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Scale and Transaction Costs in the U.S. Biopower Industry

Ira J. Altman* Peter G. Klein† Thomas G. Johnson‡

*Southern Illinois University – Carbondale, ialtman@siu.edu
†University of Missouri – Columbia, kleinp@missouri.edu
‡University of Missouri – Columbia, JohnsonTG@missouri.edu

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Abstract

With increasing interest in renewable energy from agriculture, including biopower and cellulose ethanol, there is a need for better understanding of the economic organization of this emerging industry. Study of the organization of the biopower industry represents an under-researched area and a new application of transaction cost theory to an emerging industry.

Refinement of the theory can also result from challenging applications. This article provides an application of transaction cost economics to the existing United States biopower industry while challenging the empirical convention of excluding production cost variables from transaction cost analysis. Utilizing survey data from 53 biopower generators we study the relationship between physical asset specificity, site specificity, and scale in explaining firms' decisions to procure inputs internally, externally, or to use both methods. Consistent with transaction cost theory, both site specificity and scale are good predictors of organizational form. Given this evidence, this article reconsiders the impact of scale and transaction costs on the choice of organizational from.

KEYWORDS: organizational choice, transaction costs, scale, biopower industry

1. Introduction

Recent years have seen a growing interest in the development of renewable energy industries for environmental benefits, rural growth and development, and energy security. While the technical aspects of biopower production have been extensively studied (van Loo and Koppejan, 2003, Brown, 2003 and Klass, 1998), less is known about the economic organization and governance of the biopower industry. How should agro-biopower facilities procure their fuel: from the spot market, through contracts with independent biomass producers, by producing the biomass themselves, or by some combination of external and internal procurement? What are the characteristics of purchase and supply contracts in biopower? Who will be the major players in biopower, existing power companies that convert to biopower production or new entrants? Can incumbents operate multiple facilities, some using biomass and others using non-renewable fuels, or will firms tend to specialize in one technology or the other?

To begin addressing some of these questions we focus on a fundamental alternative facing any firm (Coase, 1937), the "make-or-buy decision." Using the transaction cost framework developed by Williamson (1985, 1996), we examine the vertical structure of the current biopower industry with survey data from 53 US biopower producers. Our analysis focuses not only on asset specificity—the main variable of interest in the empirical transaction cost literature (Klein, 2005)—but also on the technology of production and the corresponding economies of scale. While transaction cost economics (TCE) allows production costs to affect the choice of organizational form—indeed, in the integrated Riordan and Williamson (1985) model, production costs and transaction costs are determined jointly—in practice, most of the empirical literature has taken production costs as given and focused on transaction costs. Or, as Langlois and Foss (1999) describe the problem, the TCE literature tends to assume that knowledge about production is easily and costlessly acquired, while market transactions are fraught with hazards brought about by information and agency costs.

Our results suggest that physical asset specificity is not a statistically significant determinant of vertical integration in biopower. Instead, characteristics of the production process, such as scale of the biopower facility, appear to be more important. Moreover, several firms in our sample both supply their own biomass and purchase biomass from independent suppliers, a practice difficult to explain within the usual "make-or-buy" framework of TCE. Of course, our results may be specific to biopower and may not generalize to vertical relationships in other industries. Nonetheless, the findings suggest that the standard TCE framework may require modification to account for complex arrangements such as simultaneous internal and external procurement.[1] In this article we focus on scale in empirical analysis as a TCE variable and offer some evidence to support the hypothesized relationship in TCE between the choice of organizational form and scale.

