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Applying Transaction Cost Economics: A Note on Biomass Supply Chains

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Agricultural supply chains, especially those from producer to first handler, are relatively mature institutions. While agricultural economists often observe the evolution of marketing structures in developing nations, it is a rare opportunity to research a developing market within North America. The emerging bioenergy industry—which relies on non-food crops such as straw—provides the potential to research and potentially impact the development of new supply chains. Here, we briefly review the literature related to biomass supply chains, pose a transaction cost approach to studying their development, and then discuss the procurement strategies of an industry leader: the Iogen Corporation.

Key Words: biomass supply chains, organization, transaction cost

Bioenergy industries based on agricultural row crop waste (e.g., straw) and dedicated energy crops (e.g., switch grass) hold the potential to reduce dependence on fossil fuels, revitalize rural communities, and contribute to environmental improvement. Many also argue that technologies for processing agricultural products into renewable energy are nearing financial feasibility. However, transaction costs from organizing biomass exchange may be an important non-technical barrier to commercial development. The choices of procurement and marketing strategies are keys to competing on transaction costs just as the choice of manufacturing technology is key to competing on production costs.

While there is much research investigating bioenergy technology, other topics, such as transaction costs, organizational decisions, and biomass supply chain issues, remain under-researched. Row crop waste and energy crop supply chains are less developed than other biomass-based renewable energy industries. The current U.S. biopower industry is based on concentrated wood and food waste streams with highly vertically integrated supply chains. Further, unlike traditional corn-to-ethanol

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production, where well-developed supply chains exist, row crop waste and energy crop biomass supply channels will have to overcome significant organizational hurdles. The current ad hoc supply systems involving informal contracting and barter must evolve to more formal systems to meet the needs of large-scale processors. The purpose of this paper is to use transaction cost economics to examine how the biomass supply chain may evolve for one such processor, the Iogen Corporation.

In the following section of this paper, the biomass and bioenergy literature is reviewed. Next, an explanation and application of transaction cost economics to the general relationship between biomass producer and processor is provided to demonstrate the use of the theory. The illustrative case of the Iogen Corporation is then presented, with the underlying objective of examining Iogen's procurement strategy through the lens of transaction cost economics. A summary and concluding remarks are given in the final section.

Biomass Supply Chains and Transaction Cost Economics

Biomass and bioenergy researchers have rarely applied an adequate organizational theory to this nascent industry. Klass (1998) draws attention to this failure in the area of storage and shipping of wood biomass. Further, van Loo and Koppejan (2003) document examples where organizational adaptations have solved technological problems. Their work underscores the importance of understanding and addressing organizational issues within the biomass industry.

Current research on biomass supply chains is mixed. Downing, Volk, and Schmidt (2005) suggest agricultural cooperatives as potential organizational structures for research, financing, and exchange mechanisms in the bioenergy industry. Alternatively, Overend (1993, p. 2) claims that the "industry must rely on short-term contracts or the spot market for fuel purchases." Both lines of research suggest the relevant question: When are spot markets preferable, and when do more integrated procurement systems better serve the bioprocessing industries? An adequate organizational theory is required to provide a framework for addressing this question.

Other authors have focused on logistic decisions such as biomass harvest, transportation, storage, and preprocessing methods. These decisions must take into account the type of crop—whether it is an energy crop like switch grass, or row crop waste such as wheat straw. The processing technology also impacts logistics. Atchison and Hettenhaus (2003) recommend a one-pass harvest system where biomass waste is collected in conjunction with the grain harvest, and processing plants are located near waterways to utilize barge transportation. A one-pass harvest system, however, is less appropriate when the processing technology requires a dry biomass product, which lends itself to a multi-pass harvest system (Atchison and Hettenhaus). Transportation and processing issues are important to this industry and have been considered by prior researchers (see Tembo, Epplin, and Huhnke, 2003; Bhat, English, and Ojo, 1992) in addition to the technological perspective (Brown, 2003). Here, we focus on the organizational aspect of the supply chain within the context of transaction cost economics as specifically applied to the Iogen Corporation.

