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Modelling the Choice of the Organizational Form in the European Bioethanol Industry

Monia Ferchichi¹, Loïc Sauvée²

Abstract

With increasing interest in renewable energy from agriculture, including bioethanol for environmental benefits, rural growth and development, and energy security, there is a need for a better understanding of the economic organization of this emerging industry. Study of the organization of the bioethanol industry represents an under-researched area and a new application of transaction cost theory to an emerging industry in Europe.

Refinement of the theory can also result from challenging applications. This paper provides an application of transaction-cost economics theory to the existing European bioethanol industry in challenging the empirical convention of excluding production cost variables from transaction-cost analysis. Utilizing survey data from 41 bioethanol firms using sugar beets and/or cereals, we study the relationship between transaction's frequency, physical asset specificity, site specificity and scale in explaining firms' decisions to insure procurement of inputs either externally or through contracts. Consistent with transaction cost theory, the resolution of both dichotomous logit and probit models shows that both physical asset specificity and scale are good predictors of organizational forms. Given this evidence, this paper reconsiders the impact of scale and transaction costs on the choice of organizational form.

Keywords: Bioethanol industry, organizational choice, procurement, transaction costs, scale

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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 bioethanol processing have been extensively studied, less is known about the economic organization and governance of the bioethanol industry. How should bioethanol firms procure their inputs: from the spot market or through contracts with independent biomass producers? What are the characteristics of purchase and supply contracts in bioethanol?

To begin addressing some of these questions we focus on a fundamental alternative facing any firm (Coase, 1937), the “make-or-buy decision” (Klein, 2005). Using the transaction cost economics framework developed by Williamson (1985, 1991, 1996, 2005), we examine the vertical structure of the current bioethanol industry with survey data from 41 European bioethanol producers. Our analysis focuses not only on the frequency of the transaction and asset specificity—the main variable of interest in the empirical transaction cost literature (Klein, 2005)—but also on the economies of scale related to the technology of production. 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 acquired and costless, while market transactions are fraught with hazards brought about by information and agency costs.

Our results suggest that the frequency of inputs’ procurement is not a statistically significant determinant of external organization in bioethanol industry. Instead, characteristics of the production process, such as scale of the bioethanol firms, appear to be more important. Moreover, several firms in our sample both purchase their inputs from the spot market and through contracts with farmers and/or agricultural cooperatives, a practice difficult to explain within the usual framework of TCE. Of course, our results may be specific to bioethanol and may not be generalized to vertical relationships in other industries. Nevertheless, the findings suggest that the standard TCE framework may require adaptation to account for complex arrangements such as simultaneous external and hybrid procurement. 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 bioethanol

Biomass and bioethanol researchers have rarely considered organizational issues or applied an adequate organizational theory to this nascent industry³. 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 Kaltschmitt (1999) identify similar topics

³ 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.

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. Recently, Gallagher et al. (2007) analysed the appropriate scale, organization and implied profitability of a representative U.S. ethanol processing firms. Altman et al. (2007) studied the organization of the biopower industry through an application of transaction cost theory. However, as we will discuss below, in our sample only 6 out of 41 firms procure inputs on the spot market while the others purchase their inputs via contracts. Why do so few firms use the spot market, and what explains the choice of contracting? We turn to the theoretical framework of TCE for answers.

