



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Essentials for Producer Participation in Biomass Markets When Choices are Correlated

Mohammad Mainul Hoque, Graduate Student, Department of Economics, Iowa State University Georgeanne M.

Artz, Scientist, Department of Economics, Iowa State University

Bobby J. Martens, Assistant Professor of Supply Chain Management, Iowa State University

Darren H. Jarboe, Program Manager, Center for Crops Utilization Research, Iowa State University.

Selected Paper prepared for presentation at the Southern Agricultural Economics Association

(SAEA) Annual Meeting, Orlando, Florida, 3-5 February 2013

Copyright 2013 by [authors]. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies. Support from Iowa State University Bio-based Industry Center, Iowa Alliance for Cooperative Business Development, and USDA Rural Business-Cooperative Service are greatly acknowledged.

The Renewable Fuels Standard (RFS) mandate under the Energy Independence and Security Act of 2007 requires that biofuel production reach 36 billion gallons by 2016, with at least 16 billion gallons coming from cellulosic biomass sources. Markets for agricultural biomass are still developing, and as such, much uncertainty remains at all stages of the supply chain. Sustainable production of cellulosic biofuels largely depends on a continuous and consistent supply of biomass, which rests critically farmer interest and participation in biomass production.

Utilizing responses to a mail survey of Iowa farmers, this study evaluates farmers' attitudes toward production of three major types of biomass- corn cobs, corn stover, and energy dedicated grass. The main objectives of this study are: (i) to understand Iowan farmers' general interest in supplying various types of biomass, (ii) to develop rigorous constructs defining the essential elements for producer participation in biomass markets, and to explore how these may vary by type of biomass, and (iii) to analyze the implications of appropriate modeling techniques in the presence of potential correlation across farmers' interest in growing various types of biomass.

This study focuses exclusively on Iowa farmers. Although Iowa is currently the largest corn ethanol producing state in the U.S., and has huge potential for crop residue-based biomass production, Iowan farmers' attitudes and willingness to grow biomass remains uncertain. Tyndall and Colletti (2011) argue that Iowa alone could produce 1.53 billion gallons of cellulosic ethanol per year, if its share of the nation's collectible corn stover could be brought into production. This potential has induced two large biofuel manufacturers to build commercial scale plants in the state, POET in Emmetsburg, IA and DuPont-Danisco in Nevada, IA. Both of these plants are currently expected to operate at full scale, commercial production in 2013. A rigorous study on farmers' attitudes towards biomass production can provide these processors, and future market entrants, useful insights for biomass procurement.

Most existing studies of economic feasibility of lignocellulosic biofuel incorporate a simplified assumption that farmers would be willing to supply biomass if their expected profit from the biomass enterprise is the highest among all existing alternatives. However, since the market for biomass is subject to huge uncertainty and lacks insurance mechanisms to mitigate risk, and given that farmers' risk attitudes vary by location, firm- and

individual-specific characteristics, a simplified assumption that farmers would be willing to supply if the price is high enough is somewhat unrealistic.

A few recent studies analyze farmers' perceptions and attitudes of biomass towards development enterprises (Jensen 2007; Paulrud and Laitila 2010; Altman et al. 2011; Bergtold, Fewell and Williams 2011; and Smith et.al 2011). Besides identifying various demographic and farm-specific factors affecting farmers' biomass production decisions, these studies have also found that agronomic and environmental concerns arising from biomass harvesting (soil quality issues, reduced fertility, soil carbon loss, loss of wildlife habitat, environmental stewardship, etc.), asset specificity, storage and transportation issues, high capital investment requirements, lack of access to finance and lack of existing markets for biomass are all factors inhibiting the farmers' willingness to adopt commercial biomass production.

Farm and farmer characteristics have been found to significantly impact farmers' interest in supplying biomass. Demographics such as age, education, experience attitudes towards risk, and perceptions about the environment are some crucial individual level factors affecting farmers' technology adoption decisions. The level and sources of farm income, farm size, soil and land type, and diversity of the farming operation are characteristics of the farming operation that have been found to affect farmers' willingness to adopt biomass production. Previous experience in supplying biomass, or other crops for ethanol production augments individuals' knowledge and information and may increase interest in providing biomass in the future. Finally, the specific terms of a potential contract offered by biomass processors can also impact farmers' willingness to supply (Epplin et al., 2007; Jensen et.al. 2007; Rajagopal et al. 2007; Paulrud and Latilia 2010; Smith et.al 2011; Altman et.al 2011; Bergtold, Fewell and Williams 2011; Qualls et al, 2011).

Given seasonality in the availability of biomass, and the large volumes of biomass required to operate at an economic scale, most biofuel plants propose to rely on multiple feedstocks (Coyle, 2010). To economize on transportation costs, processors may rely on producers located within a certain radius of their processing facility, and thus, may demand that farmers supply multiple types of biomass. From the growers' perspective, choosing to engage in multiple biomass enterprises may be advantageous as well. Farmers' land may vary significantly in terms of soil quality, land structure and suitability for conventional crops such as corn and soybeans. Farmers'

knowledge and perceptions may vary by type of biomass, resulting in some farmers willing to produce different types of biomass, while others specialize in one specific type.

We include three types of biomass in this study. Corn cobs and corn stover have some similarities but differ in terms of agronomic consequences, harvesting process, and other logistics. Both stover and cobs are less similar to energy grasses. Willingness to grow various biomass types might be simultaneously based on farmers' perceptions, farm characteristics, and available information. If farmers consider some biomass types as complements they might prefer joint adoption, while they would tradeoff among biomass types they consider substitutes. Some unobserved individual characteristics may lead to preferences for one combination of biomass types over another, e.g., if farmers have strong concerns for environment, they might prefer the combination of corn cobs and energy grasses over the combination of corn stover and energy grasses. This suggests a potential for contemporaneous correlation among individual decisions across biomass types, and makes a strong case for applying a modeling technique suitable for correlated choice.

