* = \boldsymbol{\beta}_2{}'\boldsymbol{X} + \epsilon_2,\ y_2=1 \text{ if } y_2^*>0, 0 \text{ otherwise} \quad (2)$$

where $\boldsymbol{\beta}_1{}'\boldsymbol{X}$ and $\boldsymbol{\beta}_2{}'\boldsymbol{X}$ are the deterministic parts of utility from each. The stochastic terms are represented by ϵ_1 and ϵ_2, where $E[\epsilon_1] = E[\epsilon_2] = 0$ and $Var[\epsilon_1] = Var[\epsilon_2] = 1$. The correlation between the two error terms is given as Cov[ϵ_1, ϵ_2,]=ρ. The responses to the stated choice questions about preference to sell switchgrass under contract y_1 (0=no, 1=yes) and willingness to participate in a cooperative y_2 (0=no, 1=yes), represent the observed outcomes for each. These outcomes are hypothesized to be influenced by farm characteristics, farmer demographics, and farmer attitudes which are included in the $\boldsymbol{X}$ matrix. A listing of the explanatory variables included in $\boldsymbol{X}$, along with variable definitions, and means are provided in Table 1. The $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ are vectors of coefficients to be estimated. A probability model, a bivariate probit, is used to estimate the probability of a producer being interested in either contracting and/or cooperative membership.

The probability of a respondent selecting a particular set of marketing arrangements, y_1 (*CONTRACT*) and y_2 (*COOP)*, is

$$Pr(CONTRACT = y_{t1}, COOP = y_{t2}) = \Phi_2(w_{t1}, w_{t2}, \rho_t^*) \quad (3)$$

where $w_{ij} = q_{ij}\boldsymbol{\beta}_j{}'\boldsymbol{x}_{ij}$, j=1,2, $q_{t1} = 2y_{t1} - 1$, and $q_{t2} = 2y_{t2} - 1$ (Greene, 2000). The marginal probability for y_1 is $\Phi(\boldsymbol{\beta}_1{}'\boldsymbol{x})$ and for y_2 is $\Phi(\boldsymbol{\beta}_2{}'\boldsymbol{x})$. The conditional probability for y_1 is calculated as $\Phi_2(w_{t1}, w_{t2}, \rho_t^*)/\ \Phi(\boldsymbol{\beta}_2{}'\boldsymbol{x})$. To obtain estimates of the magnitude of the effects of each variable upon the probability of selecting a particular alternative or set of alternatives, marginal effects must be calculated. The marginal effects presented in this paper include the partials of the unconditional expected value $E[y_{ij}|\boldsymbol{x}_{ij}] = \Phi(\boldsymbol{\beta}_j{}'\boldsymbol{x}_{ij})$ and the conditional expected value $E[y_{i1}|\boldsymbol{x}_{i1}, \boldsymbol{x}_{i2}, y_{i2}=1] = P(y_{i1}, y_{i2}=1)/\text{Prob}[y_{i2}=1]$. Standard errors around these marginal effects are calculated using the delta-method.

Explanatory Variables and Hypothesized Signs

Farm Characteristics

Higher net farm income (*FARMINC*) is postulated to have a positive effect on oth contracting and cooperative membership. Based on prior research, having lower debt (*DEBT0, DEBT120*) is hypothesized to have a negative effect on the probability of contracting and cooperative membership. Farm diversification, measured by the number of crop and livestock enterprises (*ENTNUM*), is hypothesized to have a negative effect on the probability of a farmer being willing to enter into a marketing contract or participate in a cooperative to market switchgrass for bioenergy. Having on-farm storage (*STORE*) is expected to have a positive influence on willingness to contract, but a negative effect on willingness to participate in a cooperative that provides harvest and storage services. Farmers, who have recently used custom harvest services (*CUSTHARV*), may be more willing to participate in a cooperative that provides these services. However, farmers who own their own hay equipment (*HAYEQUIP*) are likely to be less interested in joining a cooperative that provides harvesting services. Farmers who have sold under contract (*SCONTRACT*) are hypothesized to be more experienced with contracting and therefore more likely to be interested in contracting. Farmers who have a higher share of rented land (*RENTSHR*) may wish to use more flexible market arrangements and would thus be less likely to be interested in contracting or joining a cooperative.