Transaction cost economics (TCE) as an organizational theory was pioneered by Coase (1937). Other organizational approaches include the incomplete contracting approach associated with Hart (Grossman and Hart, 1986; Hart and Moore, 1990), the measurement branch (Alchain and Demsetz, 1972; Jensen and Meckling, 1976), as well as various business theories such as the resource-based theory. But one of the most conceptually developed organizational theories is Williamson's work on TCE (1979, 1985, 1996). The behavioral assumptions of the TCE model include bounded rationality and opportunism: individuals will break their promises if they can gain. Williamson defines opportunism as an adjusted version of self-interest seeking, i.e., "self-interest seeking with guile" (Williamson, 1979, p. 234). In the biomass sector we would expect economic circumstances to be highly variable depending on the prices of fossil fuels, agronomic factors, and technological factors. This economic environment creates the potential for incomplete contracts and opportunism as potential trading partners try to establish new relationships.

All exchanges are subject to transaction costs. Transaction costs include ex ante search and negotiation costs and ex post enforcement, monitoring, and renegotiation costs. The assumption of positive transaction costs assures that disagreements arising from contract incompleteness cannot be costlessly negotiated away. The crux of TCE is the discriminating alignment hypothesis which states that economic actors will "align transactions, which differ in their attributes, with alternative governance structures, which differ in cost and competence, so as to realize a transaction cost economizing result" (Williamson, 1996, p. 371).

Three attributes of the transaction are identified: asset specificity, frequency, and uncertainty (Williamson, 1979). In TCE, special emphasis is placed on asset specificity. Asset specificity is defined as the value of assets in alternative uses. In this way, asset specificity helps identify opportunity costs of assets used to support an exchange as the key organizational determinant.

Several types of asset specificity are identified. Physical asset specificity is when assets are tailored to meet the needs of a particular trading partner. Spatial asset specificity occurs when location creates dependency. Three other types of asset specificity include dedicated assets, when expansion investments are made to meet the needs of a particular trading partner; human asset specificity or learning by doing; and temporal asset specificity, where timing of the asset's use is specific and critical.

Asset specificity is assigned primary significance in Williamson's TCE because it creates bilateral dependence between otherwise independent actors. A situation of ex ante independence may be transformed into ex post bilateral dependence where trading parties are open to the potential of opportunism. In the case of low asset specificity, independent parties are less subject to opportunism on the part of their business relations since assets hold relatively high values in alternative uses. TCE holds that the relative efficiency of alternative organizational forms depends on asset specificity.

In potential biomass industries, producers and processors are indeed independent. However, once they make specialized investments that support the biomass transaction, they typically become bilaterally dependent on each other's actions. Hence, the choice of organizational form or biomass supply chain strategy becomes central to industry development.

For bioenergy industries, the relevant assets and investments include the processing facility or power plant, the biomass harvesting equipment, storage, and transportation equipment, as well as the producer's time and managing effort. The degree of specificity of these assets will likely vary, implying that a range of organizational and supply chain mechanisms may be efficient, depending on the technological and geographical circumstances for a particular plant.

Physical asset specificity will be an issue for the processor, when the processing technology is not flexible with respect to quantity, quality, and type of biomass feedstock. In this case, processors may consider longer-term contracts, vertical coordination, or even vertical integration strategies as advantageous. Conversely, flexible processing technology with respect to biomass quantity and quality should result in a preference for flexible organizational options such as spot markets which allow facilities to switch to the lowest cost fuel.

Biomass producers will have high asset specificity if they invest in specialized machinery to produce, collect, transport, and store the biomass—in which case they may desire a longer-term committed relationship with new processors. Alternatively, where biomass producers already own the physical production assets, they should prefer to utilize spot markets, so that they are free to either sell or use the biomass depending on the highest value. For instance, they can choose to withhold supplies in order to ensure soil fertility or to sell to a local livestock industry. Producers with relatively low asset specificity will be unlikely to sacrifice these alternatives by committing to long-term supply relationships.

