Organizational Preferences and Producer Characteristics in Biomass Supply Chains

Ira J. Altman, Thomas G. Johnson, and Wanki Moon

Organizational costs in biomass transactions could be a key barrier to commercial development of cellulosic-based industries and will influence the organizational choices of biomass producers and bioenergy processors. Understanding biomass producer characteristics and preferences will be important to the future development of renewable industries like cellulosic ethanol. This paper examines survey data that identify assets biomass producers currently own, services they are willing to provide, and their preferences for selling mechanisms. A transaction cost model is used to analyze producers’ organizational preferences in a multinomial logit empirical framework.

Key Words: biomass supply organization, producer characteristics, producer preferences

To date, little research has been conducted on many aspects of developing biomass industries, such as cellulosic ethanol. Generally, energy conversion processes have yet to be developed that are cost competitive with conventional technologies. Currently, cellulosic ethanol cannot be produced at a commercial level. Even after technology improvement occurs, industry development from an organizational standpoint is not well understood. It is the latter point this paper seeks to address.

Regardless of the resulting technology from technological improvement, the biomass must be traded between grower and energy processor, unless these stages are integrated under unified ownership. How the biomass is traded directly affects the underlying cost competitiveness of the new technology. In a recent survey of the current biopower industry (a more mature thermal conversion industry), organizational costs were found to make up 15% of total costs (Altman and Johnson, 2008). Thus, in addition to traditional production costs (e.g., energy conversion and biomass feedstock costs), organizational costs will be significant.

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There are several ways to examine the organization of a potential bioenergy industry like cellulosic ethanol. Current industry structure of similar industries, such as biopower, could be examined. However, this approach has been taken elsewhere (Altman, Klein, and Johnson, 2007; Altman and Johnson, 2008). The procurement strategies and contracting efforts of potential cellulosic ethanol processors on the cusp of commercialization could also be taken into account (Altman, Sanders, and Boessen, 2007). On the other side of the transaction is the biomass producer.

In this paper, we examine the preferences and characteristics of potential biomass suppliers with the aim of understanding how future biomass-to-energy industries could develop. These data are based on a regional survey of mid-Missouri biomass producers, including those who produce corn, cereal crops, and hay in the target population. Specifically, we address how biomass producers prefer to structure potential biomass exchanges, what assets they currently own that may support the industry, and what potential services they might be willing to supply. Our findings could be useful to industry developers attempting to establish new biomass-based industries.

**Literature Review**

It is beyond the scope of this paper to review the full biomass and bioenergy literature. Yet, to provide some context and justify the approach taken, a brief literature review is presented. Generally, the biomass and bioenergy literature is focused on more technical issues, such as the environmental effects of bioenergy and technology development issues, rather than the organization of future bioenergy industries.

There is some coverage of the organizational challenges. Klass (1998) reports that shipping and storage strategies have been counter to industry developer advice. Van Loo and Koppejan (2003) observe that organizational changes like developing biomass content standards could solve technical challenges such as fouling of biopower systems. These examples indirectly document some potential organizational challenges while focusing on traditional biomass and bioenergy topics.

More directly addressing the choice of organizational form, Overend (1993) considers potential exchange mechanisms bioenergy producers and biomass suppliers could utilize. Overall, he concludes that spot markets should be developed where independent biomass producers sell their products to independent bioenergy processors. On the choice of organizational form, Downing, Volk, and Schmidt (2005) recommend vertical integration and specifically biomass producer cooperatives to organize the biomass exchange. Under this unified ownership structure, the biomass producers would vertically integrate into the bioenergy production stage. Klass (1998) goes one step further to recommend horizontal and vertical integration. Not only should there be unified ownership along the supply chain between biomass production and bioenergy production,
but producers should integrate other forms of bioenergy production—for example, producing biopower from the lignin co-product from cellulosic ethanol.

Altman and Johnson (2008) found that the current biopower industry is highly vertically integrated. Approximately 75% of the biopower industry is vertically integrated between biomass production and biopower production stages. Thus, if future bioenergy industries are anything like biopower, they could be highly vertically integrated. According to Altman, Sanders, and Boessen (2007), future cellulosic ethanol processors are considering hybrid forms of organization characterized by formal contracts. Short-term and long-term contracts are also alternative methods of exchange compared to spot markets and vertical integration.

**Methodology**

Our theoretical model is generally based on Williamson (1985, 1991, 1996). This model is unique in economics because of the focus on the choice of organizational form. The basic foundation of Williamson’s transaction cost economics approach is to model the choice of organizational form as some function of the characteristics of the transaction. Characteristics of assets that support this transaction are identified as the principal explanatory variables. The main assumption of the theory is that firms choose the least-cost organizational form to conduct the transaction.