Farmer Demographics

The age of the producer (*AGE*) is hypothesized to have a negative influence on contracting, but a positive influence on cooperative membership.

Older farmers may be less interested in long-term contracts, but they may prefer to have a cooperative hire or own the equipment needed to harvest the switchgrass. More highly educated farmers (*EDUC*) are hypothesized to be more interested in both contracting and cooperative membership.

It is hypothesized that farmers who are already members of a cooperative (*COOPM*) would be more likely to be interested in marketing switchgrass through a cooperative. Prior research has found a positive correlation between off-farm income and the use of contracting. Hence, larger off-farm income (*OFINC)* is hypothesized to have a positive influence on willingness to rely on a contract to market switchgrass. Off-farm income has also been found to be positively associated with NGC membership, thus, it is expected that off-farm income will also be positively correlated with willingness to participate in a cooperative. Finally, farmers who perceive farming to involve substantial risk (*RISK*), are more likely to be willing to market switchgrass through either a contract or a cooperative as both can reduce risks related to the asset specificity and uncertainty associated with a switchgrass crop.

Attitudes toward Switchgrass

Farmer attitudes toward switchgrass and the extent to which the market for switchgrass has developed are also likely to influence farmer attitudes toward contracting and cooperative membership. If farmers are concerned about possible planting or harvesting conflicts between switchgrass and their other crops (*PLANCON*), they may be more likely to be willing to participate in a harvesting cooperative. They may also be less likely to be willing to be locked into a long-term contract in which they may be asked to relinquish some control over the timing of switchgrass planting/harvest. Farmers concerned about the profitability of producing switchgrass relative to other crops (*SWIPRO*F) may be more likely to be interested in contracting as they may view contracting as a way to increase the profitability of switchgrass production. Farmers who are concerned about ceasing farming in the next few years due to retirement (*CEASE*) are likely to be less willing to enter into a long-term contract to produce switchgrass. Farmers who are more concerned about helping to create jobs in their local community (*JOBS*) are hypothesized to be more likely to be interested in membership in a cooperative.

Data

Data were collected from a mail survey of agricultural producers with at least $10,000 in sales, as identified by the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS). The survey was sent to 7,000 producers randomly selected by NASS from 12 southeastern states (Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia). The first mailing of the survey was followed with a reminder postcard and a second mailing of the survey for non-responders. A total of 1,301 useable surveys were returned for an 18.59% response rate.[c]

Survey questions addressed producers': 1) knowledge of, and interest in, switchgrass production; 2) opinions about switchgrass; 3) farm characteristics; 4) financial information; and 5) demographic characteristics. After being provided information on switchgrass production, producers were asked how interested they were in growing switchgrass as a crop for energy production. If somewhat or very interested, they were also asked whether they would (i) prefer to grow switchgrass under a contract; and (ii) be interested in participating in a cooperative that harvests, transports, stores, and markets switchgrass.

Results

Of the 1,301 respondents, 1,247 answered the question regarding interest in growing switchgrass. Of these, 751 (60.22%) were either somewhat or very interested in growing switchgrass. Of the 751 interested producers, 678 answered the question regarding contracting, with 418 (61.65%) preferring to use a contract if they grew switchgrass. A total of 691 answered the question regarding interest in participating in a cooperative. Of these, 533 (77.13%) were interested in participating in a cooperative that harvests, transports, stores, and markets switchgrass. To estimate the bivariate probit model, only observations from both the contract and cooperative membership questions and the explanatory variables which were non-missing could be used. When missing values for all variables used in the bivariate probit model were dropped, the total number of observations remaining was 452.

The results for the estimated bivariate probit model are presented in Table 2. The significantly positive value of Rho suggests a positive correlation of the error terms for the *CONTRACT* and *COOP* equations. Correlated error terms indicate that the two equations should be estimated together rather than separately. A likelihood ratio test revealed the model to be statistically significant overall at the 99% confidence level. The model correctly classified 69.25% of the observations for the *CONTRACT* dependent variable and 81.64% of the observations for the *COOP* dependant variable.