Data

Data for this analysis were gathered by a mail survey sent to 2,250 Iowa producers with 50 acres or more land in February, 2011. The sample was evenly divided among five regions: Northwest Iowa, Southwest Iowa, North Central Iowa, South Central Iowa and Eastern Iowa. The survey gathered information on interest in several biomass production types, farm and farmer characteristics, previous exposure to biofuel markets, general knowledge and perceptions about biomass production and operation, concerns regarding biomass production, harvest, transport, financing of capital, government policies, contract issues and, importance of various public and private information sources for advancing the biomass production. After excluding ineligible farmers and 89 partially completed surveys, a total of 784 completed surveys were returned, for a response rate of approximately 30%¹. The response rate varies across regions in the range of 21.77% in the South Central part of Iowa to 41.77% in the Eastern part. Sampling weights were assigned to account for the variation in response rates across regions. Table 1 provides descriptions of key variables used in the analysis.

¹ In this study, we consider survey respondents ineligible and exclude them from the analysis if: (i) the respondent is a farmer, currently owning or managing less than 50 acres of land, or (ii) the respondent is a landowner but not making farming decisions, (iii) the operation is a feedlot only or not a farm, and (iv) the respondent is no longer a farmer or landowner.

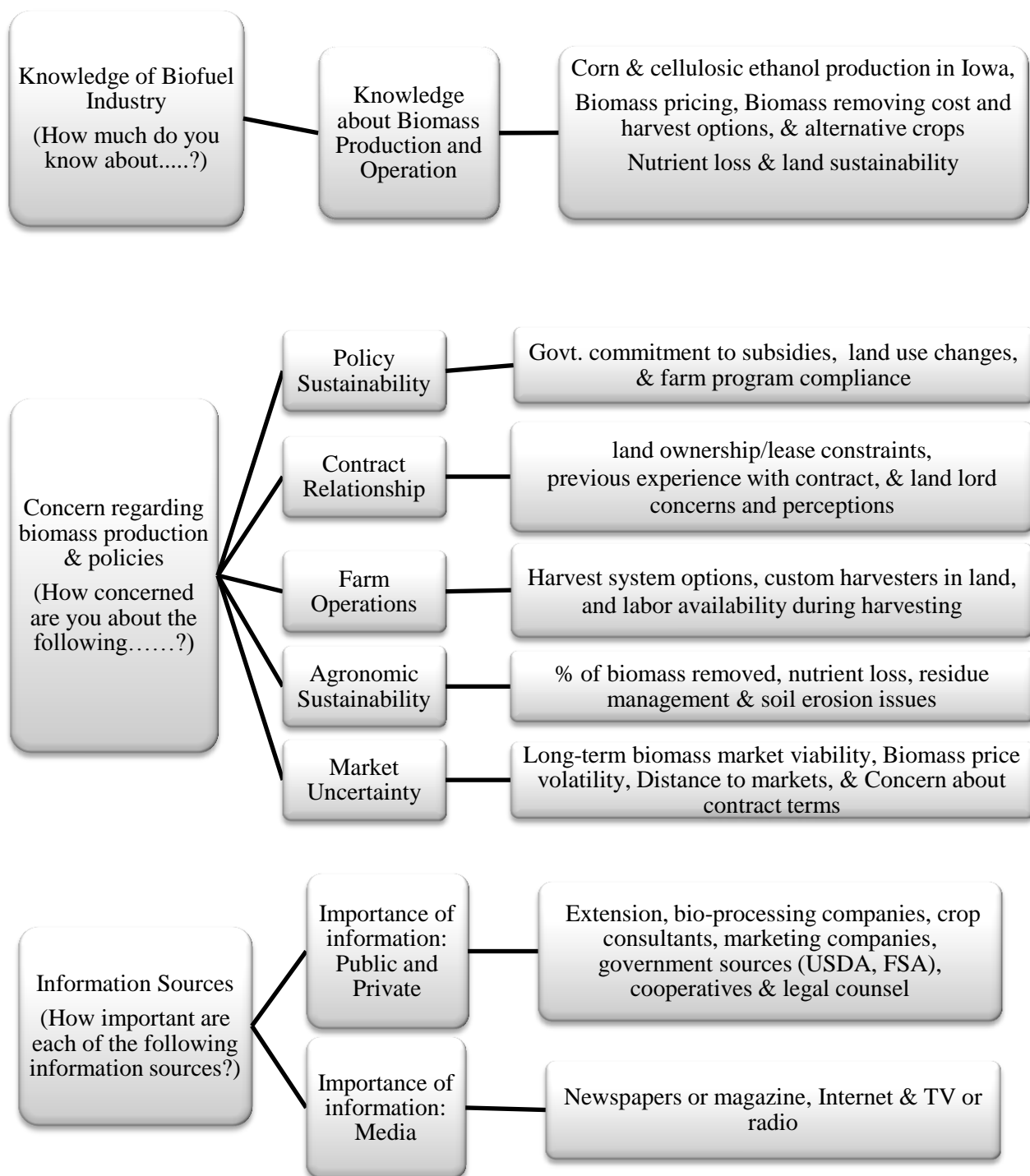
The survey contained approximately 60 questions on issues related to farmers' knowledge, perceptions, concerns, and perceived importance of information sources. Survey respondents expressed their subjective evaluation of knowledge, perceptions, and concerns based on a Likert scale of one to seven, where the right (left) extreme number on the scale shows the highest (lowest) knowledge/concern/importance. To condense the amount of information in this data, we use exploratory factor analysis to guide our groupings of important variables.²

The factor analysis was conducted following the method outlined in Martens, Crum and Poist (2011). Factor analysis was performed on items grouped by two major themes: 1) knowledge and information about biomass production, and 2) concerns regarding biomass production, and operation. The analysis was implemented using the principal-component factors (PCF) extraction method, and the resulting number of measures was chosen based on Scree tests of the component eigenvalues.³ All items were subsequently allowed to load on factors based on their correlations, and the component matrix was rotated using the Varimax with Kaiser Normalization method. Steps were taken to validate the measures during the factor analysis process. Based on the factors produced we created eight multi-item constructs on areas related to knowledge, information perceptions, and concerns regarding various stages of biofuel production and marketing. These are shown in figure 1. A scale was constructed for each of the eight measures by taking the simple average of responses for items in that measure. We examine differences in these eight scale-constructs on knowledge, information, and concerns across biomass types, and, along with farm and farmers' characteristics use them as control variables in a version of our multivariate probit model to explain farmers' joint adoption of three different types of biomass. The mean values for each factor are reported in table 1.