2. Literature

2.1 Biomass and bioenergy

Biomass and bioenergy researchers have rarely considered organizational issues or applied an adequate organizational theory to this nascent industry.[2] Some authors indirectly discuss organization when considering non-technical barriers in biomass production. Roos et al. (1999) and Costello and Finnell (1998) develop broad-based frameworks for considering organizational issues. They identify critical factors in the choice of organization including the degree of integration, the scale of operation, the degree of competition, the institutional environment such as national and local policy including public infrastructure availability, and the perceptual beliefs of key actors. Rösch and Kaltsehmitt (1999) identify similar topics adding insurance issues and efficiency of knowledge and information flows along the supply chain. Lunnan (1997) takes an in-depth view of the institutional environment created by bioenergy policy, and especially how bioenergy policy and more general agricultural policy can be coordinated.

More closely related to the organization of exchange Downing et al. (2005) describe the role of agricultural cooperatives in research, financing, and exchange mechanisms in the agro-bioenergy industry. They do not, however, compare cooperatives to contracting and spot market procurement as suggested by organizational theory.

Overend (1993) describes the main features of a general biomass industry and recommends optimal exchange structures. Contrary to Downing et al., on the choice of organizational form, Overend recommends spot markets and short term contracting. Further, many biopower firms currently rely on captive supplies and

[1] Du, Lu, and Tao (2006) and He and Nickerson (2006) also study "bi-sourcing," the simultaneous reliance on both in-house and external procurement. Du, Lu, and Tao (2006) use bargaining theory to show how simultaneously making and buying can mitigate the holdup problem associated with exclusive reliance on an external supplier. He and Nickerson (2006) tell a more nuanced story in which "the interaction of efficiency, appropriability and competition concerns" explains simultaneous bi-sourcing.

[2] For example, Klass (1998) identifies storage and shipping strategies for wood biomass and van Loo and Koppejan (2003) discuss how organization has solved technical issues in some cases in Europe.

integrated systems for fuel procurement. However, as we discuss below, in our sample only 3 of 53 firms procure fuel on the spot market, with the remainder about evenly split between internal procurement and external procurement via long-term contract. Why do so few firms use the spot market, and what explains the choice between vertical integration and long-term contracting? We turn to the theoretical framework of TCE for answers.[3]

2.2 Transaction cost economics

Central to TCE is the discriminating alignment hypothesis, which states that the choice of organizational form depends on the characteristics of the transaction (Williamson 1996, p.371). Economic agents behave in such a way that transactions, which vary in degrees of asset specificity, uncertainty and frequency, are aligned with organizational forms, which can be considered efficient if no feasible alternative can be implemented with net gains. The central problem in Williamson's framework is the bilateral dependency that results from an increase in asset specificity or relationship-specific investment. Asset specificity describes the condition under the value of assets depends on a particular exchange relationship. Parties that invest in relationship-specific assets risk losing some of the rents accruing to those assets if their trading partners take advantage of unanticipated changes in circumstances to renegotiate the terms of the exchange relationship in their favor. To protect those investments, parties will craft governance structures such as detailed long-term contracts with adequate adjustment provisions or vertical integration (internal procurement).

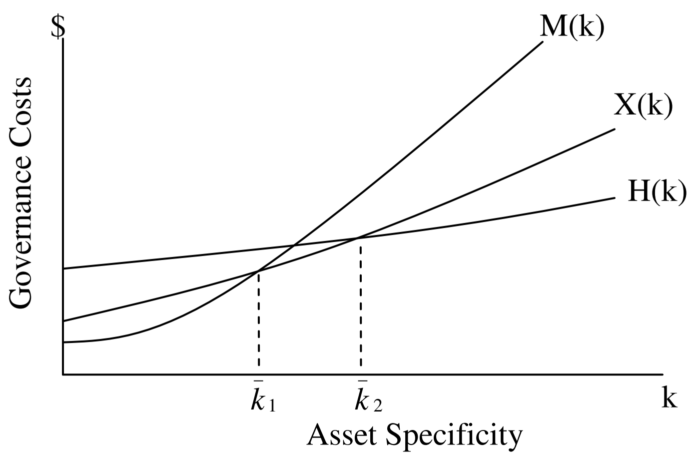
Riordan and Williamson's (1985) formulation seeks to integrate TCE with neoclassical production theory. Extending the basic TCE model to include production costs, Williamson (1985) and Riordan and Williamson (1985) argue that markets have a production cost advantage over internal organization because the market can realize economies of scale and scope from aggregation of demand (Williamson 1985, p.92). Internal organization, since it only supplies the firm itself, cannot achieve the same benefits of scale achieved by a market. Thus the