2.2 Transaction cost economics

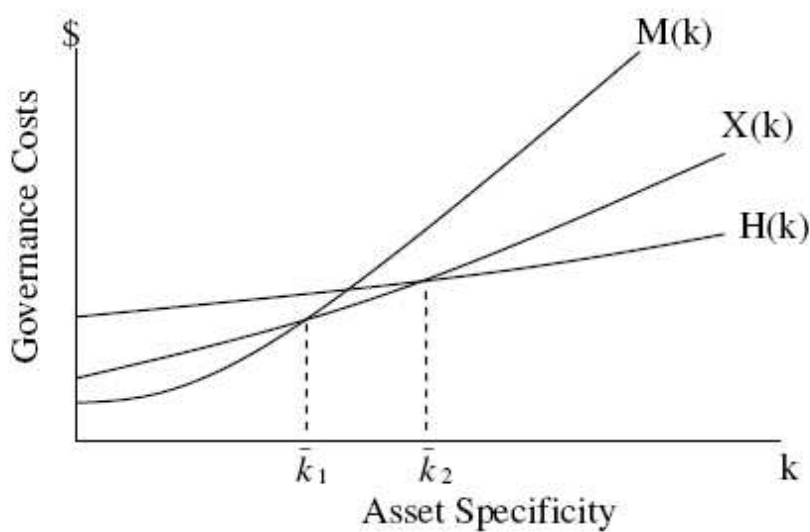
Central to TCE is the discriminating alignment hypothesis, which states that the choice of organizational form depends on the characteristics of the transaction (Williamson 1996, p.371). Economic agents behave in such a way that transactions, which vary in degrees of asset specificity, uncertainty and 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 which 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 greater the potential for realizing external economies of scale, the less likely hybrid and internal organization will be observed⁴.

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.

This issue can be depicted as a cost-minimization problem. Market organization and internal organization are assumed to have different transaction costs⁵. When asset specificity is low, market transaction costs are lower than the costs of hybrid form and of course internal organization (because of administration costs), but as asset specificity rises, the costs of market transactions increase more rapidly than the costs of hybrid form and internal organization as well, 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

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 , hybrid forms 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,

⁵ It is recognized that there are other transaction costs in addition to those associated with the procurement of inputs. 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 sugar beets/cereals procurement decision.

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 form. 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 bioethanol production, 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 bioethanol plant increases, external procurement should be more likely and hybrid 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; Masten, 1996; Rindfleisch and Heide, 1997; Klein, 2005; Macher and Richman, 2006). In the vein of TCE, research works on hybrid forms have shown that the underlying logic of such alternative modes of organization are far from being elucidated (Ménard, 2004, 2005).

The choice of organizational form is usually modelled 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 modelled as continuous variables, although 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 fishermen 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 comes from a survey of bioethanol firms and experts of the sector. We identified 41 active companies in Europe which are producing ethanol from sugar beets and/or cereals.

In the bioethanol industry, key assets include the plant and storage, collection, and transportation equipment. The degree of asset specificity of these assets varies. For example, a bioethanol operation that utilizes wheat that can be easily redeployed to use barley or other cereals would be considered, for given levels of supplier concentration, to have a low degree of asset specificity⁶. 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 the theory would suggest that the types of organizational arrangements should vary with the type of equipment employed by the plant⁷.

There are two organizational alternatives. The first one is external procurement. This system involves independent firms purchasing sugar beets or cereals from independent producers. This category covers spot markets. The second organizational choice is the hybrid one by which firms can procure their inputs through contracts with farmers and/or with cooperatives. We note that the vertical integration or internal procurement is excluded in this case because bioethanol plants are not able to procure neither sugar beets nor cereals internally and are, therefore, obliged to purchase their inputs from farmers or cooperatives through spot markets or contracting.

These organizational choices are of interest when the choice of scale is also taken into consideration.

Of our 41 bioethanol firms, 35 rely on hybrid procurement by contracting. These companies produce ethanol especially from sugar beets through contracts with the farmers and cereals through contracts with farmers and/or cooperatives. The remaining 6 firms procure all their inputs externally in using spot markets. These companies are Spanish and German ones that have chosen to enter the bioethanol production.

As in most forms of fuel production, bioethanol plants rarely rely on spot market purchases for their inputs. Several empirical TCE studies compare hybrid (contract) procurement and internal procurement (Joskow 1985, 1987 and 1990). In this paper we compare hybrid procurement and external procurement through spot markets.