² The factor analysis is conducted only on responses which show willingness to grow at least one type of biomass in our choice set. The reason for this would be explained later in this section.

³ To decide on number of final factors, we relied on both Scree tests and eigenvalues. The Scree test examines a graph of the associated eigenvalues, looking for natural bends or break points where the results flatten [Martens, Crum and Poist (2011)].

Figure 1. Variable Groupings from Factor Analysis



Willingness to Grow Biomass

Roughly 37 percent (292 out of 781) of respondent farmers expressed willingness to grow at least one of three biomass types included in our analysis.⁴ Of these interested farmers 64 percent were willing to grow more than one type of biomass. Figure 1 provides a breakdown of interested farmers by their interest in biomass types. Around one quarter of the interested farmers are willing to grow both corn cobs and corn stover, and slightly more, 27 percent were willing to grow all three types of biomass. Combinations of stover and grass, or stover and cobs were much less popular.

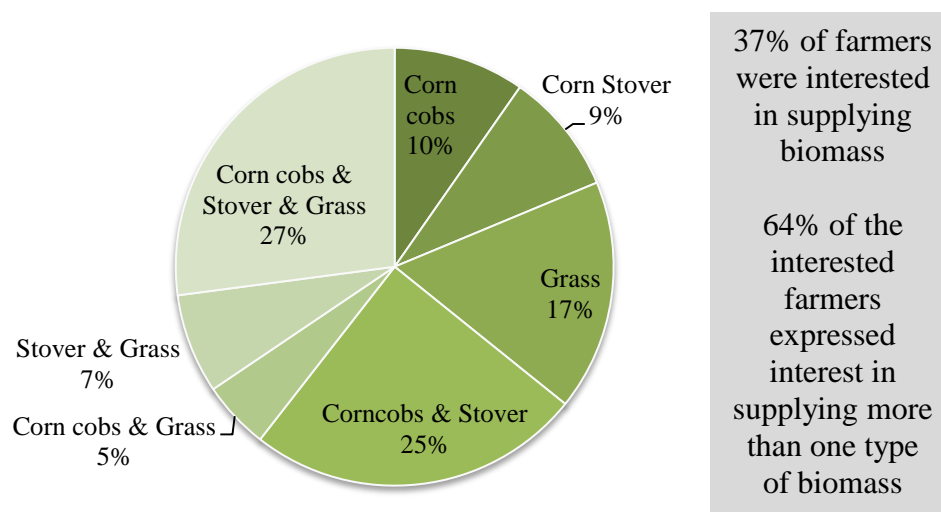


Figure 2: Respondents' Interest in Growing Biomass by Type

Table 1 compares mean characteristics of the interested and not-interested group. Farmers interested in supplying biomass are relatively younger, have less experience in farming and more schooling compared to the non-interested group. Most of the household income of interested farmers comes from off-farm sources, although the difference between groups is not statistically significant. Interested farmers have more experience selling corn to ethanol plants, have significantly larger mean farm size and are more likely to plan to farm in the next year. Also, interested farmers have, on average, a smaller proportion of land in CRP or pasture. However, the magnitude of these differences is very small.

⁴ Although we are analyzing only three biomass choices in this study, our survey includes two more biomass types-legumes and trees. We exclude those from the analysis to focus on more popular choices, both from the perspective of growers and processors. Considering farmers' willingness to grow legume and trees, we find that 325 farmers show interest in biomass, i.e., percentage of interested farmers in biomass stand around 42%.

Farmers interested in biomass production rate themselves higher on knowledge about biomass production and operation, although all farmers' rate their knowledge about a majority of the biomass production and operation issues in the survey quite low. Interested farmers also place greater importance of all types of information sources for learning about biomass production.

Farmers were asked to rate the importance of various information sources in helping them learn and make decisions about biomass production opportunities. Interested farmers consistently assign higher values to the importance of all sources. Ranking different information sources by the mean response value, we observe that interested farmers believe that government extension programs, magazines and newspapers, companies offering biomass contracts, and government sources such as USDA and FSA might play a significant role in disseminating information regarding biomass.

Across all concern items, farmers who are willing to grow biomass reveal more concern compared to those who are not willing to grow biomass, and the difference is always statistically significant. This is reasonable since farmers who are interested in biomass are expected to be more concerned with potential challenges. Table 2 reports the top ten concerns of interested farmers across three major biomass types. The mean rating for most of these concern items exceeds 5, which indicates that interested farmers have strong concerns about these issues. Although the order of rankings varies some, the major concern items are nearly identical across all three biomass types. Nutrient loss, distance to markets, and long-term biomass market viability are the top three concerns of interested farmers for all biomass types. The next three most important concerns for all types are biomass price volatility, percent of biomass which can be removed, soil erosion issues. In-field transport and soil compaction and contract opt-out clauses are among the top ten concerns for all types, while residue management is a concern for stover and grasses, and contract terms on specific deliverables ranks highly for grass and cobs. Farmers interested in cobs rated delays due to biomass harvest as a top ten concern. Contract terms on storage was important for those considering supplying stover.

Theoretical Framework and Empirical Specification

Farmers' decisions can be modeled by random utility framework. Let V_{ij} denote farmer i 's utility from adopting biomass type " j " while V_{i0} is utility from non-adoption. Utility is a function of farmers' expected profit from the

biomass enterprise, farm characteristics, and farmer demographics. Expected profit is influenced by individual perceptions toward biomass, knowledge and information about biomass production, operation and sustainability of the biomass production as well as relevant policies. Many of these factors determining utility are observable to us; however, there are some unobservable factors as well, which might play a significant role in shaping one's adoption decision. Individual's risk attitudes toward uncertain ventures, preferences for the environment and concerns regarding national security are examples of such unobservable factors.

