EARLY CONTRACTUAL RELATIONSHIPS IN THE RENEWABLE ENERGY INDUSTRY: ASSESSING PARTIES' PREFERENCES FOR TIMELY SUSTAINABLE GROWTH

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ABSTRACT

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The motivation for this dissertation comes from early attempts to establish long-lasting relationships within the emerging supply chain for biomass-based electricity in the Midwest United States. Despite effort exerted by policy makers and government leaders (i.e. federal mandates and market facilitation), renewable electricity has yet to take off. Failure to perform is partially related to the inability of trading parties to devise effective mechanisms and incentive structures to govern biomass transactions in upstream links of the supply chain. In three essays, the present dissertation identifies deterring factors preventing the biomass-based electricity industry from developing and formulates mechanisms that are both effective and implementable from the perspective of supply chain participants.

Essay 1 studies biomass transactions in the Upper Peninsula of Michigan and examines why logging firms (i.e. biomass producers) and a dedicated renewable energy generator (i.e. biomass processors) have failed to accommodate private interests under specification contracts. The Essay borrows a theoretical framework from the incomplete contracts literature to explain that idiosyncratic assets and unforeseen market conditions led previously devised contracts out of the self-enforcing range. As a result, a significant potential was created for the energy generator to hold up logging firms by threatening to reduce its purchases unless logging firms reduced biomass prices. The problem is diagnosed as a hold-up problem (Klein 1996) and a feasible solution is presented. The use of credible commitments and collective action among logging firms could have reduced hold-up potential and led parties to exchange biomass more efficiently.

Combining the case study evidence to other deterring factors previously discussed in the literature, essay 2 and essay 3 examine preference data from agricultural producers – potential biomass suppliers – to elaborate mechanisms capable of motivating sustainable relationships. Essay 2 examines whether hesitation towards energy crops, presumably expressed by agricultural producers, emerges from stated preferences for crop attributes. Results indicate that producers are interested in growing crops holding key attributes also found in switchgrass (e.g. lower intensity of production practices when compared to corn/soybeans rotation systems), and that regional characteristics and farming capabilities influence agricultural producers' willingness to convert farmland into acres of switchgrass.

Essay 3 tackles the transaction problem identified in essay 1. The paper examines whether agricultural producers distinguish market situations with high hold-up potential from market situations with low hold-up potential; and whether contracts better equipped to deal with hold-up problems are preferred when such problems are credible. Results indicate that producers tend to misinterpret market conditions and prefer acreage-based contracts regardless of the hold-up potential. There is an indication, however, that propensity to adopt contracts capable of minimizing the negative effects of hold-up problems increases when these problems constitute credible threats.

In light of the results obtained throughout this dissertation, implications to energy crops and bioelectricity initiatives are offered to practitioners as they devise entry strategies in the biomass-based energy industry.

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I cannot miss the chance to thank all friends who made my life in Michigan more pleasant despite of the miserable winters. Each and every one of you will certainly be remembered, causing unexpected chuckles here and there as good memories come back to mind. A big thank you must be extended to my parents and family for providing strength and guiding me through perseverance to pursue this professional achievement. Special thanks goes to my wife, Marília, for her constant support, and for keeping my life balanced between work and leisure. I am forever grateful for her unrestricted support and friendship.

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INTRODUCTION

Over the past several years countless mass media have released articles about environmental disasters or human health threats related to production and use of fossil energy. Such articles shape public opinion, which seems to agree that renewable inputs must partially substitute for traditional sources of energy worldwide. Government leaders also seem to agree on the latter statement. Minutes of international meetings (UNFCCC 1998, UN 2002, UN 2012) indicate broad commitment of nations to promote production and consumption of renewable energy as well as reducing greenhouse gases (GHG) emissions. To mention a few initiatives, European Union (EU) countries are committed to reach 20% share of energy from renewable sources by 2020. In the United States (US), the Renewable Portfolio Standards (RPS) defines proportion goals of renewable electricity for 30 states with multiple deadlines.