Eleven of the 27 estimated coefficients were significant at the 10% level or better in the *CONTRACT* equation. The estimated coefficient on farm size (*ACRES*) was positive and significant as was farm income between $50,000 and $100,000 (*FINC50100*). However, none of the debt category variables were statistically significant in the *CONTRACT* equation. Having storage facilities for switchgrass (*STORE*) was significant and positive, but use of custom harvest services in the prior year (*CUSTHARV*), being a hay producer (*HAY*), and having hay equipment (*HAYEQ*) were not significant. Prior experience with contracting (*SCONTRACT*) and age of producer (*AGE*) were both significant and positive. Share of acres rented (*RENTSHR*) was not significant. Off-farm income of $50,000 to $100,000 (*OFINC50100*) had a positive influence. The variable representing willingness to take on more risks (*RISK*) was positive and significant. Concerns about planting/harvest conflicts (*PLANCON*) and possibility of ceasing farming (*CEASE*) had negative influences, while job creation (*JOBS*) was statistically significant and positive.

Similarly, eleven of the 27 estimated coefficients were significant at the 10% level or better in the *COOP* equation. The estimated coefficient on farm size (*ACRES*) was significant and positive. While none of the estimated coefficients on farm income were significant, having a debt- to-asset ratio greater than zero but less than 20% (*DEBT120*) was positive and significant. Having on-farm storage (*STORE*) had a significant and positive influence on interest in joining a cooperative. Use of custom harvest services in the prior year (*CUSTHARV*) was also significant and positive, while being a hay producer (*HAY*) was significant and negative. Prior experience with contracting (*SCONTRACT*), number of enterprises (ENTNUM), and age of producer (*AGE*) were not insignificant. Share of acres rented (*RENTSHR*) was negative and significant, while higher off-farm income was negative and significant. Concerns about planting/harvest conflicts (*PLANCON*) possibility of ceasing farming (*CEASE*), and job creation (*JOBS*) were each statistically significant in the *COOP* equation. While *PLANCON* and *CEASE* had negative coefficients, the estimated coefficient on *JOBS* was positive.

The magnitudes of the effects of each of the explanatory variables on the probability of a farmer who is interested in producing switchgrass being willing to market that switchgrass through either a contract (*CONTRACT)* or by participating in a cooperative (*COOP)* are presented in Tables 3 and 4, respectively. The effects on marginal probability (unconditional probability that *CONTRACT*=1 or *COOP*=1) are presented in the first set of columns in each table. The second set of columns in Tables 3 and 4 show the marginal effects of each independent variable conditional on the other dependant variable condition being true, i.e., the second set of columns in Table 3 shows the marginal effects of the independent variables on CONTRACT conditional on COOP=1, while the second set of columns in Table 4 shows the marginal effects of the independent variables on COOP conditional on CONTRACT=1.

As hypothesized, larger farm size (*ACRES*) increased the probability of a farmer being willing to enter into a contract to market switchgrass. Moderate farm income (*FINC50100*) had a positive effect on willingness to enter into a contract compared to farmers having less than $15,000 in net farm income. Since the marginal effects of the other net farm income dummy variables were not significant, this result suggests non-linearity of the effects of farm income, unlike the positive influence that was hypothesized. As expected, having storage (STORE) and prior experience with contracting (*SCONTRACT*) had a positive marginal effect on the probability of being interested in contracting. However, prior use of custom harvest services (*CUSTHARV),* hay production *HAY*, ownership of (*HAYEQ),* share of land rented (*RENTSHR*) and the number of farm enterprises (*ENTNUM*) did not have a significant marginal effect on interest in contracting. Contrary to our hypothesis, the age of the producer (*AGE*) had a positive marginal effect on interest in producing switchgrass under contract. Education level *(EDUC*) did not have a significant marginal effect on interest in contracting nor did current membership in a cooperative (*COOPM*). Moderate off-farm income (*OFINC50100)* had a positive marginal effect on probability of interest in contracting switchgrass. Farmers who perceive farming to involve substantial risk (*RISK*) were more likely to be interested in producing under contract suggesting that they may view contracts as a way to mitigate the risks of switchgrass production.