If X_{ij} is the vector representing all the observable factors, and ϵ_{ij} is the vector denoting unobservables, individual utility from adoption of biomass type j under a linear approximation is $V_{ij} = f(X_{ij}) + \epsilon_{ij}$ while for non-adoption it is $V_{i0} = f(X_{i0}) + \epsilon_{i0}$. The farmer will adopt the biomass type " j " if $V_{ij} > V_{i0}$. It can be stated as

$$Pr(B_{ij} = 1 | X_{ij}) = Pr(f(X_{ij}) + \epsilon_{ij} > f(X_{i0}) + \epsilon_{i0}) = Pr(f(X_{ij}) - f(X_{i0}) > \epsilon_{i0} - \epsilon_{ij}) \quad (1)$$

One can operationalize the above conceptual idea for modeling the adoption decision of biomass type " j " as function of observables factors X_{ij} exploiting individual probit or logit modeling techniques. Since we have three different biomass ($j=1,2,3$) types, investigating critical factors in farmers' biomass adoption decision would require us to estimate three different probit equations. Since we only observe one's willingness to adopt a particular biomass type, we have the following latent structure for each biomass type:

$$B_{ij}^* = X_{ij}'\beta_j + \epsilon_{ij}, \quad i = 1, 2, \dots, n; \quad j = 1, 2, 3$$

$$B_{ij} = \begin{cases} 1, & B_{ij}^* > 0 \\ 0, & B_{ij}^* < 0 \end{cases} \quad (2)$$

where the dependent variable B_{ij} assumes either a value of 1 in the case of farmer's willingness to adopt, or 0 for reluctance to adopt. However, the problem of individual probit or logit estimation is that it does not consider potential correlation across unobservable factors, ϵ_{ij} across biomass types. Willingness to grow various biomass types might be simultaneously based on farmers' perceptions, farm characteristics, and information. If farmers consider some biomass types as complements they might prefer joint adoption, while they would tradeoff among biomass types if they view them as substitutes. For example, if the harvesting equipment and storage procedures match between two biomass types such as corn cobs and energy grasses, farmers might consider these two

apparently different biomass types as complements, and express willingness to grow both of them simultaneously. If farmers have strong concerns for environment, they might prefer the combination of corn cobs and energy grasses over the combination of corn stover and energy grasses. These plausible examples suggest potential contemporaneous correlation among individual decisions across biomass types, and make a strong case for applying a modeling technique of correlated choice. In the presence of correlation among unobserved factors across biomass types, the probit or logit estimates will produce biased and inconsistent estimates of standard error for β_j , and inferences based on those for determining critical factors for farmers' biomass adoption would lead to inconsistent results (Greene, 2008, Marennya and Barrett, 2007). Multivariate probit modeling techniques are appropriate for correcting such biases generated from correlation across choices⁵(Train, 2009 and Greene, 2008).

We jointly estimate equation (2) for all three different biomass types allowing the covariance between the errors to be correlated across biomass types. We assume the error terms in (7) are jointly standard normally distributed with mean zero and covariance vector $\boldsymbol{\rho}$:

$$\begin{pmatrix} \epsilon_{i1} \\ \epsilon_{i2} \\ \epsilon_{i3} \end{pmatrix} \sim N \left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{21} & 1 & \rho_{23} \\ \rho_{31} & \rho_{32} & 1 \end{pmatrix} \right]$$

$$\text{where, } E[\epsilon_{ij} \epsilon_{ik}] = \begin{cases} \rho_{jk}, & \forall j \neq k \\ 1, & \forall j = k \end{cases} \quad (3)$$

The off diagonal elements (ρ_{jk}) in $\boldsymbol{\rho}$ reflect the correlation across choices of biomass types which is of particular interest to us. A statistically significant ρ_{jk} , provides evidence of correlation, either positive or negative, among the choices of biomass types. The joint adoption decision for three different biomass types would involve eight different choice probabilities for each individual: (i) $Pr[B_{i1} = 1, B_{i2} = 0, B_{i3} = 0]$ (ii) $Pr[B_{i1} = 1, B_{i2} = 1, B_{i3} = 0]$ (iii) $Pr[B_{i1} = 1, B_{i2} = 0, B_{i3} = 1]$ (iv) $Pr[B_{i1} = 0, B_{i2} = 0, B_{i3} = 1]$ (v) $Pr[B_{i1} = 0, B_{i2} = 1, B_{i3} = 0]$ (vi) $Pr[B_{i1} = 1, B_{i2} = 1, B_{i3} = 1]$ (vii) $Pr[B_{i1} = 0, B_{i2} = 1, B_{i3} = 1]$ (viii) $Pr[B_{i1} = 0, B_{i2} = 0, B_{i3} = 0]$.

⁵ The multivariate probit technique allows for possible contemporaneous correlation across elements in choice sets. Other studies have used it for modeling agricultural technology adoption, for example, see Valendia *et.al* 2009; Marennya and Barrett 2007; Gillespie, Davis, and Rahelizatovo 2004; Huffman and Lange 1989; Fernandez-Cornejo, Hendricks, Mishra 2005.

Our model estimates three choice decisions simultaneously. The choice variables are respectively farmers' willingness to adopt corn cobs, corn stover, and energy grasses. Farmers expressed their interest in growing these biomass types on a Likert scale of 1-7, where 1 indicates "not interested" and 7 indicates "very interested". For any biomass type, if a farmer's response lies between 4 (moderate interest) and 7, we consider the farmer interested in growing that biomass, otherwise, we consider the farmer not-interested.

Explanatory variables in the model include farmer demographics, farm characteristics, and prior exposure to biofuel markets. We include knowledge about biomass production, concerns regarding biomass production, operation and contract issues, and perceptions about the importance of various information sources in an expanded version of the model.

Results

We present the regression results in two parts. First, we present a probit model to analyze the critical elements for Iowan farmers' interest in supplying cellulosic biomass in general; second, we discuss the results obtained from the multivariate framework to identify any differential patterns across biomass types. In the regression models, the independent variables on knowledge, information and concerns are those measures constructed based on our factor analysis. We chose to exclude the concern items from the bivariate probit since we suspect endogeneity; there is strong possibility that only interested farmers truthfully express their concerns about various biomass issues, and we lack a good instrument for these concern items. By restricting our sample to interested farmers only, we alleviate the possible endogeneity problem, and therefore incorporate the concern measures in the multivariate probit framework to examine how concern measures vary across biomass types.