Industry supply chains are likely to develop more quickly if the trading partners—producers and processors—desire the same type of relationship. For instance, if a flexible production plant with low asset specificity is built in an area where farmers already own biomass harvesting equipment, such as haying equipment, then a spot market for biomass feedstock should quickly develop. Likewise, if a highly asset-specific plant were to locate in an area where farmers had to invest in new biomass production technologies, then longer-term supply contracts would likely emerge between processors and biomass producers.

Procurement processes may hinder the industry when the asset specificity of the processor and biomass producer do not align. If a processor plans to enter an area where producers do not own the necessary production equipment, then it will be challenging to get producers to respond and invest in equipment if they expect spot market transactions. To induce investment by producers, processors might need to offer more committed relationships, even though they will increase transaction costs compared to a spot market. Clearly, the accompanying transaction costs must be considered when choosing the supply chain strategy.

There are several questions that must be answered to predict the most efficient supply chain strategy in the emerging bioenergy industries.

- First, will the processing technology be flexible with respect to the biomass feedstock?
- Second, will the processor be entering an area where farmers already own the necessary equipment to serve the industry?
- Finally, will special biomass production techniques—i.e., the development of human assets—be expected from biomass producers?

The answers to these questions will determine if low-cost spot markets develop or if the industry evolves long-term supply contracts or even cooperatives that entail much higher administrative costs.

Next, we look at one company's approach to addressing these issues in biomass procurement. While there are a number of alternative procurement situations that could be examined (see Atchison and Hettenhaus, 2003), here we chose to focus on a private firm, the Iogen Corporation. Iogen is very near the commercialization stage of its technology; therefore, the results of this investigation may have greater relevancy for the developing biomass industry.

The Case of Iogen

The Iogen Corporation is a Canadian biotech company that is a leader in scientific research to produce cellulose-based ethanol from straw, corn stover, and dedicated energy crops. Iogen's genetically modified enzyme process, enzymatic hydrolysis, produces sugars from the cellulose and hemicellulose portions of the biomass. The sugars can then be fermented with traditional yeast strains to produce ethanol. With financial investments from Petro Canada, the Canadian Government, Royal Dutch Shell, and Goldman Sachs (Brown, 2006; McCoy, 2006), Iogen is nearing commercialization of the technology. Currently, Iogen is investigating where to locate the first cellulose-to-ethanol plant. In this section we present the supply chain strategies with which Iogen is experimenting and examine them in the context of transaction cost economics.[1]

Iogen is targeting a processing plant that would require 1,500 tons per day of wheat straw feedstock to produce 45 million gallons of ethanol per year. The cost of such a plant will be \$300–\$400 million, nearly 10 times the cost of a similar corn-based ethanol facility (Brown, 2006). The feedstock requirement will pull from approximately 1,000 acres per day of land resources. This quantity requirement, in combination with the innate bulkiness of straw, makes an efficient supply chain

[1] We would like to thank an anonymous reviewer who points out that some of Iogen's location decisions may be an attempt to maximize rents from tax breaks and local government subsidies. Undoubtedly, rent seeking is an issue; however, it is unlikely to override the need for a long-term feedstock supply and well-organized supply chain.

strategy essential, and it may be the key organizational variable to successful commercialization.

At present, Iogen has signed production contracts with farmers in three locations, two in western Canada and one in Idaho, with the intention of building a processing facility in one of these locations, depending on the financial incentives from various levels of government (Pratt, 2005). Iogen has chosen to utilize standard production contracts signed with individual farmers. One feature of this relationship is that Iogen has a 5–6 year option to buy the producers' straw. Depending on where the plant is ultimately located, Iogen will exercise its option on contracts for that area and allow the other contracts to expire (Pratt).

Farmers have a choice between two pricing schemes: a fixed price option of approximately $10 per ton (laid in the field) or a variable price tied to the price of oil. In the variable pricing system, straw prices would then vary from $7–$15 per ton (laid in the field) depending on the price of crude oil (Pratt, 2005). In concept, variable pricing allows the farmer to manage input cost risk—fertilizer and diesel—which should also move with crude oil prices. Farmers have the option to sell all their straw in alternating years or half their straw every year, allowing them some flexibility to manage soil structure with the residue.