Farmers who were more concerned about planting/harvest conflicts (*PLANCON*) were less likely to be interested in contracting. Thus, farmers who are more concerned with planting/harvesting conflicts may view contract marketing arrangements as limiting their flexibility in planting/harvesting switchgrass. Farmers who were more concerned about the profitability of switchgrass relative to other crops (*SWIPROF*) were more likely to be interested in contracting. Among the opinion variables about switchgrass, *SWIPROF* had the largest positive marginal effect on probability of being interested in contracting. As would be expected, farmers concerned about ceasing farming (*CEASE*) were less likely to be interested in entering contract market arrangements. Interest in creating jobs (*JOBS*) had a positive marginal effect on interest in contracting.

As shown in Table 4 larger farm size (*ACRES*) increased the probability of being willing to participate in a cooperative, as was hypothesized. Farm income had no significant impact on marginal probability of being interested in joining a cooperative. The debt-to-asset range of 1% to 20% (*DEBT120*) had a positive influence on probability of interest in joining a cooperative compared to higher debt farmers (debt-to-asset ratio greater than 20%). This result suggests a non-linear effect of debt-to-asset ratio upon interest in joining a cooperative. One possible explanation is that farmers may perceive that an upfront investment will be needed for a startup cooperative. Thus, those with no debt might not be willing to incur debt to join the coop, while those with higher debt may not believe they would be able to borrow sufficient amounts to invest in a cooperative. The marginal effect of *STORE* was positive and significant for *COOP*. The fact that farmers were still interested in joining the cooperative even if they had storage could indicate that they either perceived additional benefits from joining the cooperative, they would continue to use their storage for existing uses, or they might produce more switchgrass than their current storage capacity. Use of custom harvest (*CUSTHARV*) had a positive influence on interest in joining a cooperative. This result suggests that farmers who are already using custom harvest services would value a cooperative that could provide these services to them. While having hay equipment (*HAYEQ*) had no significant impact on willingness to participate in a cooperative, producing hay (*HAY)* had a negative effect on interest in joining a cooperative. This result could suggest that farmers who are currently able to use or market hay are not as concerned about marketing switchgrass and thus, less worried about asset specificity of a switchgrass crop. Also as expected, the share of land rented (*RENTSHR*) had a negative effect on interest in joining a cooperative. Education level *(EDUC*) did not have a significant marginal effect on interest in joining a cooperative. Current membership in a cooperative (*COOPM*) did not have a significant marginal effect on interest in joining a switchgrass handling and marketing cooperative. As postulated, higher off-farm income had a positive influence on interest in cooperative membership as off-farm income between $50,000 and $100,000 (*OFINC50100*) and $100,000 or above (*OFINC100P*) both had positive marginal effects.

Farmers who were more concerned about planting/harvest conflicts (*PLANCON*) were less likely to be interested in joining a cooperative. As with contracting, farmers who are more concerned with these issues may view cooperative marketing arrangements as limiting their flexibility in planting/harvesting switchgrass. As anticipated, farmers concerned about ceasing farming (*CEASE*) were less likely to be interested in cooperative membership, while farmers who were more concerned about local job creation (*JOBS*) were more interested in joining a cooperative. Among the opinion variables, *JOBS* had the largest positive marginal effect on *COOP*, while *CEASE* had the largest negative marginal effect.

The signs and significances of the conditional marginal effects were generally similar to those of the unconditional marginal effects. As seen in Table 3, seven of the eleven independent variables that had a significant unconditional marginal effect on the probability of farmers being interested in contracting, had a similar significant marginal effects on interest in contracting conditional on cooperative membership. The only exceptions, i.e., independent variables with a significant unconditional marginal effects but insignificant conditional marginal effect on interest in contracting were having storage (*STORE*), farmer age (*AGE*), concerns about planting/harvesting conflicts (*PLANCON*), and ceasing farming soon (*CEASE*).