Table 3 reports the results from a simple probit model to explain farmers' biomass adoption decisions, incorporating the variables on farmer demographics, farm characteristics, knowledge, and importance of various information sources as explanatory variables. Marginal effects are also reported⁶. Among the farmers and farm characteristics, only farm size and percentage of land under no-tillage are statistically significant predictors of interest in biomass. All else equal, a farmer with more than 2500 acres is 24 percent more likely to supply

⁶ For various dichotomous independent variables in the model, the marginal effect is calculated as the difference in predicted probabilities across assumed value of 0 and 1 for that independent variable, assuming all other explanatory variables remain unchanged.

biomass compared to the farmers with fewer acres. Farms with more than half their land under no-till practice are 14 percent less likely to express interest in biomass production. Farmers with experience with corn ethanol are 14 percent more likely to be interested in biomass production, while greater knowledge about biomass production and operation, and higher perceptions about the importance of various information sources have smaller, positive effects on the likelihood that a farmer will be interested in biomass production.

Table 4 reports the multivariate probit model estimates by biomass type. Table 5 reports the estimates for the correlation structure. The factors that significantly affect interest do vary across types. Land quality on the farms appears to matter for interest in biomass type. Farms with a high percentage of erodible land and no-till practice are less likely to express interest in supplying corn stover, while farms with some erodible land and no-till practice are more likely to express interest in supplying energy grasses. Having a large farm (more than 2500 acres) increases the probability of interest in cobs, but has no significant effect on interest in grass or stover. Farms with a smaller percentage of off-farm income are less likely to express interest in corn stover. Farmers who have sold corn to an ethanol plant in the past are less likely to show an interest in growing energy grasses.

The estimates show a positive relationship between higher levels of concern regarding market uncertainty (biomass price volatility, long term market viability, distance to market and concerns about market terms) and willingness to supply both grass and corn stover. Similarly, concerns about farm operations (harvest systems, labor availability during harvest) are positively related to interest in supplying corn cobs. Farmers who are more concerned about biomass-related government policies (land use change policy, farm program compliance issues, crop rotation) and agronomic sustainability (what percentage of biomass can be removed, nutrient loss due to stover removal, soil erosion, and residue management) are less likely to show interest in corn stover.

The multivariate probit model also estimates the correlation structure across biomass types. Table 5 shows that interest in supplying corn stover and corn cobs is positively correlated. In contrast, the correlation between corn cobs and energy grass, and corn stover and energy grass is negative. All the correlation estimates are individually and jointly significant. Unobserved factors that positively influence farmers' adoption of agricultural residue biomass exert negative influence on adoption of energy grasses. However, unobserved factors that make a farmer interested in corn stover also lead the same farmer to be interested in corn cobs.

Conclusions and Implications

This study investigates the critical determinants for Iowan farmers' willingness to supply three biomass types: corn cobs, corn stover and energy grasses. We find that farm size, previous experience supplying corn to ethanol plants, and land quality attributes each influence the likelihood that farmers would supply cellulosic biomass. These characteristics can suggest suitable groups of farmers that could be targeted for different types of biomass adoption. Farmers report a lack of knowledge about biomass production, yet this analysis finds that those who rank value information sources more highly are more likely to express interest in growing biomass. In particular, farmers interested in all three types of biomass rated Extension programs as the most valuable source of information, highlighting both the need for information dissemination programs and the role of educational institutions in this regard.

The biomass types in our sample are quite differentiated from a production perspective. Although corn cobs and corn stover are residue biomass from corn production, they have significantly different implications for agronomic, logistic and land sustainability concerns. Corn residue biomass and energy grasses require very different production practices. Moreover, unobserved characteristics might lead some individuals to adopt certain types of biomass, which implies a possibility of correlation across choice of biomass types. This analysis finds that farmers' choices among biomass types are significantly correlated; farmers interested in supplying cobs are more likely to show interest in stover as well, whereas, those expressing interest in producing energy grasses are less likely to be interested in cobs or stover. The implication for processors is that it may be difficult to procure multiple feedstocks from a given group of farmers. In addition, factors determining farmers' biomass choice vary across biomass types. Farmers interested in supplying corn stover show more concerns regarding various agronomic impacts, and policy and market uncertainty. For corn cobs, harvesting issues are of primary concern for interested farmers while for energy grasses market uncertainty is the only concern item found to be statistically significant. More of the farm land under no-tillage and CRP/Pasture affect adoption of corn residue biomass negatively, but similar characteristics increase farmers' adoption of energy grasses. Taking steps to alleviate these farmer concerns will aid processors in procuring a consistent supply of biomass.

Table 1: List of Dependent Variables, Farm and Farmer Characteristics in the model

| Table 1: List of Dependent Variables, Farm and Farmer Characteristics in the model | | | Chi-square test of relationship with Interest in Biomass (p value) ^b | Mean difference across interested & not-interested ^b |
|--|--|------|---|---|
| Variable Name | Description of Categories | Mean | | |
| <u>Dependent Variables</u> | | | | |
| Interest in corn cobs | Yes=1, No=0 | 0.25 | | |
| Interest in corn stover | Yes=1, No=0 | 0.25 | | |
| Interest in energy grasses | Yes=1, No=0 | 0.21 | | |
| <u>Independent Variables</u> | | | | |
| <i>Demographics</i> | | | | |
| Age | | 62.0 | | 5.29 *** |
| Education | High School =0 | 0.56 | 0.000 *** | |
| | Some college education =1 | 0.22 | | |
| | College Degree=2 | 0.22 | | |
| Farming Experience | <30 yrs experience = 0 | 0.27 | 0.054 | |
| | >30 yrs experience = 1 | 0.73 | | |
| Off-Farm Income | <50% income from off-farm activities = 0 | 0.18 | 0.809 | |
| | >50% income from off-farm activities = 1 | 0.82 | | |
| Previous exposure to biofuel | Did not sell corn to ethanol plant = 0 | 0.49 | 0.000*** | |
| | Sold corn to ethanol plant=1 | 0.51 | | |
| <i>Farm Characteristics</i> | | | | |
| Farm size | Farm size < 2500 acres = 0 | 0.96 | 0.037** | |
| | Farm size > 2500 acres = 1 | 0.04 | | |
| Farming Plan next Year | Will not farm next year =0 | 0.08 | 0.02 ** | |
| | Will farm next year =1 | 0.91 | | |
| Total farm land in Corn | <50% or more farmland in corn=0 | 0.32 | 0.835 | |
| | >50% or more farmland in corn=1 | 0.68 | | |
| Total farm land in CRP/ Pasture | No land in CRP and Pasture=0 | 0.61 | 0.508 | |
| | < 50% land in CRP and Pasture=1 | 0.35 | | |
| | > 50% land in CRP and Pasture=2 | 0.03 | | |
| Beef cattle | No Beef Cattle=0 | 0.60 | 0.820 | |
| | Some Beef Cattle (< 55)=1 | 0.19 | | |
| | Large Number of Beef Cattle (>55)=2 | 0.21 | | |