The key flow of causation in transaction cost economics is that characteristics of the assets which support the exchange cause different levels of transaction costs for potential organizational forms. Asset specificity, or the degree of redeployability of an asset, is identified as a central transaction cost variable (Williamson, 1985). If an asset is easily redeployable, the low-cost organizational form is expected to be spot markets. In contrast, if an asset is not redeployable, alternative organizational forms like contracting and vertical organization are expected to protect against opportunism. This theoretical relationship is depicted in figure 1.

In figure 1, as the level of asset specificity \( k \) increases, the low-cost organizational form changes from the market \( M \) to hybrid/contracting \( X \) to hierarchy or vertical organization \( H \). Each form of organization has different organizational or governance costs associated with it. As the level of asset specificity changes, the governance cost changes for all organizational forms; however, each organizational form possesses different capabilities to address opportunism. At low levels of asset specificity, the market is more efficient since it has lower administrative costs and the threat of opportunism is low.

In this application to potential biomass exchanges, important assets include the various equipment necessary for biomass collection, transportation, and storage. The degree of asset specificity is measured simply as the existence of the equipment in the producer’s current operation. Hence, if the producer has already invested in the necessary equipment for hay, straw, or stover harvest and delivery, this is assumed to be an indication of high redeployability (low asset specificity).
If a producer already owns harvest and transportation equipment, it is assumed this equipment would be redeployable to its current use, if the bioenergy industry did not develop. Such an observation is expected to be associated with a preference for spot markets or short-term contracts. Otherwise, if a producer does not already own the equipment and would need to purchase such equipment to take part in the new biomass industry, then higher asset specificity would be indicated—expected to be associated with preferences for vertical integration or long-term contracting.

In addition to asset characteristic variables, producer demographic characteristics are added in an ad hoc fashion. Thus, several of the explanatory variables are included in an inductive manner and do not have expected signs.

Data were collected in a mail survey conducted by the University of Missouri-Columbia Community Policy Analysis Center and the Southern Illinois University-Carbondale Department of Agribusiness Economics. The survey was mailed to 2,500 producers based on a random sample from a list provided by the USDA’s National Agricultural Statistics Service. The targeted population consisted of those producers in mid-Missouri who produce corn, cereals, or hay. From this population, 590 producers responded with returned surveys and 10 responded over the phone, representing a 24% response rate. The original sample of 600 included all producers who responded to the survey. However, based on a list of reasonable explanations (such as retirement and death), several individuals were unable to complete the survey. Consequently, 40 survey respondents were dropped from the sample due to lack of usable information, and the following analysis is based on a final total of 560 responses.
The survey consisted of four sections: (a) production and availability of biomass; (b) producer’s current assets and activities relevant to biomass harvest, transportation, and storage; (c) marketing preference questions; and (d) questions related to demographics. Overall, producers were asked to respond to 24 questions.

In the first section, production and availability, there were five questions. Producers were asked basic acreage questions, their general willingness to supply, and whether they would be interested in supplying half their biomass every year or supplying all biomass every other year. This is a contracting option proposed by the Iogen Corporation as it develops its cellulosic ethanol technology (Altman, Sanders, and Boessen, 2007).

The second section, producer’s current assets and activities, contained questions 6–14. Here, producers were asked whether they owned round or square balers, a tractor to pull a baler, whether they had baling experience, and whether they had a truck and trailer. This survey section also sought to identify the activities or services (windrowing, baling and stacking, storing, and delivery) the producers might be willing to supply.

The third section, marketing preference, included questions 15–20. Question 15 was a price sensitivity question, relating price to the producer’s willingness to supply biomass. Question 16 asked whether farmers would be interested in two different types of contract provisions—tying the price of their biomass to the price of oil, and long-term contracts. Questions 17 and 18 were coordination questions involving baling of biomass. Question 17 asked producers whether they would allow properly trained custom balers onto their property, while question 18 asked producers whether they would consider sharing a baler (owned by the processor) with other area producers. Question 19 is the key organizational choice question. Producers were asked to rate their preference for four exchange or supply organization mechanisms—spot market, short-term contract, long-term contract, and marketing cooperative. Question 20, the final marketing question, asked producers whether they would be interested in investing in a biomass processing facility.

The final section of the biomass producer survey included demographic questions that collected background information on the respondents. These included age, income, and land ownership questions. For regression analysis, variables were selected from these questions, guided by transaction cost theory and the correlation coefficients and category of the variable.