In terms of harvest and delivery, Iogen could have producers responsible for both functions by negotiating a delivered price. Instead, Iogen has chosen to rely on custom harvest and delivery through separate contracts (Pratt, 2005). Specifically, Iogen contracts with producers for only the biomass supply laid in the field, and relies on custom operators to complete harvest and delivery. Clearly, this approach requires two separate contracting relationships. A potential third option would have been to contract with producers for harvested biomass, but not the delivery function. Although not yet designed or offered, the harvest and delivery contracts will necessarily include access to the land, baling, collection, and storage of the bales, as well as timely delivery through the marketing year. Given the bulkiness of the feedstock and the land mass required, the collection, storage, and long-haul transport will create considerable costs. It is not perfectly clear why Iogen chose dual contracting arrangements, but TCE can provide some insight into this arrangement and how it might evolve.

Iogen's strategy of pursuing longer-term contracts may stem from the corporation's own asset specificity. Iogen's modified enzymes are feedstock specific, requiring a certain quantity and quality of wheat straw. Switching production to other feedstocks, such as barley straw, would require fairly expensive "re-tooling" of the enzymatic process. Therefore, Iogen will benefit from longer-term contracts, even with the higher administrative costs. From the wheat producer's standpoint, the production of straw laid in the field requires minimal additional asset investment beyond the swathing and harvest methods currently employed. So, the flexibility of low-cost spot markets may be their preferred marketing alternative. However, the firm that harvests, stores, and delivers straw will need to invest in specific assets to perform these functions, especially since the proposed locations are not in traditional straw- or hay-producing areas. Consequently, the custom harvester has high asset specificity and will desire longer-term contracts.

Based on these asset characteristics, TCE suggests that longer-term contracting arrangements should develop between Iogen and the custom harvesters. However, since the producers have low asset specificity, and an agronomic need to be flexible on harvesting straw, they may naturally prefer the low costs and flexibility associated with spot markets. These factors could prompt the development of a spot market for laid-in-the-field straw, where the custom harvester buys spot straw in the field and sells it under a long-term contract to Iogen. Of course, a number of alternative scenarios are possible, including the formation of straw harvesting and marketing cooperatives. Likewise, the development of new technological processes, such as mobile processing equipment, could alter asset specificity and hence the organizational structure. Still, TCE provides an economic roadmap for considering how the biomass supply chain may evolve.

Summary and Conclusions

This note takes an organization approach to introducing biomass supply chain strategies. First, the need for an organizational theory is demonstrated in the existing biomass and bioenergy literature. Second, a specific organization economics theory, transaction cost economics, is explained and applied to the biomass industry using the example of the Iogen Corporation.

Transaction cost economics suggests that a firm's level of asset specificity will determine its contracting preferences. Iogen's choice of dual long-term contracts with both producers and harvesters may stem from the asset rigidity of enzymatic hydrolysis. Under the dual system instigated by Iogen, harvesters—who invest in assets to harvest, store, and deliver straw—may also prefer longer-term contracts. However, producers—who make no incremental asset investment—will likely desire the flexibility of spot markets. Therefore, the supply chain structure could evolve to a spot market for in-the-field straw with long-term supply contracts between harvesters and Iogen. Alternatively, farmers could essentially share harvesting assets through the formation of a harvesting and marketing cooperative.

Regardless of the ultimate form, it is important that the supply chain evolve in an efficient manner so as not to create a barrier to commercialization. This research presents just one possible way to study and guide the development of this emerging supply chain. The bioenergy sector offers enormous economic potential for agriculture. Moreover, it represents a rare opportunity for academics to participate in the evolution of a new agricultural sector within a developed economy. Agricultural economists should be working closely with agribusiness leaders to overcome supply chain and other economic and organizational barriers facing the bioenergy industry.

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