Table 1: List of Dependent Variables, Farm and Farmer Characteristics in the model (Continued...)

| Variable Name | Description of Categories | Mean | Mean difference across interested & not-interested ^{a,c} |
|-------------------------------|--|------|---|
| % of total land erodible | 0% of land erodible=0 | 0.26 | 0.96 |
| | < 50% land erodible=1 | 0.43 | |
| | > 50% land erodible=2 | 0.31 | |
| % of total land in no-till | 0% of total land in no-till=0 | 0.51 | 0.793 |
| | <50% of land in no-till=1 | 0.26 | |
| | >50% of land in no-till=2 | 0.23 | |
| <i>Factors^a</i> | | | |
| Knowledge | Knowledge about biomass industry | 2.71 | 0.482*** |
| Policy Sustainability | Concern about govt. policy, farm programs | 4.16 | 0.381*** |
| Contract Relationship | Concern about land ownership, lease terms | 3.63 | 0.728*** |
| Farm Operations | Concern about biomass harvesting | 3.50 | 0.955*** |
| Agronomic Sustainability | Concern about agronomic impacts of biomass | 4.70 | 0.818*** |
| Market Uncertainty | Concern about pricing, distance to markets, contract terms | 4.40 | 1.27*** |
| Information: Public & Private | Importance of public & private information sources | 3.40 | 0.951*** |
| Information: Media | Importance of media information sources | 3.34 | 1.00*** |

^a All items included in factors are measured on a Likert scale ranging from 1 to 7. ^b Asterisks denote significance at the 10 percent (*), 5 percent (**) and 1-percent (***) levels.

Table 2: Interested Farmers' Top Ten Concerns and Rankings of Important Information Sources

| | Stover | | Grass | | Corn Cobs | |
|--|--------|-------------|-------|-------------|-----------|-------------|
| | Rank | Mean Rating | Rank | Mean Rating | Rank | Mean Rating |
| <i>Concern</i> | | | | | | |
| Biomass price volatility | 4 | 5.26 | 5 | 5.44 | 4 | 5.38 |
| Contract opt-out clauses | 8 | 4.99 | 9 | 5.10 | 8 | 5.14 |
| Contract terms (specific deliverables) | - | - | 10 | 5.03 | 9 | 5.10 |
| Contract terms of storage | 9 | 4.93 | - | - | - | - |
| Delays due to biomass harvest | - | - | - | - | 10 | 5.10 |
| Distance to markets | 2 | 5.52 | 2 | 5.65 | 3 | 5.57 |
| In-field transport and compaction | 7 | 5.00 | 8 | 5.13 | 7 | 5.23 |
| Long-term biomass market viability | 3 | 5.44 | 3 | 5.58 | 2 | 5.57 |
| Nutrient loss | 1 | 5.55 | 1 | 5.80 | 1 | 5.73 |
| Percent of biomass removed | 6 | 5.13 | 6 | 5.35 | 5 | 5.36 |
| Residue management | 10 | 4.92 | 7 | 5.31 | - | - |
| Soil erosion issues | 5 | 5.19 | 4 | 5.58 | 6 | 5.33 |
| <i>Information Source</i> | | | | | | |
| Extension | 1 | 4.63 | 1 | 4.54 | 1 | 4.60 |
| Co's offering Biomass Contracts | 2 | 4.49 | 2 | 4.48 | 4 | 4.32 |
| Crop Consultants /Marketing Co's | 8 | 4.08 | 9 | 3.89 | 9 | 3.83 |
| Govt Sources (i.e. USDA or FSA) | 4 | 4.39 | 4 | 4.34 | 3 | 4.38 |
| Cooperatives | 5 | 4.34 | 6 | 4.28 | 5 | 4.16 |
| Legal Counsel | 10 | 3.57 | 10 | 3.51 | 10 | 3.44 |
| Neighbors or Friends | 6 | 4.31 | 5 | 4.28 | 6 | 4.07 |
| Newspapers or magazines | 3 | 4.44 | 3 | 4.45 | 2 | 4.42 |
| TV/Radio | 9 | 3.99 | 8 | 3.99 | 8 | 3.91 |
| Internet | 7 | 4.10 | 7 | 4.02 | 7 | 4.03 |