Numerous scientific articles have analyzed the effectiveness of federal policies in reaching the goals intended by government leaders and desired by public opinion (Berry and Jaccard 2001, Menz 2005, Palmer and Burtraw 2005, Wiser et al. 2007, Carley 2009, Bird et al. 2011). In the US, these policy analyses provide great contribution but seldom explain why the federal RPS mandate or state-level programs reach mixed results (i.e. ability to reduce GHG emissions, participation of renewable inputs, ability to motivate economic development, job creation). Discussing whether policy outcomes are aligned with initial intentions is by all means important, but capturing what specific factors are preventing the bioenergy industry from gaining the expected momentum takes us to a higher level of comprehension. Therefore, it is safe to assert that the research agenda in the realm of the developing renewable energy industry in the US is far from complete.

Some scholars have taken the first steps to discuss critical factors associated with the development of sustainable relationships in bioenergy markets (Roos et al. 1999, Goldemberg 2004, Alexander et al. 2012). Results point out that stable transactions, dedicated transportation systems, sophisticated information flows, and economies of scale and scope in existing fossil energy industries constitute barriers to the establishment of renewable energy supply chains. Other authors add input substitution challenges and entry barriers for feedstock producers in upstream links of the supply chain (e.g. transactions between suppliers of biomass feedstock and generators of bioelectricity or advanced biofuels) to the list of establishment barriers (Sherrington et al. 2008).

It is in this context that the first essay of this dissertation emerges. Essay 1 examines early attempts of logging firms and a bioelectricity generator to trade biomass feedstock under contract arrangements. The primarily goals are to diagnose whether transaction challenges represent barriers to development and to propose a theory-based mechanism to overcome those challenges as the industry grows. Essay 1 uses a case study research methodology (Yin 2009) to analyze unsuccessful attempts of biomass producers and processors to conduct feedstock transactions in the Michigan Upper Peninsula. The article argues that logging firms are susceptible to hold-up problems (Williamson 1975, Goldberg 1976, Hart and Moore 1988) if complex production contracts or more vertically integrated governance strategies are not put into use; and that credible commitments (Williamson 1983) might introduce enough complexity to minimize the probability of hold-up potential and improve contract efficiency.

The literature in place, nevertheless, indicates that agricultural producers – perhaps the largest group of decision makers who can dedicate assets to energy crops – seem skeptical to growing energy crops. A recent study conducted in 12 southeastern states indicates that ‘hesitation’ has significant effects on willingness to grow energy crops and on farmland conversion (Qualls et al. 2012). Using a similar methodology, Hayden (2013) finds little interest of Michigan producers in renting out marginal land for production of energy crops even when the rental rate offered exceeds market rates for conventional field crops. Together these studies suggest that unsuccessful experiences lived by some biomass suppliers might have spread doubts and skepticism over broader populations of potential producers. Skepticism and hesitation might in fact have become two of the most important barriers to development.

The second and third essays of this dissertation search mechanisms and incentive structures capable of overcoming these developing barriers. Essay 2 proposes an innovative approach to examine whether agronomic or technical characteristics of energy crops underlie the hesitation argument discussed in the literature. The study starts from the working assumption that cropping systems are primary substitutes, fulfilling similar purposes of agricultural producers (e.g. seeking profit, maximizing utility). Each cropping system is interpreted as a fixed set of attributes with varying levels from which agricultural producers derive value. The paper conducts a discrete choice experiment in which agricultural producers make production decisions and are assumed to derive utility expectations as in the random utility maximization (RUM) model (McFadden 1974, 1981).

Differently from other studies that attempt to estimate agricultural producers' willingness to change land use, Essay 2 refines mean-based assumptions commonly made in simulation exercises and does not generalize sample specific findings. More specifically, some scholars simulate production decisions for a 'representative farm' and extrapolate results to the entire region of interest with little consideration for regional characteristics (Scheffran and BenDor 2009, Bocquého and Jacquet 2010, Sherrington and Moran 2010, Griffith et al. 2012). This paper recognizes that regional particularities as well as producers' heterogeneity regarding operational capabilities are important factors affecting production decisions.