After presenting summary statistics, the main empirical model is based on a choice model, a multinomial logit (m-logit). In the m-logit, multiple alternatives of the dependent variable can be regressed against continuous and noncontinuous explanatory variables. The dependent variable in this application is the indicated preference for the choice of organizational form by the individual producer. In this model, the choice of organizational form includes four alternatives: spot market, short-term contract, long-term contract, or vertical integration (a producer cooperative). The choice of organizational form is regressed against producer characteristics such as age, and characteristics of the operation such as assets owned, and scale (seeded acres).
In general, mathematical notation for the empirical model can be described as producer \( i \) facing \( J \) unordered choices. The response probability that producer \( i \) prefers alternative \( j \) \( (P_{ij}) \) is modeled as:

\[
P_{ij} = P(Y_i = j \mid X) = \frac{\exp(\beta_j X_i)}{1 + \sum_{j=1}^{J} \exp(\beta_j X_i)},
\]

where \( P_{ij} \) is the probability that \( Y_i = j \), or that producer \( i \) prefers category \( j \) organizational form given the explanatory variable vector \( X \); \( \beta_j \) is the estimated parameter vector; and \( X_i \) is the observed characteristic vector of producer \( i \).

In specific form, there are four choices of organizational form; thus, \( j = 0, 1, 2, 3 \), and \( i = 341 \), the number of completed surveys that had usable data. The log-likelihood function for this multinomial logit can be expressed as:

\[
\ln L = \sum_{i=1}^{341} \sum_{j=0}^{3} d_{ij} \ln(P_{ij}),
\]

where \( d_{ij} = 1 \) if firm \( i \) chooses organizational form \( j \). Explanatory variables based on equipment ownership are binary variables, acreage is continuous, and variables like age are categorical groups.

In multinomial logit models, the \( p \)-values are valid, making significance tests meaningful, but the signs and magnitudes of the coefficients have no direct interpretation. The partial marginal effects for continuous variables can be calculated as:

\[
\frac{\partial P_{ij}}{\partial X_k} = P_{ij} \left\{ \beta_{jk} - \left[ \sum_{h=1}^{J} \beta_{hk} \exp(X\beta_h) \right] / g(X, \beta) \right\},
\]

where \( \beta_{hk} \) is the \( k \)th element of \( \beta_h \),

\[
g(X, \beta) = 1 + \sum_{h=1}^{J} \exp(X\beta_h),
\]

and the marginal effects of limited explanatory variables are calculated as the difference between probabilities (Wooldridge, 2002).

With multinomial probits and logits, an econometric issue can arise, denoted the “irrelevance of independent alternatives.” In m-logits and m-probits, alternatives are assumed to be independent and the existence of one alternative should not influence the probability of observing other alternatives. This could be an issue in the current application if spot markets and short-term contracts, or short-term contracts and long-term contracts, are found to be interrelated.
Results

The objectives of this paper were to identify the assets and services producers have or are willing to provide in order to support a bioenergy industry based on row crop waste and surplus hay, while investigating their preferences on how to organize the industry. In terms of the assets and services, this area was found to be well equipped—89% of producers indicated they have a tractor capable of operating a round baler, while 61% stated they have a round baler. Fewer producers (10%) reported having a square baler. The percentage of producers with baling experience was 86%, and two-thirds (66%) owned a truck and trailer capable of hauling bales. Table 1 presents summary statistics for producer assets.

With respect to the services the producers were willing to provide, the results were not as high (table 2). Results indicate 34% to 44% were willing to render the various services of providing their biomass in a windrow, baling and stacking in the field, long-term storage, or delivery.

Overall, the general willingness to supply biomass was in the range of 21% to 38% (table 3). Producers were asked, “Under the right conditions, such as price and agronomic factors, what is the maximum portion of your annual cereal straw, corn stover, and hay that you could make available for market?”

The preferred organizational form analysis first examines the main dependent variable, the choice of organizational form. The data are then examined with the m-logit procedure. The summary statistics on the dependent variable are presented in table 4, followed by the m-logit regression results reported in table 5.

The dependent variable for this analysis is the preference of organizational form (survey question 19). As observed in table 4, approximately 38% of respondents preferred spot markets, 22% producer cooperatives, and 16% each for short-term and long-term contracts. Another 6.8% listed multiple top-choice preferred organizational forms.

Taking into account second choices, spot markets were among the top two choices for 65% of producers, while cooperatives were a top two choice of 52% of producers. Short-term contracts were chosen as a top two choice by 51% of producers, but long-term contracts were a top two choice of only 37%.

Based on these rankings, producers in this area prefer spot markets. Once second choices are taken into account, cooperatives are followed closely by short-term contracts. Long-term contracts would appear to be the least preferred organizational form. From this evidence, short-term relationships in the form of spot markets and short-term contracts could be efficient exchange mechanisms. This finding would also be supported by the high percentage of producers who already own baling equipment.