Table 3. Probit Estimates of Factors Determining Participation in Biomass

| | Model 1 | | Model 2 | |
|--|--------------------|-----------------|---------------------|-----------------|
| | Coefficient | Marginal Effect | Coefficient | Marginal Effect |
| Age | -0.04 (0.12) | -0.02 | -0.158 (0.107) | -0.060 |
| Education: Some College | -0.08 (0.17) | -0.03 | 0.072 (0.143) | 0.028 |
| Education: College Degree | 0.23 (0.15) | 0.09 | 0.208 (0.140) | 0.081 |
| Experience in Farming> 30 years | 0.09 (0.17) | 0.03 | 0.016 (0.152) | 0.006 |
| >50% of Income from Farming | -0.08 (0.17) | -0.03 | 0.007 (0.147) | 0.003 |
| Farm Size>2500acres | 0.61** (0.29) | 0.24** | 0.347 (0.277) | 0.136 |
| Have a Farming plan next year | -0.16 (0.29) | -0.06 | 0.091 (0.267) | 0.034 |
| More than 50% land in Corn | -0.1 (0.18) | -0.04 | -0.030 (0.161) | -0.012 |
| Some land in CRP & Pasture | -0.14 (0.17) | -0.05 | 0.057 (0.148) | 0.022 |
| >50% of land in CRP & Pasture | 0.17 (0.35) | 0.06 | 0.216 (0.332) | 0.084 |
| Number of Beef-cattle < 55 | 0.07 (0.18) | 0.03 | 0.020 (0.155) | 0.008 |
| Number of Beef-cattle>55 | -0.21 (0.16) | -0.08 | -0.293** (0.149) | -0.109 |
| <50% of Land erodible | 0.24 (0.16) | 0.09 | 0.116 (0.144) | 0.044 |
| >50% of Land Erodible | 0.14 (0.20) | 0.05 | 0.065 (0.164) | 0.025 |
| <50% of Land in No-till | -0.18 (0.15) | -0.07 | -0.049 (0.141) | -0.019 |
| >50% of Land in No-till | -0.39** (0.18) | -0.14** | -0.145 (0.152) | -0.055 |
| Previously Sold Corn to Ethanol Plant | 0.37*** (0.13) | 0.14*** | 0.291*** (0.120) | 0.111 |
| Knowledge about Biomass Production and Operation | 0.12** (0.06) | 0.04** | 0.229*** (0.048) | 0.088 |
| Importance of information: Public and Private | 0.24*** (0.06) | 0.09*** | | |
| Importance of information: Media | 0.29*** (0.06) | 0.11*** | | |
| Constant | -2.38*** (0.47) | | -1.021 (0.412) | |

Notes: Asterisks denote significance at the 10 percent (*), 5 percent (**) and 1-percent (***) levels.

Table 4. Multivariate Probit Estimates of factors determining adoption across biomass types

| Variable | Model 1 | | | Model 2 | | |
|---|-------------------|--------------------|--------------------|-------------------|--------------------|-------------------|
| | Grass | Stover | Cobs | Grass | Stover | Cobs |
| Age | -0.12 (0.18) | 0.31 (0.21) | -0.07 (0.19) | -0.29 (0.20) | 0.37* (0.23) | 0.01 (0.20) |
| Education: Some College | -0.23 (0.24) | 0.84*** (0.28) | 0.16 (0.24) | -0.34 (0.26) | 1.03*** (0.31) | 0.27 (0.27) |
| Education: College Degree | -0.17 (0.23) | -0.11 (0.24) | 0.32 (0.23) | -0.29 (0.24) | -0.15 (0.26) | 0.35 (0.26) |
| Experience in Farming > 30 years | 0.15 (0.26) | 0.01 (0.27) | -0.20 (0.26) | 0.23 (0.27) | 0.05 (0.28) | -0.42 (0.27) |
| >50% of Income from Farming | 0.28 (0.25) | -0.47* (0.28) | -0.26 (0.26) | 0.32 (0.27) | -0.62** (0.29) | -0.42 (0.28) |
| Farm Size > 2500 acres | -0.24 (0.37) | 0.29 (0.42) | 1.10*** (0.38) | -0.41 (0.40) | 0.33 (0.43) | 1.24*** (0.41) |
| Have a Farming plan next year | 0.57 (0.52) | 1.22*** (0.47) | -0.21 (0.54) | 0.49 (0.47) | 0.99** (0.48) | -0.17 (0.48) |
| More than 50% land from Corn | 0.03 (0.27) | 0.20 (0.28) | -0.01 (0.26) | 0.19 (0.27) | -0.18 (0.30) | -0.09 (0.28) |
| Some land in CRP & Pasture | 0.57** (0.26) | 0.00 (0.28) | -0.14 (0.25) | 0.45* (0.27) | -0.01 (0.29) | 0.03 (0.29) |
| >50% of land in CRP & Pasture | 1.41** (0.59) | -1.36** (0.65) | -1.47*** (0.67) | 1.45** (0.75) | -1.93** (0.80) | -1.36* (0.76) |
| Beef cattle < 55 | 0.40 (0.26) | 0.24 (0.27) | -0.04 (0.28) | 0.47* (0.28) | 0.1 (0.29) | -0.25 (0.31) |
| Beef cattle > 55 | -0.41* (0.25) | 0.03 (0.26) | 0.09 (0.24) | -0.18 (0.25) | -0.06 (0.27) | 0.08 (0.25) |
| <50% Land erodible | 0.47* (0.24) | -0.13 (0.28) | 0.01 (0.24) | 0.62** (0.27) | -0.26 (0.31) | -0.07 (0.27) |
| >50% Land Erodible | -0.24 (0.30) | -0.63** (0.31) | -0.24 (0.30) | -0.16 (0.33) | -0.67* (0.36) | -0.17 (0.35) |
| <50% Land in No-till | 0.09 (0.23) | -0.74*** (0.26) | -0.21 (0.23) | -0.03 (0.25) | -0.75*** (0.30) | -0.2 (0.27) |
| >50% Land in No-till | 0.50* (0.29) | -0.81*** (0.27) | -0.10 (0.28) | 0.51 (0.32) | -0.83*** (0.29) | -0.09 (0.31) |
| Sold Corn to Ethanol Plant | -0.47** (0.21) | 0.18 (0.22) | -0.18 (0.21) | -0.47** (0.21) | 0.19 (0.23) | -0.09 (0.22) |
| Biomass Knowledge | 0.03 (0.09) | 0.10 (0.10) | 0.16* (0.09) | 0.04 (0.09) | 0.17 (0.12) | 0.14 (0.09) |
| Public and Private Info | 0.02 (0.09) | 0.10 (0.11) | 0.14 (0.10) | -0.08 (0.12) | 0.22* (0.12) | 0.17 (0.12) |
| Media Info | 0.02 (0.08) | 0.12 (0.09) | 0.03 (0.09) | -0.04 (0.10) | 0.1 (0.10) | 0 (0.10) |
| Concern: Policy Sustainability | | | | 0.13 (0.10) | -0.22* (0.11) | 0.01 (0.10) |
| Concern: Farm Operation | | | | -0.12 (0.11) | 0.06 (0.11) | 0.45*** (0.11) |
| Concern: Agronomic Sustainability | | | | 0.08 (0.11) | -0.47*** (0.14) | -0.01 (0.13) |
| Concern: Market Uncertainty | | | | 0.29** (0.12) | 0.25** (0.13) | -0.19 (0.13) |
| Concern: Contract Relationship | | | | -0.09 (0.09) | 0.06 (0.09) | -0.13 (0.09) |
| Constant | -0.88 (0.86) | -1.53* (0.93) | 0.04 (0.88) | -1.91** (0.89) | 0.14 (1.09) | -0.04 (0.90) |
| Number of observations | 209 | | | | | |
| log pseudo likelihood / Wald $\chi^2(75)$ | -1599.5 / 247.73 | | | | | |

Notes: Estimates from a multivariate probit model with simulated maximum likelihood (500 draws). Standard errors in parentheses.