[3] Choinière (2002) presents a formal model of the future agro-biopower industry. The model analyzes the farmer's investment decision in the presence of learning-by-doing and concludes that underinvestment by farmers and power generators could occur. The choice of organizational form could address the underinvestment problem if the form chosen adequately protects both trading partner's investments. We broaden the nature of the problem considered beyond the investment decision to focus on the choice of organizational form in the current biopower industry.

greater the potential for realizing external economies of scale, the less likely internal organization will be observed.[4]

This issue can be depicted as a cost-minimization problem, as follows. Market organization and internal organization are assumed to have different transaction costs.[5] When asset specificity is low, market transaction costs are lower than the costs of internal organization (such as administration costs), but as asset specificity rises, the costs of market transactions increase more rapidly than the costs of internal organization, such that at some threshold level of asset specificity, internal procurement is the least costly alternative.

These implications are also explained graphically in Williamson (1991) where M denotes market governance costs, H hierarchy (or internal organization) and X is used to indicate governance costs of hybrid forms, such as long-term contracting. Adding hybrid simply implies: $M(0) < X(0) < H(0)$ and $M' > X' > H' > 0$. Figure 1 demonstrates Williamson's 1991 model.



Source: Adapted from Williamson, 1991

Figure 1: Governance costs as a function of asset specificity

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[4] The idea is that the firms minimize total costs (production and transaction costs) in their choice of organizational form. The TCE empirical literature, however, tends to focus on asset specificity and uncertainty to the neglect of production costs.

[5] It is recognized that there are other transaction costs in addition to those associated with the procurement of biofuels. This model focuses on the procurement costs in the biomass transaction. Other costs will influence firm behavior as well. This model focuses only on the fuel procurement decision.

Figure 1 shows that for $k < \bar{k}_1$ the market will be most efficient, that is, *M(k)* is the lowest over that range. For values of asset specificity between $\bar{k}_1$ and $\bar{k}_2$, hybrids have the lowest governance costs and will be most efficient. Finally, hierarchy will have the lowest costs for values of $k > \bar{k}_2$.

The lower envelope curve is the locus of minimum governance costs. The organization forms that correspond to those points will be most efficient. If additional curves were added for multiple organizational structures, including different contractual arrangements (short term, long term, formal, informal), firm organization (joint ventures, strategic alliances, cooperatives), and even government, the resulting lower boundary would be a concave envelope of least cost organizational forms.

The benefit of this version of the model is that comparative statics analysis can be easily conducted. Shift parameters include technological change, policy and uncertainty. For instance, if policy is implemented that discourages hierarchy (perhaps to restrict monopoly power), this would cause an upward shift in *H(k)*. The change in policy would increase $\bar{k}_2$ and make hierarchy less likely compared to the hybrid. However, the range of market optimality would remain unaffected.

This analysis suggests that the greater the level of asset specificity, the more likely that firms will rely on hybrid or hierarchical forms of procurement. Moreover, given the high-fixed-cost, low-variable-cost nature of biopower production (Klass, 1998 and Brown, 2003), we expect substantial scale economies to exist, suggesting that firms needing to procure large quantities of inputs will tend to rely on spot-market procurement rather than internal or hybrid procurement. Therefore, given the existence of economies of scale, as scale of a power plant increases external procurement should be more likely and internal procurement less likely.

2.3 Empirical research in transaction cost economics

Previous empirical research in a variety of industry settings has tended to support the basic predictions of TCE, particularly regarding the relationship between asset specificity and vertical integration (Shelanski and Klein, 1995; Klein, 2005; Macher and Richman, 2006).