As shown in Table 4, eight of the eleven independent variables that had a significant unconditional marginal effect on the probability of farmers being interested in joining a cooperative had a similar significant marginal effect on interest in joining a cooperative conditional on interest in contracting, with the only exceptions being farm size (*ACRES*), one of the off-farm income variables (*OFINC100P*), and concerns about planting/harvesting conflicts (*PLANCON*) were no longer significant, while two of the farm income dummy variables (*FIN2550*) and (*FINC50100*) were significant and negative suggesting that interest in participating in a cooperative decreases as farm income increased for those who were willing to enter into a contract.

Comparison of the marginal effects across *CONTRACT* and *COOP* provides some interesting insights. The positive marginal effect of farm size (*ACRES*) was much larger on *CONTRACT* than on *COOP*, suggesting that while farmers with larger farms were more likely to prefer either a contract or a cooperative to a cash spot market, farm size had a greater effect on the preference for contracts than on the preference for cooperatives. This finding could be due to larger farms may having less need for the subsidiary services provided by a cooperative and/or the ability to spread transactions costs associated with a long term contract over a larger quantity of switchgrass.

Positive and significant marginal effects in both equations for the storage variable (*STORE*) indicate farmers with storage tended to favor both the cooperative and contract market arrangements over spot markets. While use of custom harvest services (*CUSTHARV*) did not significantly impact *CONTRACT*, it did impact *COOP*. Hence, a cooperative initiated to help harvest, store, and market switchgrass might target its efforts toward farmers who are already using custom harvest services. The marginal effects on PLANCON were negative and significant in both equations, suggesting that farmers who are concerned about planting/harvesting conflicts may desire the flexibility of marketing through spot markets. While farmers who were concerned about switchgrass profitability (*SWIPROF*) were more likely to be interested in contracting, there was no significant effect on interest in joining a cooperative. Therefore, farmers may view contracting as being more likely to improve the profitability of switchgrass production than participating in a cooperative or using a spot market. The marginal effects on *JOBS* were positive in both the contracting and cooperative equations, perhaps suggesting that those who are more interested in job creation view these arrangements as preferable.

Conclusions

Theoretically, the asset specificity and uncertainty that characterize the developing switchgrass for bioenergy market suggest that biorefineries are unlikely to rely on spot markets to acquire switchgrass. Similarly, empirical analysis of existing bioenergy feedstock markets suggests a heavy reliance on vertical coordination in the form of contracts or vertical integration as energy producers also produce their own feedstock. Thus, the willingness of farmers to participate in a vertically coordinated market is another important piece of the puzzle to determining the conditions under which farmers are going to be willing to produce switchgrass as a biomass feedstock.

This research suggests that farmers who are interested in growing switchgrass as a biomass feedstock are generally willing to grow it under a contract and/or participate in a cooperative that harvests, transports, stores, and markets switchgrass. This willingness to engage in these alternative marketing arrangements was greater among farmers who farmed more acres, had facilities in which they could store switchgrass, and had substantial off-farm income. Thus, these alternative marketing arrangements were popular among farmers who had the physical resources to take advantage of the opportunity but who were also likely to be time-constrained. This result suggests that farmers may see these alternative marketing arrangements as a way to utilize their physical assets while limiting their time commitment by accessing "technical advice, managerial expertise, market knowledge, and access to technological advances" (Perry et al., 1999, p. 12). On the other hand, farmers who were concerned about conflicts with planting and/or harvesting of other crops or expected to cease farming in the not too distant future were less interested. Thus, farmers may also be concerned about the extent to which contracts and cooperatives represent long-term commitments or investments that may limit their flexibility going forward.