The frequency of the transaction is an important issue to bioethanol firms since it affects their organisational choice according to our questionnaire with experts of the sector. In our sample, 15 firms have a low frequency of inputs procurement. These firms produce ethanol from sugar beets and the procurement of such a product occurs once a year during the harvest period (October-December). The remaining 26 firms have a high frequency of purchasing cereals in order to saturate the production capacity during the year. Table 1 summarizes statistics on our frequency variable.

⁶ Supplier-market concentration must be taken into account because assets that are specialized to a particular use 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.

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.

Table 1. Frequency of Transaction in the European Bioethanol Firms

		<i>Frequency</i>	<i>Percent</i>	<i>Valid Percent</i>	<i>Cumulative Percent</i>
Valid	Low	15	36,6	36,6	36,6
	High	26	63,4	63,4	100,0
Total		41	100,0	100,0	

Spatial asset specificity, or what Williamson (1985) calls “site specificity”, is measured as the average input hauling distance in increments of 0-25, 25-50, 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 inputs from a greater distance are less restricted in space. Those firms that procure all their inputs 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 bioethanol plants was based on proximity to their primary source. Table 2 summarizes this variable⁸.

Table 2. Frequency of Average Hauling Distances

		<i>Frequency</i>	<i>Percent</i>	<i>Valid Percent</i>	<i>Cumulative Percent</i>
Valid	0-25 miles	15	36,6	36,6	36,6
	25-50 miles	2	4,9	4,9	41,5
	Over 50	24	58,5	58,5	100,0
Total		41	100,0	100,0	

The flexibility of the bioethanol technology with respect to the use of sugar beets or cereals is an important issue to bioethanol firms. We use the degree of flexibility as an ordinal indicator of physical asset specificity. If the plant can easily switch between primary sources (cereals/sugar beets), for given levels of supplier concentration, the degree of physical asset specificity of the firm would be low. The asset is easily redeployable and the value of alternative uses of the bioethanol plant is high. If it is difficult and costly to convert the firm to the use of cereals instead of sugar beets then, controlling for supplier concentration, the asset is not as redeployable and the degree of asset specificity would be high. The value of the plant in alternative uses is relatively low.

In our survey, firms were asked to rate the flexibility of their plant as either: inflexible (their bioethanol plant can not be converted to use another input); moderately flexible (their plant could use mainly cereals or sugar beets after minor adjustment and delays); highly flexible (their plant could easily be converted to use mainly cereals or sugar beets without adjustments and delay). Table 3 summarizes the responses to this question.

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 bioethanol production. Temporal specificity is discussed in footnote 11 below.

Table 3. Flexibility of European Bioethanol Plants

		<i>Frequency</i>	<i>Percent</i>	<i>Valid Percent</i>	<i>Cumulative Percent</i>
Valid	Inflexible	30	73,2	73,2	73,2
	Moderately	3	7,3	7,3	80,5
	Highly flexible	8	19,5	19,5	100,0
Total		41	100,0	100,0	

Scale of bioethanol plants is measured by the level of inputs the plant uses per year. The scale of the plants could also be measured in terms of scale or production capacity in metric tons which is a common scale measure for bioethanol plants. In our sample the production capacity ranges from a low of 2000 tons per year to a high of 240000 tons per year. Table 4 summarizes statistics on our scale variable.

Table 4. Summary Statistics-Scale

<i>Variable</i>	<i>Observations</i>	<i>Mean (Tons/year)</i>	<i>Standard Deviation (Tons/year)</i>	<i>Minimum (Tons/year)</i>	<i>Maximum (Tons/year)</i>
Scale	41	10952,553	70130,558	2000	240000

Table 5 summarizes the explanatory variables used in this analysis and the expected signs based on the transaction cost economics results and our surveys with both ethanol plants leaders and experts of the sector.

Table 5. Explanatory Variables and Expected Sign

<i>Explanatory variable</i>	<i>Expected sign</i>
Frequency of inputs procurement	Increase in the probability of observing external procurement
Average hauling distance	Increase in the probability of observing external procurement
Flexibility to inputs use	Increase in the probability of observing external procurement
Scale	Increase in the probability of observing external procurement

3.2 Analytical methods

Because our dependant variable is categorical, we use both dichotomous logit and probit models since the organizational choice of bioethanol firms can be either an external procurement through spot markets or a hybrid form through contracts with farmers and/or cooperatives. In models of this class, the dependant variable can take on only two values, which it is convenient to denote by 0 and 1.