The choice of organizational form is usually modeled as a function of asset specificity and other explanatory variables. Cross-sectional analyses often utilize a logit or probit model to deal with the qualitative and discontinuous nature of the dependent variable. Some contractual attributes, such as prices, length of contracts, or other measurable contract provisions, can be modeled as continuous variables, though the presence of a contract provision is typically measured as a qualitative variable.

Studies that use scale or size as an explanatory variable tend not to support the TCE hypothesized relationship between the choice of organizational form and scale. Wiggins and Libecap (1985) find that, contrary to TCE theory, that firm size is positively related to vertical integration in oil field organization. In agriculture, the use of contracts and vertical integration are found to be positively correlated with farm size (James et al., 2005). Wilson (1980) uses the size of the fishing operation as an indicator of trust. Anecdotally, larger fishers tend to have long term reciprocal relationships with buyers. Again size is found to be positively correlated with internal organization. These studies contradict the hypothesis made by TCE theory that scale is negatively related to internal organization. From the empirical transaction cost literature, support for scale as a transaction cost variable is much weaker than support for asset specificity.

3. Empirical Results

3.1 Data

Our data come from a survey of biopower generator firms conducted by the University of Missouri-Columbia. We identified 210 firms designated by the Energy Information Administration as producing power from wood or agricultural biomass sources in 2003. The Energy Information Administration conducts an annual questionnaire of all power plants that have a capacity of one megawatt or greater. Of the 210 companies that produce biopower, 12 have plants that are listed as retired, leaving 198 in active production. Of the active-production plants, 164 are listed as operable, 17 are on stand-by and 17 are listed as out of service. We sent mail surveys to the 198 active companies and 53 responded, a 27 percent response rate.

In the biopower industry, key assets include the power plant and storage, collection, and transportation equipment. The degree of asset specificity of these assets varies. For example, a biopower operation that utilizes a co-fire technology that can be easily redeployed to use different proportions of biomass and fossil fuels (and no biomass at all) would be considered, for given levels of supplier concentration, to have a low degree of asset specificity.[6] Other systems that are not as flexible with respect to biomass quantity and quality and are not as redeployable would have higher degrees of asset specificity, ceteris paribus. Thus

[6] Supplier-market concentration must be taken into account because assets that are specialized to a particular use (e.g., burning biomass) may not be relationship-specific assets, in the TCE sense, if there is a thick market for biomass. For given levels of supplier-market concentration, the degree to which assets can be put to different uses can be a good proxy for asset specificity.

the theory would suggest the types of organizational arrangements should vary with the type of equipment employed by the generators.[7]

There are three general organizational alternatives. The first is vertical integration or internal procurement. Vertically integrated systems typically involve the biomass producer integrating forward into biopower production and, in rare cases, power producers backward integrating into biomass production. A second organizational choice is external procurement. This system involves independent power producers purchasing biomass as fuel from independent biomass producers. This category includes both the use of spot markets, formal contracts, and informal arrangements. Third, firms can procure part of their fuel need from internal sources and source the rest externally.

These organizational choices are of interest when the choice of scale is also taken into consideration. Why do some firms choose a smaller scale and internal procurement combination while some choose a larger scale and rely on both internal and external procurement?

Of our 53 sample firms, 28 rely on vertically integrated systems or a system that uses internal procurement. These companies include forestry, wood, and pulp and paper manufactures as well as food and agricultural companies that have integrated forward into biopower production. Rather than sell their waste products to other processors or dispose of them, they have chosen to utilize their wastes in biopower production. Thirteen of the sample firms procure all their biomass externally, using spot markets or contracts. These companies are generally traditional power companies that have chosen to enter biopower production. Of these 13, three rely on spot markets while the other ten use contracts ranging from three months to 20 years in length. The remaining 12 firms use both internal procurement and external procurement. These include wood and agricultural manufacturing companies that have increased the scale of their power plants beyond their own waste capacity or utilities that have partially integrated into fuel production.