For regression analysis, six explanatory variables were selected from a potential of 21 based on correlation coefficients and category of the variable. For example, in the category of crop acreage, cereal acreage was found to have a correlation
Table 1. Summary Statistics for Producer Assets

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Observations</th>
<th>Frequency of Affirmative Response</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round Baler Ownership</td>
<td>551</td>
<td>340</td>
<td>61.71</td>
</tr>
<tr>
<td>Tractor Ownership</td>
<td>548</td>
<td>493</td>
<td>89.96</td>
</tr>
<tr>
<td>Square Baler Ownership</td>
<td>545</td>
<td>59</td>
<td>10.83</td>
</tr>
<tr>
<td>Baling Experience</td>
<td>545</td>
<td>471</td>
<td>86.42</td>
</tr>
<tr>
<td>Truck and Trailer Ownership</td>
<td>547</td>
<td>362</td>
<td>66.18</td>
</tr>
</tbody>
</table>

Table 2. Summary Statistics for Services

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Observations</th>
<th>Frequency of Affirmative Response</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windrowing</td>
<td>558</td>
<td>187</td>
<td>33.51</td>
</tr>
<tr>
<td>Baling</td>
<td>558</td>
<td>244</td>
<td>43.73</td>
</tr>
<tr>
<td>Storing</td>
<td>558</td>
<td>201</td>
<td>36.02</td>
</tr>
<tr>
<td>Delivering</td>
<td>558</td>
<td>212</td>
<td>37.99</td>
</tr>
</tbody>
</table>

Table 3. Summary Statistics for General Willingness to Supply

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Observations</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw</td>
<td>416</td>
<td>38.09</td>
<td>41.3592</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Stover</td>
<td>400</td>
<td>32.52</td>
<td>39.87090</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Hay</td>
<td>431</td>
<td>21.45</td>
<td>33.35961</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 4. Summary Statistics for Preference of Organizational Form (survey question 19)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency of Response</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot Market</td>
<td>155</td>
<td>37.99</td>
</tr>
<tr>
<td>Short-Term Contract</td>
<td>69</td>
<td>16.91</td>
</tr>
<tr>
<td>Long-Term Contract</td>
<td>66</td>
<td>16.18</td>
</tr>
<tr>
<td>Producer Cooperative</td>
<td>90</td>
<td>22.06</td>
</tr>
<tr>
<td>Multiple Top Choice</td>
<td>28</td>
<td>6.86</td>
</tr>
<tr>
<td>Total</td>
<td>408</td>
<td>100%</td>
</tr>
</tbody>
</table>
coefficient of 0.036, corn acreage 0.032, and hay 0.029. Therefore, to avoid multicollinearity, cereal acreage was chosen from this category. The six variables selected were cereal acreage, tractor ownership, square baler ownership, whether producers currently shredded their corn stocks, willingness to supply biomass in a windrow, and age.

The dependent variable for the regression analysis is the top choice of organizational form. In our sample, 341 producers identified a clear top choice, while the remaining respondents either did not answer this question or identified multiple top choices. Of these 341 respondents, 155 (38%) selected spot markets as their top choice, 69 (17%) chose short-term contracts, 66 (16%) long-term contracts, and 90 (22%) producer cooperatives (table 4).

As observed from the m-logit regression results reported in table 5, few explanatory variables are statistically significant in explaining the difference between spot markets and the other choices of organizational forms. Out of 18 potential variables, only three were statistically significant. Statistical significance is determined by the $p$-value. Variables with $p$-values less than 0.10 are statistically significant at the 90% confidence level.

When short-term contracts are the alternative to spot markets, no variables are statistically significant. One variable is statistically significant in explaining the difference between spot markets and long-term contracts—Cereal Acres has a $p$-value of 0.009. Two variables are found to be statistically significant when a producer cooperative is the alternative (Square Baler Ownership and Tractor Ownership). The stronger statistical results when long-term contracts and cooperatives are compared could be due to the fact that long-term contracts and cooperatives have more differences than spot markets and short-term contracts.

Statistical tests, however, reveal that the alternatives are indeed independent. In conducting the Hausman test and Small-Hsiao test for the independence of irrelevant alternatives, neither test rejects the null hypothesis that the assumption of the independence of irrelevant alternative holds. In two subsequent models, spot markets and short-term contracts are combined, and short-term contracts and long-term contracts are combined as alternatives. Neither model increased the statistical significances of explanatory variables. Table 6 presents the results from the Small-Hsiao test.