The logit and probit models, together with their multi-response and multivariate generalizations, are now widely used in applied econometric work. Such models are typically estimated by maximum likelihood methods which require the numerical maximization of a log likelihood function (Davidson et al, 1982). Since this is usually much more expensive than, say, calculating ordinary least squares estimates for a linear regression model, investigators often display a natural reluctance to test the specification of the model as

thoroughly as would normally be done in the regression case. There is thus a clear need for specification tests of logit and probit models which are easy to understand and inexpensive to compute.

In this context, it seems natural to investigate the use of Lagrange multiplier, or score tests, because they require only estimates under the null hypothesis, and they can often be computed by means of artificial linear regressions. The literature on LM tests for logit and probit models is, however, remarkably limited. The recent survey of qualitative response models by Amemiya (1981) does not mention LM tests at all, and the survey of LM tests by Engle (1982) describes only one such test for logit and probit models, which appears to be new.

The probability that y_i ⁹, the i^{th} observation on the dependent variable is equal to 1 is given by $F(x_i\beta)$. The distribution function F is an increasing function of x_i which has the properties that $F(-\infty) = 0$ and $F(+\infty) = 1$. x_i is a possibly nonlinear function, which depends on X_i a row vector of exogenous variables, and β , a column vector of parameters to be estimated.

The only difference between the logit and probit models is that they employ different functions for F (Gourieroux, 1989). In the case of the logit model,

$$p_i = \Pr ob(y_i = 1 / x_i) = F(x_i\beta) = \frac{1}{1 + e^{-x_i\beta}}, \quad \forall i = 1, \dots, N \quad (1)$$

where F denotes the logistic function.

In the case of the probit model,

$$p_i = \Pr ob(y_i = 1 / x_i) = F(x_i\beta) = \int_{-\infty}^{x_i\beta} \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}} dz, \quad \forall i = 1, \dots, N \quad (2)$$

where F denotes the cumulative distribution function of the standard normal distribution.

The logistic and cumulative normal differ little, and only at the tails (Amemiya, 1981). Hence, unless the sample size is very large, the empirical results obtained from the two will be very close. Note that, for both (1) and (2), $F(-z) = 1 - F(z)$. Provided the functions have this symmetry property, everything we say below will apply to them as well.

In specific form, there are two choices of organizational form for the 41 European bioethanol plants: either spot markets or contracts. Thus $N = 41$ and $p_i = \Pr ob(y_i = 1 / x_i)$ is the probability of observing the external organization.

Thus the likelihood function for these dichotomous models associated with the observation y_i can be expressed as

$$L(y_i, \beta) = p_i^{y_i} (1 - p_i)^{1-y_i} \quad (3)$$

The likelihood function for a sample size of $N = 41$, denoted by $y = (y_1, \dots, y_{41})$, is

⁹ The value of y_i depends on certain variables and unknown parameters.

$$L(y, \beta) = \prod_{i=1}^{41} p_i^{y_i} (1 - p_i)^{1-y_i} = \prod_{i=1}^{41} [F(x_i \beta)]^{y_i} [1 - F(x_i \beta)]^{1-y_i} \quad (4)$$

where $F(x_i \beta) = \frac{1}{1 + e^{-x_i \beta}}$ for the logit model and $F(x_i \beta) = \int_{-\infty}^{x_i \beta} \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}} dz$ for the probit model.

We shall denote by $\text{Log}L(y, \beta)$ the contribution to the log likelihood function made by the i^{th} observation. Therefore this function can be expressed as

$$\text{Log}L(y, \beta) = \sum_{i:y_i=1} \log F(x_i \beta) + \sum_{i:y_i=0} \log [1 - F(x_i \beta)] \quad (5)$$

In the linear case, this function is globally concave for both the logit and probit models. Thus ML estimates may be found in a straightforward fashion by maximizing it.