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Table 1. Variable Names, Definitions, and Descriptive Statistics

Variable Name	Definition	Mean, Std. Dev. (N=452)	Percent
Farm Characteristics			
ACRES	Acres farmed (00s acres)	4.195 (6.617)	
FINCLT15	Net farm income in 2008, *FINCLT15*=1 if <$15,000 (omitted category), *FINC1525*=1 if $15,000-$24,999, 0 otherwise; *FINC2550*=1 if $25,000-$49,999, 0 otherwise; *FINC50100*=1 if $50,000-$99,999, 0 otherwise; *FINC100P*=1 if at least $100,000, 0 otherwise		49.12%
FINC1525			12.39%
FINC2550			12.61%
FINC50100			9.07%
FINC100P			16.81%
DEBT0	Debt to asset ratio, *DEBT0*=1 1 if debt to asset ratio is zero, 0 otherwise; *DEBT120*=1 1 if debt to asset ratio is 1% to 20%, 0 otherwise; *DEBT20P*=1 if debt to asset ratio is >20%, 0 otherwise (omitted category)		59.96%
DEBT120			22.35%
DEBT20P			17.70%
STORE	1 if storage facilities for switchgrass, 0 otherwise		55.75%
CUSTHARV	1 if used custom harvest services in 2008, 0 otherwise		22.79%
HAY	1 if produce hay, 0 otherwise		63.27%
HAYEQ	1 if own hay equipment, 0 otherwise		70.13%
SCONTRACT	1 if have produced commodity under contract, 0 otherwise		27.43%
RENTSHR	Share of farmland that is rented	0.222 (0.369)	
ENTNUM	Number of crop and livestock enterprises on the farm	2.577 (1.378)	
Farmer Demographics			
AGE	Farm age in years	56.799 (11.809)	
EDUC	1=elementary/middle school, 2=some high school, 3= high school, 4=some college, 5=college graduate, 6= post graduate	4.277 (1.512)	
OFINCL15	Off farm income in 2008, *OFINCL15*=1 <$15,000, 0 otherwise (omitted category), *OFINC1525*=1 if $15,000-$24,999, 0 otherwise; *OFINC2550*=1 if $25,000-$49,999, 0 otherwise; *OFINC50100*=1 if $50,000-$99,999, 0 otherwise; *OFINC100P*=1 if at least $100,000, 0 otherwise		11.54%
OFINC1525			4.40%
OFINC2550			23.89%
OFINC50100			31.19%
OFINC100P			28.98%
COOPM	1 if a cooperative member, 0 otherwise		34.07%
RISK	You must be willing to take substantial financial risks to be a successful farmer (1=strongly disagree,…,5=strongly agree)	3.170 (1.151)	

Table 1. Continued

Variable Name	Definition	Mean, Std. Dev.	Percent
<u>Importance in Deciding to Grow Switchgrass</u>			
PLANCON	Possible conflicts between planting/harvest period for switchgrass and other crops(1=not at all, 2=not very, 3=somewhat, 4=very, 5=extremely)	2.491 (1.181)	
SWIPROF	Profitability of growing switchgrass compared with other farming alternatives(1=not at all, 2=not very, 3=somewhat, 4=very, 5=extremely)	3.823 (0.937)	
CEASE	Possibility that you will cease farming in the next few years due to retirement or other reasons (1=not at all, 2=not very, 3=somewhat, 4=very, 5=extremely)	2.206 (1.200)	
JOBS	Potential for creating jobs in your community(1=not at all, 2=not very, 3=somewhat, 4=very, 5=extremely)	3.223 (1.150)	