There are other possible explanations for why variables are not significant. In this analysis, we do not observe the actual choice of organizational form or characteristics of the transaction because a transaction has not yet occurred. Rather, we know the producers’ preferred choice of organizational form and preferred characteristics of the biomass market if an industry is established. Observing actual transactions could lead to more statistically significant results. Missing explanatory variables such as producers’ previous experience in biomass markets or with other crops might also account for insignificant variables.
Table 5. M-Logit Regression Results (dependent variable = Preferred Organization)

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Coefficient</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-Term Contract Alternative:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.013</td>
<td>0.958</td>
</tr>
<tr>
<td>Windrow</td>
<td>0.379</td>
<td>0.216</td>
</tr>
<tr>
<td>Corn Stocks Shredded</td>
<td>0.045</td>
<td>0.899</td>
</tr>
<tr>
<td>Square Baler Ownership</td>
<td>0.230</td>
<td>0.673</td>
</tr>
<tr>
<td>Tractor Ownership</td>
<td>0.757</td>
<td>0.254</td>
</tr>
<tr>
<td>Cereal Acres</td>
<td>0.0008</td>
<td>0.529</td>
</tr>
<tr>
<td><strong>Long-Term Contract Alternative:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.443</td>
<td>0.132</td>
</tr>
<tr>
<td>Windrow</td>
<td>0.303</td>
<td>0.352</td>
</tr>
<tr>
<td>Corn Stocks Shredded</td>
<td>0.555</td>
<td>0.118</td>
</tr>
<tr>
<td>Square Baler Ownership</td>
<td>0.184</td>
<td>0.745</td>
</tr>
<tr>
<td>Tractor Ownership</td>
<td>1.036</td>
<td>0.194</td>
</tr>
<tr>
<td>Cereal Acres</td>
<td>0.002</td>
<td>0.009*</td>
</tr>
<tr>
<td><strong>Producer Cooperative Alternative:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.347</td>
<td>0.183</td>
</tr>
<tr>
<td>Windrow</td>
<td>0.026</td>
<td>0.929</td>
</tr>
<tr>
<td>Corn Stocks Shredded</td>
<td>0.204</td>
<td>0.537</td>
</tr>
<tr>
<td>Square Baler Ownership</td>
<td>0.760</td>
<td>0.099*</td>
</tr>
<tr>
<td>Tractor Ownership</td>
<td>1.468</td>
<td>0.060*</td>
</tr>
<tr>
<td>Cereal Acres</td>
<td>−0.0007</td>
<td>0.665</td>
</tr>
</tbody>
</table>

Notes: An asterisk (*) denotes statistical significance at least at the 90% confidence level. Top choice = Spot Market is the base outcome.

Table 6. Small-Hsiao Tests of IIA Assumption (N = 341)

<table>
<thead>
<tr>
<th>Omitted</th>
<th>ln(L(Full))</th>
<th>ln(L(Omit))</th>
<th>χ²</th>
<th>D.F.</th>
<th>p &gt; χ²</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>−127.573</td>
<td>−117.773</td>
<td>19.600</td>
<td>14</td>
<td>0.143</td>
<td>for H₀</td>
</tr>
<tr>
<td>2</td>
<td>−153.572</td>
<td>−146.307</td>
<td>14.529</td>
<td>14</td>
<td>0.411</td>
<td>for H₀</td>
</tr>
<tr>
<td>3</td>
<td>−118.617</td>
<td>−108.719</td>
<td>19.796</td>
<td>14</td>
<td>0.137</td>
<td>for H₀</td>
</tr>
</tbody>
</table>

Note: H₀: Odds (Outcome J vs. Outcome K) are independent of other alternatives.

Conclusion

This study provides some evidence that producers in our sample prefer spot markets or short-term relationships over other exchange mechanisms in the choice of organizational form. This contradicts what has taken place in the biopower industry where vertical integration has occurred in three-quarters of that industry.
Likewise, early attempts to organize the cellulosic ethanol industry have resulted in technology developers, such as Iogen, signing long-term contracts with producers.

Econometric models do not reveal statistically significant patterns explaining why producers express these organizational preferences. Most variables are not statistically significant; the organizational preferences are unrelated to asset or demographic variables. Addressing econometric issues such as the independence of irrelevant alternatives did not reverse statistical significance in this sample.

Results for assets and services that producers are willing to provide should be compared to results from other areas. Overall, producers in our study area of mid-Missouri seemed to have the assets needed to support the industry. The services required to support the industry were less certain. Researchers expanding on this area of study should also work with industry developers to advance other indicators, variables, and additional important biomass producers’ preferences and characteristics.

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