Essay 3 complements Essay 2 and assesses whether hesitation towards energy crops is related to transaction challenges. This study seeks to measure (i) whether agricultural producers distinguish market conditions with high hold-up potential from those with low hold-up potential, and (ii) whether preference for contract provisions change as market conditions create more or less exposure to hold-up problems. A specific objective of Essay 3 is to examine whether contracts better equipped to deal with hold-up problems are preferred when such problems are credible.

The modern contract theory (Bolton and Dewatripont 2005), nevertheless, shows that the collective use of credible commitments – as discussed in Essay 1 – is not the only mechanism available to minimize probability of hold-up potential and consequently enhance efficiency of supply chain relationships. In addition to private enforcement capital mechanisms (Klein 1996), parties might draft specific performance contracts as presented in Aghion et al. (1994) or option contracts as in Nöldeke and Schmidt (1995). The literature in place also contends that the existence of effective mechanisms to overcome transaction challenges does not guarantee implementation (Peterson et al. 2001). From the empirical standpoint, the question that remains unanswered is whether offered solutions to hold-up problems sustain in real-world settings; and if so, which one is preferred by agricultural producers.

Taking these theory developments as motivation, Essay 3 uses preference data collected from agricultural producers located in Midwestern states to examine which (if any) theory-based solution to hold-up problems are likely to prevail. Due to major limitations regarding access to field data on contractual relationships and strategic alliances (Just and Wu 2009), Essay 3 relies on the random utility maximization (RUM) model (McFadden 1974, 1981) and estimates agricultural producers decisions from stated choice data.

Essay 3 contributes to the development of bioenergy markets on three fronts. On the empirical front, it digs deeper into contract provisions and highlights the contract specification that is more likely to motivate engagement of agricultural producers with energy crops. It also discusses whether preference for contract provisions varies as market conditions set the state for varying levels of hold-up potential. On the theoretical front, it provides valuable evidence to whether theory-driven solutions to hold-up problems suffice in the developing bioenergy industry. On the outreach front, results of the choice experiment contribute to extension programs of land grant universities by exposing bounded rational behavior of agricultural producers. With such information, effectiveness of orientation programs might be enhanced to educate agricultural producers of how to settle long-lasting relationships within the emerging bioenergy industry even if market conditions carry high probability of hold-up potential.

This dissertation proceeds as follows. Essay 1 examines early attempts of biomass suppliers and utilities of generation to engage in contractual partnerships to trade biomass feedstock. Essay 2 analyzes agricultural producers' preferences for cropping system attributes, ties results to characteristics of switchgrass, and identifies sub-regions within the Midwest United States where farmers are more likely to convert farmland into acres of switchgrass. Essay 3 examines producers' preferences for contract provisions and discusses whether the preferable structures are likely to sustain long-lasting relationships under market conditions with high hold-up potential or low hold-up potential. Finally, a concluding chapter offers closing remarks.

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ESSAY 1: ASSESSING TRANSACTION EFFICIENCY FOR BIOMASS: A CASE STUDY OF THE UPPER PENINSULA OF MICHIGAN

1. Introduction

Renewable energy has been extensively promoted for its potential to contribute to energy security, stable energy prices, and climate change mitigation (Khanna et al. 2008). In the state of Michigan such promotion has been pushed through the Renewable Energy Plan (REP[1]), enacted in 2008 by the Michigan Public Service Commission (MPSC) in concordance with the federal Renewable Portfolio Standards (RPS) program. The plan requires every distribution utility in the state to have 10% of the total supply generated from renewable sources (i.e. solar, wind, hydro, and biomass) by 2015 (MPSC 2012).