As in most forms of power production, power plants in our sample rarely rely on spot-market purchases for their inputs. For this study we group spot market and contracting into one option, external contracting. The other options for the choice variable are internal organization, and a combination of internal and external procurement. Several empirical TCE studies compare hybrid (contract) procurement and internal procurement (Joskow 1985, 1987 and 1990); we add the possibility that companies can use both external organization and internal organization simultaneously.

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[7] We assume here that supplier concentration does not vary systematically across plant types. Unfortunately we do not have measures of supplier density in our data, and there are insufficient degrees of freedom to include county or state dummy variables.

The flexibility of the generation technology with respect to the use of fossil or other fuels is an important issue to power generators (van Loo and Koppejan, 2003). We use the degree of flexibility as an ordinal indicator of physical asset specificity. If the generator can easily switch between biomass and fossil fuels then, for given levels of supplier concentration, the degree of physical asset specificity of the power plant would be low; the asset is easily redeployable and the value of alternative uses of the power plant is high. If it is difficult and costly to convert the power plant to the use of fossil fuels then, controlling for supplier concentration, the asset is not as redeployable and the degree of asset specificity would be high; the value of the power plant in alternative uses is relatively low. In our survey generators were asked to rate the flexibility of their power plant as either: highly flexible, their power plant could easily be converted to use mainly fossil fuels without adjustments and delay, moderately flexible, their power plant could use mainly fossil fuels after minor adjustment and delays, or highly inflexible, their power plant can not use mainly fossil fuels without major adjustment or delay. Table 1 summarizes the responses to this question.

Table 1. Fossil Fuel Flexibility in the Sample of Biopower Generators

Flexibility	***Frequency***	***Percent***	***Cumulative Frequency***
Highly Inflexible	26	49.05	49.05
Highly Flexible	12	22.64	71.69
Moderately Flexible	15	28.30	100.00
Total	53	100.00	

Scale of power plants is measured by the level of biomass inputs the generator uses per year. The scale of the plants could also be measured in terms of scale or generation capacity in megawatts which is a common scale measure of a power plant. However, for a study of organizational form in biomass procurement, scale of involvement in the biomass market, that is, the quantity of biomass fuel is the most appropriate indicator of scale. Capacity in megawatts is inappropriate since it is possible that only a small percentage of that is devoted to biopower for the given plant. In our sample the quantity of biomass fuel ranges from a low of 70 tons per year to a high of 1.4 million tons per year. Table 2 summarizes statistics on our biomass scale variable. Scale in megawatts provides an additional control variable.

Table 2. Summary Statistics– Scale

Variable	*Observations*	*Mean (Tons/year)*	*Standard Deviation (Tons/ year)*	*Minimum (Tons/ Year)*	*Maximum (Tons/ year)*
Scale	53	225,071.7	261,342.8	70	1,445,937

Spatial asset specificity, or what Williamson (1985) calls "site specificity," is measured as the average fuel hauling distance in increments of 0-10, 10-50, and over 50 miles. Following Joskow's (1985, 1987, 1990) work on coal-fired plants, low average hauling distances are expected to be indicators of high site specificity. The logic here is that firms that procure fuel from a greater distance are less restricted in space. Those firms that procure all their fuel near their plant often do so because sources at any greater distance are not feasible. In fact, it is likely that the initial location decision of these power generators was based on proximity to their primary source. Table 3 summaries this variable.[8]

Table 3. Frequency of Average Hauling Distances

	Frequency	*Percent*	*Cumulative Frequency*
0-10 miles	14	26.42	26.42
11-50 miles	25	47.17	73.58
Over 50	14	26.42	100.00
Total	53	100.00	