We shall denote the gradient of (5) with respect to β by the row vector $G(\beta)$. Its expression is done by

$$G(\beta) = \sum_{i:y_i=1} \frac{f(x_i \beta)}{F(x_i \beta)} x_i' - \sum_{i:y_i=0} \frac{f(x_i \beta)}{[1 - F(x_i \beta)]} x_i' \quad (6)$$

Here x_i' denotes the derivative of x_i with respect to β , $f(x_i \beta)$ denotes the first derivative of $F(x_i \beta)$.

The ML estimates $\hat{\beta}$ must of course satisfy the first-order conditions

$$\hat{\beta} = \arg \max[\log L(y, \beta)] \quad (7)$$

$$\frac{\partial \log L(y, \hat{\beta})}{\partial \hat{\beta}} = \sum_{i=1}^{41} \frac{[y_i - F(x_i \hat{\beta})] f(x_i \hat{\beta})}{F(x_i \hat{\beta}) [1 - F(x_i \hat{\beta})]} x_i' = G(\hat{\beta}) = 0 \quad (8)$$

where $G(\hat{\beta})$ denotes the gradient associated to the log likelihood $\partial \log L(y, \hat{\beta})$ evaluated at the point $\hat{\beta}$. In the case of the logit model this gradient is done by the expression

$$G_L(\hat{\beta}) = \sum_{i=1}^{41} [y_i - F(x_i \hat{\beta})] x_i' = 0 \quad (9)$$

For the probit model, this gradient is expressed as

$$G_P(\hat{\beta}) = \sum_{i=1}^{41} \frac{[y_i - F(x_i \hat{\beta})] f(x_i \hat{\beta})}{F(x_i \hat{\beta}) [1 - F(x_i \hat{\beta})]} x_i' = 0 \quad (10)$$

Explanatory variables: frequency, average hauling distances and flexibility are coded as single categorical variables with two or three categories, while scale is a continuous explanatory variable (the tons of bioethanol per year).

In both dichotomous logit and probit models the p-values are valid, making significance tests meaningful, but the signs and magnitudes of the coefficients have no direct interpretation (Alban, 2000). The partial marginal effects for continuous variables can be calculated as:

$$\frac{\partial p_i}{\partial x_i^{[j]}} = \frac{\partial F(x_i \beta)}{\partial x_i^{[j]}} = \frac{\partial F(x_i \beta)}{\partial (x_i \beta)} \cdot \frac{\partial (x_i \beta)}{\partial x_i^{[j]}} = \frac{\partial F(x_i \beta)}{\partial (x_i \beta)} \beta_j = f(x_i \beta) \beta_j \quad (11)$$

where $x_i^{[j]}$ denotes the j^{th} explanatory variable for the observation i .

For the logit model, this derivative is expressed as

$$\frac{\partial p_i}{\partial x_i^{[j]}} = \frac{e^{x_i \beta}}{(1 + e^{x_i \beta})^2} \beta_j \quad (12)$$

For the probit model, the partial marginal effects can be calculated as

$$\frac{\partial p_i}{\partial x_i^{[j]}} = \frac{1}{\sqrt{2\pi}} \exp\left[-\frac{1}{2}(x_i \beta)^2\right] \beta_j \quad (13)$$

The marginal effects of limited explanatory variables are calculated as the difference between probabilities (Altman et al, 2007).

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). 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 (41 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 these models the probability of the choice of organizational form (CHOICE) is regressed against four key explanatory variables¹⁰: frequency of the procurement (FREQ), flexibility with respect to inputs use (FLEX) as a measure of physical asset specificity, average hauling distance (DIST) as a measure of site specificity, scale of the plant (SCALE) measured in tons of bioethanol per year. Results of the logit model are reported in table 6 and those of the probit model in table 7.