Among other implications the REP has motivated the establishment of new transaction flows within the wood value chain of Michigan. A great part of this development has taken place in the Upper Peninsula (UP) where the logging industry is predominant, enjoying synergies associated with economies of scale and scope as well as complementarity (Milgrom and Roberts 1992) of physical assets and human capital. To put into perspective, logging firms have identified the emerging biomass market as an opportunity for diversification. As these firms trade regularly with landowners and public parks to harvest trees, managers at logging firms have decided to invest in productive assets (i.e. chippers) for collection of forest residue[2], a source of energy that was commonly left in the field before the REP. In 2007, a year before the enactment of REP, there

[1] Specific information on this can be found at http://www.michigan.gov/mpsc/0,1607,7-159-16393---,00.html
[2] Forest residue is for instance trees rejected during logging operations (on account of trunk diameter and wood quality), standing wood decay, tree bark, and branches. Economic agents refer to forest residue as biomass.

were 23 commercial logging firms in the UP of Michigan. After four intense years of entry and exit, there were 25 logging firms in operation in 2011[3] (Manufacturers News Inc., 2013).

The decision of investing in new capacity was not exclusive to logging firms. Based on a positive interpretation of the REP, biomass processors have also invested in equipment (i.e. boilers, steam turbines, and generation units) to either reduce production costs (in the case of manufacturing firms) or profit from agreements with distribution utilities (in the case of independent power generators). Total capacity of power generation based on biomass increased from 433.6MW in 2007 to 475.6MW in 2011 – year in which the MPSC released the first report to the Michigan Senate and House of Representatives[4]. In the case of the UP of Michigan, installed capacity increased 40.7% – from 68.8MW in 2007 to 96.8MW in 2011 (EIA, 2013). Although such capacity growth is considerable, it came from the expansion of a single firm, probably indicating high barriers to entry due to expensive initial investments at the biomass processor's link of the value chain.

Performance figures, however, reveal a market that has not gained the momentum policymakers were expecting from the REP. Supply of renewable electricity has barely reached half of the mandatory goal with a little over one year to its deadline. In February 2014 the Commission reported that 5.4% of the electricity distributed across the state in 2012 was renewable (Quackenbush et al. 2014). Such slow development seems to derive from transaction problems within the emerging biomass value chain, which has consequently led to slow growth of biomass harvesting and processing capacity.

[3] During this time period eight firms entered the industry in the UP of Michigan and six firms exited. These figures capture the commercial loggers but may not account for individual loggers who are sole proprietors and do not have any permanent employees (Manufacturers News Inc., 2013).
[4] One firm entered the industry, four firms expanded, and one firm retrenched operation (EIA, 2013).

This paper focuses on biomass transactions in the UP of Michigan, aiming to identify the bottlenecks that are preventing the biomass-based electricity industry from developing faster in the state. This article conducts a qualitative analysis using a deductive approach (i) to examine trading relationships through the lenses of transaction cost economics (TCE), (ii) to interpret the underlying causes of transaction problems through the private enforcement capital model (Klein 1996), and (iii) to propose plausible alternatives to assist market development.

Our research work begins with an extensive and rather rich qualitative primary data collected from key agents of the woody biomass value chain (i.e. landowners, logging firms, and biomass processors) via focus group interviews. The data allows us to sketch the wood value chain structure in Michigan and identify five important biomass transactions. Interview data for each set of transactions are then examined using Williamson's framework (1996) to predict how trading parties should coordinate relationships in order to devise an efficient market. The paper proceeds by comparing theory predictions to observed coordination strategies. Data collected in focus group interviews are used as supporting arguments throughout the analysis.

After identifying a misalignment between theory prediction and reality, Klein's private enforcement capital model (1996) is put forward as a refinement of the classic Williamson's transaction cost model. The application of Klein's model takes our discussion beyond the traditional coordination strategy question and explains why logging firms and biomass processors face hold-up problems (Williamson 1975, Goldberg 1976, Hart and Moore 1988); an usual type of transaction problem in emerging markets when parties draft, to the best of their knowledge, incomplete contracts (Bolton and Dewatripont 2005). The article concludes with a proposed alternative strategy to alleviate hold-up problems. It is argued that a credible commitment mechanism (or hostages as defined by Schelling 1956 and Williamson 1983) might lead logging firms and biomass processors towards long-term sustainable partnerships. That would occur, however, only if managers at logging firms set aside some competitive behavior and engage in collaborative action.