Table 2. Estimated Bivariate Probit Model

	CONTRACT				*COOP*			
Variable	Est. Coeff.	Std. Error	Z		Est. Coeff.	Std. Error	Z	
Intercept	-2.123	0.693	-3.06	***	-0.725	0.754	-0.96	
ACRES	0.054	0.021	2.57	*	0.038	0.018	2.06	**
FINC1525	0.130	0.207	0.63		0.132	0.253	0.52	
FINC2550	0.177	0.220	0.80		-0.375	0.236	-1.59	
FINC50100	0.545	0.303	1.80	*	-0.406	0.294	-1.38	
FINC100P	-0.118	0.230	-0.51		-0.288	0.253	-1.14	
DEBT0	-0.092	0.203	-0.45		0.253	0.219	1.16	
DEBT120	-0.031	0.224	-0.14		0.431	0.249	1.73	*
STORE	0.282	0.140	2.01	**	0.464	0.158	2.93	***
CUSTHARV	-0.066	0.178	-0.37		0.399	0.222	1.80	*
HAY	-0.045	0.160	-0.28		-0.438	0.195	-2.24	**
HAYEQ	-0.213	0.180	-1.18		0.166	0.211	0.79	
SCONTRACT	0.304	0.167	1.82	*	0.149	0.187	0.80	
RENTSHR	-0.050	0.198	-0.25		-0.719	0.221	-3.26	***
ENTNUM	0.046	0.060	0.77		0.057	0.067	0.86	
AGE	0.013	0.007	1.84	*	0.012	0.008	1.57	
EDUC	-0.053	0.061	-0.86		-0.053	0.069	-0.77	
OFINC1525	0.547	0.401	1.36		0.193	0.400	0.48	
OFINC2550	0.278	0.243	1.14		0.410	0.257	1.60	
OFINC50100	0.477	0.236	2.02	**	0.667	0.259	2.58	***
OFINC100P	0.283	0.238	1.19		0.422	0.255	1.66	*
COOPM	-0.039	0.149	-0.26		-0.042	0.168	-0.25	
RISK	0.107	0.058	1.87		0.028	0.065	0.44	
PLANCON	-0.106	0.059	-1.79	*	-0.122	0.067	-1.83	*
SWIPROF	0.285	0.075	3.78		0.110	0.085	1.29	
CEASE	-0.110	0.064	-1.73	*	-0.227	0.073	-3.11	***
JOBS	0.154	0.059	2.61	***	0.197	0.067	2.94	***
Rho	0.330	0.102	3.25	***				
LLR Test (X^2), w/52 df	108.44	***						
% of observations correctly classified	69.25				81.64			

* Statistical significance at the 10% level.
** Statistical significance at the 5% level.
*** Statistical significance at the 1% level.

Table 3. Estimated Marginal Effects on Marginal and Conditional Probabilities for *CONTRACT*

	Marginal			Conditional on *COOP*=1		
Variable	Marg. Effect	Std. Error	Z	Marg. Effect	Std. Error	Z
ACRES	0.019	0.007	2.63 ***	0.017	0.007	2.41 **
FINC1525	0.046	0.074	0.63	0.039	0.070	0.56
FINC2550	0.063	0.078	0.80	0.077	0.075	1.03
FINC50100	0.194	0.107	1.80 *	0.205	0.103	1.99 **
FINC100P	-0.042	0.082	-0.51	-0.028	0.078	-0.36
DEBT0	-0.033	0.072	-0.45	-0.043	0.069	-0.61
DEBT120	-0.011	0.080	-0.14	-0.029	0.077	-0.38
STORE	0.100	0.050	2.01 **	0.077	0.048	1.60
CUSTHARV	-0.024	0.063	-0.37	-0.040	0.061	-0.66
HAY	-0.016	0.057	-0.28	0.004	0.055	0.06
HAYEQ	-0.076	0.064	-1.18	-0.080	0.061	-1.31
SCONTRACT	0.108	0.059	1.83 *	0.098	0.056	1.74 *
RENTSHR	-0.018	0.070	-0.25	0.014	0.068	0.21
ENTNUM	0.016	0.021	0.77	0.013	0.020	0.66
AGE	0.004	0.002	1.84 *	0.004	0.002	1.63
EDUC	-0.019	0.022	-0.86	-0.016	0.021	-0.76
OFINC1525	0.195	0.142	1.37	0.180	0.136	1.32
OFINC2550	0.099	0.086	1.15	0.078	0.083	0.94
OFINC50100	0.170	0.084	2.02 **	0.135	0.081	1.68 *
OFINC100P	0.101	0.085	1.19	0.079	0.081	0.98
COOPM	-0.014	0.053	-0.26	-0.012	0.051	-0.23
RISK	0.038	0.020	1.87 *	0.036	0.020	1.83 *
PLANCON	-0.038	0.021	-1.79 *	-0.031	0.020	-1.54
SWIPROF	0.101	0.027	3.78 ***	0.093	0.026	3.63 ***
CEASE	-0.039	0.023	-1.73 *	-0.028	0.022	-1.28
JOBS	0.055	0.021	2.61 ***	0.044	0.020	2.20 **

* Statistical significance at the 10% level.
** Statistical significance at the 5% level.
*** Statistical significance at the 1% level.