A final variable considered in this analysis is generation technology. Most power plants that use biomass use a steam turbine technology. However, the boiler technology may be co-fire, where a percentage of biomass fuel can be used with fossil fuels or direct fire where mainly biomass is used (van Loo and Koppejan, 2003). Fifteen of our respondents indicated the use of a co-fire technology while 34 indicated they use direct fire. Also, four indicated another technology, such as internal combustion or gasifier. While we have no prediction on the sign of this variable, we include it as a control for possible relationships

[8] Besides physical asset specificity and site specificity, the transaction cost literature (following Williamson, 1996) also considers human asset specificity (transaction-specific knowledge or human capital), brand-name capital, "dedicated assets" (substantial, general-purpose investments that would not have been made outside a particular transaction, the commitment of which is necessary to serve a large customer), and temporal specificity (assets which must be used in a particular sequence). Physical asset specificity and site specificity are the most obvious transaction cost variables relevant to biopower production. Temporal specificity is discussed in footnote 11 below.

between the technology chosen, asset specificity, and scale.[9] Table 4 summarizes the explanatory variables used in this analysis and the expected signs.

Table 4. Explanatory Variables and Expected sign

Explanatory variable	***Expected sign***
Flexibility to fossil fuel use	Decrease in the probability of observing internal organization
Scale	Decrease in the probability of observing internal organization
Average hauling distance	Decrease in the probability of observing internal organization
Technology type	undetermined

3.2 Analytical methods

Because our dependent variable is categorical, we use a multinomial logit model.[10] In this model firm i faces J unordered choices. The response probability, that firm i chooses alternative $j(P_{ij})$ is modeled as

$$P_{ij} \equiv P(Yi = j \mid X) = \frac{\exp(\beta_j X_i)}{1 + \sum_{j=1}^{J} \exp(\beta_j X_i)} \tag{1}$$

where P_{ij} is the probability $Y_i = j$ or that firm i chooses category j given the explanatory variable vector X, β_j is the estimated parameter vector and X_i is the observed characteristic vector of firm i.

In specific form, there are three choices of organizational form, thus

[9] We also considered two additional control variables, a binary variable indicating generators that are also power companies, and plant capacity measured in Mega Watts. Including the company type indicator introduces multicollinearity and reduces our significance levels, though the signs and magnitudes of the relevant coefficients are not strongly affected. A regression with scale in Mega Watts is reported in table 7. The authors would like to thank an anonymous reviewer for this suggestion.

[10] We considered, but rejected, using a nested logit and ordered probit or logit models. A nested logit would be appropriate in an organizational assessment that featured both the governance level and contract level. Choices of governance could be featured at the branch level while contract choices could be on the twig level. However, we lack sufficient details on the contractual characteristics to specify such a nesting structure. We do not use an ordered probit or logit because our dependent variables lack an inherent rank ordering.

j = 0,1,2 and *i* = 53. The log likelihood function for this multinomial logit can be expressed as

$$\ln L = \sum_{i=1}^{53} \sum_{j=0}^{2} d_{ij} \ln P_{ij} \tag{2}$$

where d_{ij} = 1 if firm *i* chooses organizational form *j*. Explanatory variables flexibility, average hauling distances and technology type are coded as single categorical variables with three categories, while scale is a continuous explanatory variable (the tons of biomass per year).

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:

$$\frac{\partial P_{ij}}{\partial X_k} = P_{ij}\{\beta_{jk} - [\sum_{h=1}^{J} \beta_{hk} \exp(X\beta_h)] / g(X, \beta)\} \tag{3}$$

where β_{hk} is the kth element of β_h,and

$$g(X, \beta) = 1 + \sum_{h=1}^{J} \exp(X\beta_h)\,. \tag{4}$$

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

Potentially complicating issues include endogeneity (due to simultaneity of organizational form and asset specificity), unobserved variables (such as transaction costs/only the choice or organizational form is observed), and causality problems (between asset specificity and organizational form for instance). These issues are addressed in the literature (see Saussier (2000), Joskow (1987), Masten and Crocker (1985), and Masten et al. (1991)). In general these studies tend not to change the support of the theory but rather reinforce the validity of the tests.