This study is expected to contribute to the agribusiness literature on three important fronts: (i) it provides a comprehensive analytical assessment of transactions in the emerging biomass value chain; (ii) it diagnoses transaction problems based on two well known TCE studies (Williamson 1996, Klein 1996), task seldom seen in prior work; and (iii) it proposes a mechanism to alleviate hold-up problems while aligning suggested strategies to predictions of Williamson's model (1985; 1996) as well as placing transactions back on Klein's (1996) self-enforcing range of agreements.

The reminder of this paper is organized as follows. Next section describes the analytical methodology and primary data. Section three presents the biomass value chain, examines focus groups data based on TCE concepts (i.e. uncertainty, asset-specificity, complexity, and frequency), and compares the adopted coordination strategies to efficient coordination mechanisms as predicted through Williamson's framework (1996). Section four presents Klein's private enforcement capital model (1996) and its applied version to further explain why specification contracts expose logging firms and biomass processors to hold-up problems. In section four, a credible commitment mechanism is presented as an alternative to alleviate hold-up problems. Section five offers concluding remarks.

2. Analytical Methodology and Primary Data

This article uses a case study research methodology (Yin 2009) to identify the facts influencing coordination decisions in Michigan's emerging biomass value chain, interpret the problems associated with these decisions, and propose mechanisms to improve transaction efficiency. Case study corresponds to a research methodology that provides guidance for rigorous data collection, presentation and analysis. As Yin (2009) suggests, case study fits best for qualitative analysis if: (i) research focuses on *why* or *how* questions, (ii) research is interested in contemporary context, and (iii) investigator has no control over the set of events analyzed. Yin (2009) adds that case studies are appropriate for situations in which multiple sources of evidence and prior theoretical propositions are considered to guide data collection and analysis.

The methodology used in this article matches all three conditions mentioned above. As outside observers, we analyze *how* economic agents engage in transactions and what problems have caused concerns. Sequentially, TCE theory (Williamson 1985, 1996; Klein 1996) is used to examine *how* partnerships can overcome current transaction limitations and minimize probability of hold-up potential. Following the inductive approach (Corbin and Strauss 1990, Strauss and Corbin 1990, Peterson 2011) our analysis indicates that credible commitments are powerful mechanisms to solve some intractable misalignments, if specified correctly and collectively adopted.

Primary data were collected in two focus group sessions and one set of phone call interviews: one session with small-scale private landowners (SPLs), one session with large-scale commercial landowners (LCLs), and three phone call interviews with managers at biomass processing plants; all conducted in August 2011 (complete questionnaires are available from the authors upon request). Questionnaires were previously developed and tested with experts (i.e.

scholars, educators, and consultants) of the Michigan forestry industry. The main goal of the interviews was to examine the perceptions of participants about the challenges and opportunities in trading biomass.