¹⁰ Several other variables were considered for this analysis including the number of suppliers, plant dispatch type as a temporal asset specificity variable, uncertainty related to the inputs procurement and technology type. These variables are not included in the final model either because they are statistically insignificant or insufficient data.

Table 6. Regression results : Logit model

	<i>Estimate</i>	<i>Std. Error</i>	<i>z value</i>	<i>Pr(> z)</i>
(INTERCEPT)	-2.819e+01	3.419e+03	-0.008	0.9934
FREQ	1.399e+01	3.419e+03	0.004	0.9967
DIST	2.213e+00	2.318e+00	0.955	0.3397
FLEX	3.551e+00	1.820e+00	1.951	0.0511 .
SCALE	4.216e-05	2.187e-05	1.928	0.0539 .

Signif. Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 34.137 on 40 degrees of freedom

Residual deviance: 12.751 on 36 degrees of freedom

AIC: 22.751

Number of Fisher Scoring iterations: 19

All the coefficients have the expected signs for both logit and probit models, though only one of the asset specificity variables, FLEX, is statistically significant at the 90% level for the logit model and at 95% level for the probit model. (The other, DIST, has a p-value of 0.3165, which may be due to the small sample size). SCALE is also statistically significant at the 90% level for the logit model and at 95% level for the probit model. In these models, external procurement (1) is the comparison group. The model as a whole is statistically significant at the 95% level.

Table 7. Regression results : Probit model

	<i>Estimate</i>	<i>Std. Error</i>	<i>z value</i>	<i>Pr(> z)</i>
(INTERCEPT)	-1.155e+01	7.184e+02	-0.016	0.9872
FREQ	3.248e+00	7.184e+02	0.005	0.9964
DIST	1.342e+00	1.340e+00	1.002	0.3165
FLEX	2.004e+00	9.186e-01	2.181	0.0292 *
SCALE	2.478e-05	1.160e-05	2.137	0.0326 *

Signif. Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 34.137 on 40 degrees of freedom

Residual deviance: 12.715 on 36 degrees of freedom

AIC: 22.715

Number of Fisher Scoring iterations: 19

The marginal effects are also consistent with TCE. The marginal effects of the two asset specificity variables, flexibility with respect to inputs use and average hauling distance, have the expected signs. Also higher the frequency of inputs procurement and larger the scale of the plant, more important will be the probability of external procurement. This is also

consistent with the theory and the surveys that we have made with bioethanol plants leaders and experts of the sector. Table 8 reports these marginal effects.

Table 8. Marginal effects of logit and probit models

<i>Variable</i>	<i>Logit</i>	<i>Probit</i>
FREQ	0.0402	0.0431
DIST	0.0417	0.0424
FLEX	0.1036	0.0526
SCALE	0.0590	0.0697

When the frequency of inputs procurement becomes high and the average hauling distance increases from 0-25 miles to 50+ miles the probability of observing external procurement increases by 4% for both logit and probit models. In other words, in order to satisfy plant needs of inputs and to realize the expected bioethanol production, the procurement of raw materials through spot markets seems to be the most convenient organizational choice and a change from high to low site specificity is associated with an increase in the probability of external organization. A higher level of plant flexibility with respect to inputs increases the probability of observing external procurement by 10% for the logit model and 5% for the probit model which means that a change from high to low physical specificity is associated with an increase in the probability of external procurement and a decrease of the hybrid one. Scale also has the correct sign. A change in scale from 2000 to 240000 tons per year increases the probability of external organization by 6% in the logit model and 7% in the probit model.

4. Conclusions

The bioethanol plants face important organizational and strategic challenges, but there is so far little literature applying organizational economics to this 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 European bioethanol plants with a special focus on the effect of scale on the choice of organizational form. A survey of bioethanol firms produced information on several important variables such as the frequency of the procurement, physical asset specificity, spatial asset specificity and scale of bioethanol production. These variables are regressed in both dichotomous logit and probit models providing similar results, 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 bioethanol plants. Transaction costs and economies of scale are demonstrated to be two key trade-offs in organizational decisions.

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