Given the small data set (53 observations), and various limited explanatory variables (scale is the only continuous variable), we focus on testing the basic theory with these data and interpreting the marginal effects. Addressing endogeneity and related issues requires more and better data.

3.3 Results

In this model the probability of the choice of organizational form (ORGFROM) is regressed against four key explanatory variables: flexibility with respect to fossil fuel use (FLEXFF) as a measure of physical asset specificity, average hauling distance (AVEHD) as a measure of site specificity, scale of the plant (SCALE) measured in tons of biomass used per year and technology type (TECHTYPE).[11] Results are reported in table 5 and marginal effects in table 6.

All the coefficients have the expected signs, though only one of the asset specificity variables, AVEHD, is statistically significant at the 90% level. (The other, FLEXFF, has a p value of 0.16, which may be due to the small sample size.) In this model, internal procurement (0) is the comparison group. Average hauling distance and scale are statistically significant at the 90% confidence level when external procurement (1) is the organizational form. The model as a whole is statistically significant at the 95% level.

Table 5. Regression Results: Multinomial Logit

Log likelihood:	**-44.523375**			**Number of Observations:**	**53**
				LR chi2(8):	**18.87**
				Prob > chi2:	**0.0155**
				Pseudo R2:	**0.1749**
Organizational Form External	**Coefficient**	**Standard Error**	**P>|z|**	**[95% Conf. Interval]**	
FLEXFF	.6245263	.4469447	0.162	-.2514692	1.50052
AVEHD	1.080492	.5978011	0.071*	-.0911766	2.25216
SCALE	3.52e-06	1.87e-06	0.060*	-1.50e-07	7.1e-06
TECHTYPE	-.8807087	.7510431	0.241	-2.352726	.591308
CONS	-2.898541	1.021664	0.005	-4.900966	-.89611
Organizational Form Both					
FLEXFF	.0789956	.4739609	0.868	-.8499506	1.00794
AVEHD	.5419809	.5439205	0.319	-.5240838	1.60804
SCALE	4.76e-06	1.86e-06	0.010**	1.12e-06	8.4e-06
TECHTYPE	.4868234	.5668151	0.390	-.6241138	1.59776
CONS	-2.7934	.947754	0.003	-4.650963	-.93583
Outcome organizational form equal to 0 (internal organization) is the comparison group					

* Statistically significant at the 90% confidence interval
** Statistically significant at the 95% confidence interval

[11] Several other variables were considered for this analysis including the number of suppliers, plant dispatch type as a temporal asset specificity variable, biomass fuel flexibility as a potential physical asset specificity variable, power plant fuel scope as well as multiple interaction terms. These variables are not included in the final model either because they are statistically insignificant or insufficient data.

The marginal effects are also consistent with TCE. The marginal effects of the two asset specificity variables, flexibility with respect to fossil fuels and average hauling distance, have the expected signs. Also, larger scale of the plant is found to increase the probability of external procurement and decrease the probability of internal procurement. This is also consistent with the theory. Table 6 reports these marginal effects.

Table 6. Marginal Effects of Multinomial Logit Model

mlogit: Changes in Predicted Probabilities for ORGFORM				
FLEXFF				
	Average Change	**External**	**Both**	**Internal**
Min to max	.14705233	.22057848	-.04019131	-.1803872
AVEHD				
Min to max	.25442452	.31146399	.07017279	-.3816368
SCALE				
Min to max	.50094266	.03968221	.71173181	-.75141397
-+ ½	6.954e-07	3.576e-07	6.557e-07	-1.073e-06
-+ sd/2	.17424998	.09363356	.1677414	-.26137498
Marginal effect	6.822e-07	3.709e-07	6.524e-07	-1.023e-06
TECHTYPE				
Min to max	.17964793	-.25556941	.26947188	-.01390249