Table 5: Correlation Structure Across Biomass Crops

| Correlation Between: | Coefficient | Std. Err. | t-test |
|----------------------|-------------|-----------|--------|
| Cob and Stover | 0.490 | 0.112 | 4.360 |
| Cob and Grass | -0.431 | 0.108 | -3.990 |
| Stover and Grass | -0.312 | 0.129 | -2.420 |

Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{32} = 0$: $\chi^2(3) = 2553.28$; Prob $> \chi^2 = 0.000$

References

- Abdulai, A., Huffman, W.E. (2005). “The diffusion of new agricultural technologies: The case of crossbreeding technology in Tanzania”. *American Journal of Agricultural Economics* 87, 645–659.
- Altman, I., Bergtold, J., Sanders, D., and Johnson, T., (2011), “Producer Willingness to Supply Biomass: the Effects of Price and Producer Characteristics”, Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Corpus Christi, TX, February 5-8, 2011
- Bergtold, J., Jason Fewell, and Jeffery Williams, (2011) “Farmers’ Willingness to Grow Sweet Sorghum as a Cellulosic Bioenergy Crop: A Stated Choice Approach”, Selected Paper prepared for presentation at the Agricultural & Applied Economics Association’s 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011.
- Cappellari, L., Jenkins. S. P., 2003. Multivariate probit regression using simulated maximum likelihood. *The Stata Journal* 3, 278–94.
- Coyle, W.T. *Next-Generation Biofuels: Near-term Challenges and Implications for Agriculture*. Washington DC: U.S. Department of Agriculture, Economic Research Service, Outlook Report. BIO-01-01, May, 2010.
- Fernandez-Cornejo, J., C. Hendricks, and A. Mishra. “Technology Adoption and Off-Farm Household Income: The Case of Herbicide Tolerant Soybeans.” *Journal of Agricultural and Applied Economics* 37(2005):549–63
- Foster, A.D., and M.R. Rosenzweig (1995), “Learning by doing and learning from others: Human capital and technical change in agriculture”, *Journal of Political Economy* 103:1176-1209.
- Gillespie, J.M., C.G. Davis, and N.C. Rahelizatovo. “Factors Influencing the Adoption of Breeding Technologies in U.S. Hog Production.” *Journal of Agricultural and Applied Economics* 36(2004):35–47.
- Greene, W.H., 2008. *Econometric Analysis*, 6th Edition. Prentice Hall, Upper Saddle River, NJ.
- Huffman, W.E., and M.D. Lange, “Off-farm work decisions of husbands and wives: joint decision making”, *Review of Economics and Statistics*, 71(1989):471-480
- Huffman, W.E. (2001). “Human capital: Education and agriculture”. In: Gardner, B., Rausser, G. (Eds.), *Handbook of Agricultural Economics*. Elsevier Science, Amsterdam, pp. 334–381.
- Jensen, K., C.D. Clark, P. Ellis, B. English, J. Menard, M. Walsh, and D.T. Ugarte. 2007. “Farmer willingness to grow switchgrass for energy production”. *Biomass and Bioenergy*, 31: 773-781.
- Lin, J.Y. (1991), “Education and Innovation Adoption in Agriculture: Evidence from Hybrid Rice in China”, *American Journal of Agricultural Economics* 73:713-723.
- Marenja, P.P., and C.B. Barrett. (2007), “Household-Level Determinants of Adoption of Improved Natural Resources Management Practices among Smallholder Farmers in Western Kenya”. *Food Policy* 32: 515–36.
- Martens. B.J., Crum, M.R., and Poist, R. F., (2011) “Examining Antecedents to Supply Chain Security Effectiveness: An Exploratory Study”, *Journal of Business Logistics*, 32(2): 153–166.
- Paulrud, S., & Laitila, T. (2010). Farmers' attitudes about growing energy crops: A choice experiment approach. *Biomass and Bioenergy*, xxx, 1-10.
- Smith, J.D., Schulman, C., Current, D., and K. William Easter (2011), “Willingness of Agricultural Landowners to Supply Perennial Energy Crops”, Selected Paper prepared for presentation at the Agricultural & Applied

Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24- 26, 2011.

Changing Agricultural Sector," in G.L. Gardner and G.C. Rausser, Eds., *Handbook of Agricultural Economics* Vol. 1A, New York, NY: Elsevier, 2001, pp. 155- 206.

Train, K. E., 2003. *Discrete Choice Models with Simulation*. Cambridge: Cambridge University Press.

Tyndall JC, Berg E, Colletti JP (2011) Corn Stover as a Dedicated Feedstock in Iowa's Bio-economy: An Iowa Farmer Survey. *Biomass and Bioenergy*. 35:1485-1495.

Velandia, M., Rejesus, R. M., Knight, T. O., and Sherrick, B.J. (2009), "Factors Affecting Farmers' Utilization of Agricultural Risk Management Tools: The Case of Crop Insurance, Forward Contracting, and Spreading Sales", *Journal of Agricultural and Applied Economics*, 41,1:107–123

Wozniak, G.D. (1984) "The adoption of interrelated innovation: A Human Capital Approach," *Review of Economics and statistics*, 66:70-79.

Yang, Dennis T. "Education in Production: Measuring Labor Quality and Management," *Am. J. Agr. Econ.* 79(Aug 1997):764-77