Table 4. Estimated Marginal Effects on Marginal and Conditional Probabilities for *COOP*

Variable	Marginal: Marg. Effect	Marginal: Std. Error	Marginal: Z	Conditional on *CONTRACT*=1: Marg. Effect	Conditional on *CONTRACT*=1: Std. Error	Conditional on *CONTRACT*=1: Z
ACRES	0.009	0.004	2.09 **	0.006	0.004	1.50
FINC1525	0.032	0.061	0.52	0.022	0.050	0.43
FINC2550	-0.090	0.056	-1.60	-0.081	0.046	-1.75 *
FINC50100	-0.097	0.070	-1.39	-0.100	0.058	-1.74 *
FINC100P	-0.069	0.061	-1.14	-0.053	0.050	-1.06
DEBT0	0.061	0.052	1.16	0.054	0.043	1.25
DEBT120	0.103	0.059	1.75 *	0.087	0.048	1.79 *
STORE	0.111	0.038	2.95 ***	0.082	0.032	2.54 **
CUSTHARV	0.096	0.052	1.83 *	0.082	0.043	1.90 *
HAY	-0.105	0.046	-2.26 **	-0.085	0.038	-2.22 **
HAYEQ	0.040	0.050	0.79	0.041	0.041	0.99
SCONTRACT	0.036	0.045	0.80	0.019	0.037	0.51
RENTSHR	-0.172	0.053	-3.27 ***	-0.141	0.044	-3.18 ***
ENTNUM	0.014	0.016	0.86	0.010	0.013	0.74
AGE	0.003	0.002	1.57	0.002	0.002	1.28
EDUC	-0.013	0.017	-0.77	-0.009	0.014	-0.64
OFINC1525	0.046	0.096	0.48	0.019	0.079	0.24
OFINC2550	0.098	0.062	1.60	0.071	0.051	1.40
OFINC50100	0.160	0.062	2.60 ***	0.115	0.052	2.22 **
OFINC100P	0.101	0.061	1.66 *	0.074	0.051	1.46
COOPM	-0.010	0.040	-0.25	-0.007	0.033	-0.21
RISK	0.007	0.016	0.44	0.002	0.013	0.14
PLANCON	-0.029	0.016	-1.83 *	-0.020	0.013	-1.54
SWIPROF	0.026	0.020	1.29	0.012	0.017	0.68
CEASE	-0.054	0.017	-3.13 ***	-0.041	0.015	-2.81 ***
JOBS	0.047	0.016	2.94 ***	0.033	0.014	2.45 ***

* Statistical significance at the 10% level.
** Statistical significance at the 5% level.
*** Statistical significance at the 1% level.

Endnotes

[1] Gold and Seuring (2011) provides a review of the literature on the logistics of bio-energy production more generally.

[2] For example: "Contracting can be an effective way to manage the risks presented by the market. Farmers benefit by having a guaranteed market, price, or access to a wider range of production inputs, allowing them to concentrate their management efforts on a particular part of the production process. Because most contract arrangements reduce risks in comparison with traditional production or marketing channels, income is more stable over time. Farmers receive a steady cash flow received from contract fees, giving them a safe position from which to conduct business. They also benefit from technical advice, managerial expertise, market knowledge, and access to technological advances (such as proprietary genetics) not otherwise available" (Perry, et al., 1999, p. 12).

[c] Two measures from the survey data which could be compared with the total population of farmers, as based on the 2007 Census of Agriculture, are age of farmer and acres farmed. Among those responding overall (regardless of interest in growing switchgrass or market arrangements), the average age was 60.30 years (N=1,241) and the number of acres farmed was 384.21 acres (N=1,190). This can be compared with the 2007 Census of Agriculture data average for the region of 313.77 acres and 57.92 years. Therefore, the responding farmers were somewhat older and farms somewhat larger than the Census averages for the region. Because only farms with at least $10,000 in sales were surveyed, it would be expected that farm size might be somewhat larger than overall Census values.