When average hauling distance increases from 0-10 miles to 50+ miles the probability of observing external procurement increases by 31% and internal procurement decreases by 38%. In other words, a change from high to low site specificity is associated with an increase in the probability of external organization and a decrease in the probability of internal organization. Scale also has the correct sign. A 10,000 ton increase in scale increases the probability of external procurement by 3.7% and decreases the probability of internal organization by 10%. A 10,000 ton change from the mean reveals a similar 3.5% increase in observing external procurement and 10% decrease in observing internal organization. A one standard deviation change from the mean reveals a 9% increase in external procurement and a 26% decrease in internal organization. Finally, a change in scale from min to max increases the probability of external organization by 3.9% and the combination choice by 71% while decreasing the probability of internal organization by 75%.

Scale in megawatts provides an additional control for such differences as management skills and organizational learning. While scale of production does not mean greater market power in the biomass market, it may mean that the firm has greater skills and knowledge gained by procuring other inputs (like coal or natural gas). This knowledge may influence how they purchase biomass and thus their procurement strategy. That is, larger plants may procure biomass in a particular way, independent of their biomass operations, because they are used to procuring their other inputs in that way. In table 7 results are shown to support this notion. When scale in megawatts produced is included, scale in biomass quantity is statistically significant when internal organization is compared to the other alternatives. Scale in megawatts is only significant when internal organization is compared to firms that use both internal and external procurement.

Table 7. Regression Results: Multinomial Logit with Scale in Megawatts

Log likelihood:	**-36.718958**			**Number of Observations:**	**46**
				LR chi2(8):	**20.56**
				Prob > chi2:	**0.0244**
				Pseudo R2:	**0.2187**
Organizational Form External	**Coefficient**	**Standard Error**	**P>|z|**	**[95% Conf. Interval]**	
FLEXFF	.7510738	.5283666	0.155	-.2845056	1.78665
AVEHD	1.1852	.6869032	0.084*	-.1611057	2.53150
SCALE	4.76e-06	2.57e-06	0.064*	-2.78e-07	9.8e-06
TECHTYPE	-.6597757	.7771057	0.396	-2.182875	.863323
SCALEMW	-.0148924	.0165878	0.369	-.0474038	.017619
CONS	-3.113287	1.197778	0.009	-5.460889	-.76568
Organizational Form Both					
FLEXFF	.4021982	.5327271	0.450	-.6419278	1.44632
AVEHD	.7247116	.5906583	0.220	-.4329573	1.88238
SCALE	.0000103	3.89e-06	0.008**	2.63e-06	.000017
TECHTYPE	.4838168	.5939224	0.415	-.6802497	1.64788
SCALEMW	-.0669361	.0356033	0.060*	-.1367174	.002845
CONS	-2.756596	1.057268	0.009	-4.828803	-.68438
Outcome organizational form equal to 0 (internal organization) is the comparison group					

* Statistically significant at the 90% confidence interval
** Statistically significant at the 95% confidence interval

4. Conclusions

The biomass and bioenergy industries face important organizational and strategic challenges, but there is so far little literature applying organizational economics to the industry. Application of transaction cost theory has the dual benefit of shedding valuable light on the challenges facing the growing market for biomass, and at the same time advancing theory by testing its hypotheses in a new setting.

To address these issues we apply TCE to the US biopower industry with a special focus on the effect of scale on the choice of organizational form. A survey of biopower generators produced information on several important variables such as physical asset specificity, spatial asset specificity and scale of generation facilities. These variables are regressed in a multinomial logit model against the choice of market organizational form. Contrary to preliminary empirical evidence in the transaction cost literature, larger scale of operation is associated with greater reliance on external procurement, which provides some support for the transaction cost theory predicted relationship between organization and scale.

Given this evidence both transaction costs and economies of scale are reconsidered in the choice of organizational form and scale of biopower generation facilities. Transaction costs and economies of scale are demonstrated to be two key trade-offs in organizational decisions.

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