3. Vertical coordination for biomass transactions

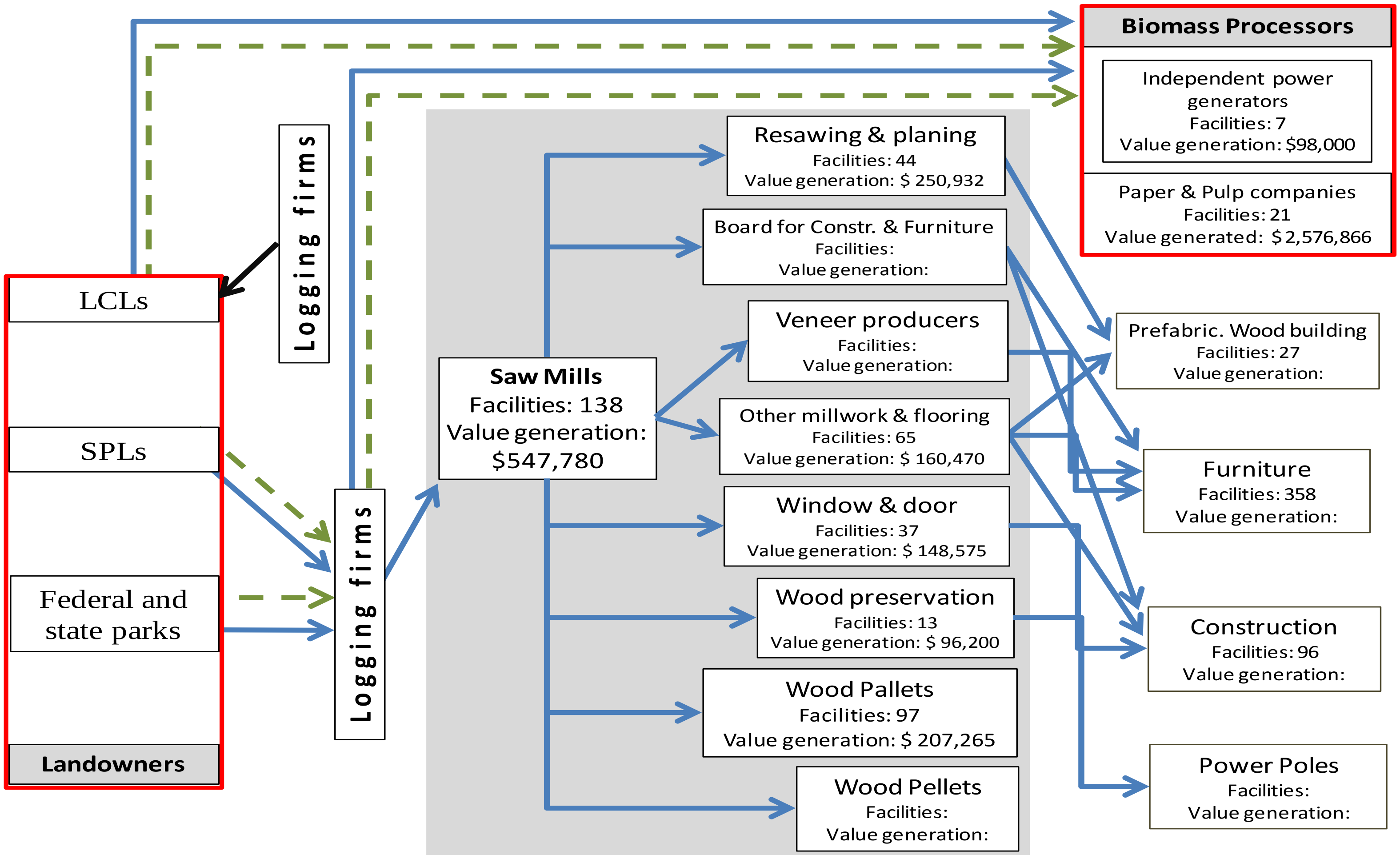
Before the enactment of the REP in 2008, harvesting rights for trees was the only service traded between landowners (SPLs, LCLs, and Public parks) and logging firms in Michigan. Once harvest was complete logging firms (or whoever maintains ownership over cut trees) would trade timber with either paper and pulp companies or saw milling firms. Paper and pulp companies would dedicate clean tree trunks (trunks without the natural bark) to pulp extraction and paper manufacture. Saw mills would process logs into lumber, which would be manufactured further into a broad array of outputs (e.g. pallets, boards for construction and furniture, veneer, windows and doors, heating pellets). In the state of Michigan, firms conducting fine processing are either independent or vertically integrated with saw milling firms (focus group interview, 2011). Processed lumber would then be traded with manufacturers of wooden goods (e.g. decorative panels, furniture, building contractors, power pole producers).

In 2008 the REP incentivized a set of new transactions between logging firms and landowners, and between logging firms and biomass processors (e.g. paper and pulp companies and independent power generators). Such transactions started to take place at the margin of existing log transactions in order to enjoy synergies and complementarity of specific assets. Transactions between logging firms and landowners, for instance, started to include rights to harvest forest residue, agreements between logging firms and paper and pulp companies included provisions for biomass (i.e. quantity, minimum quality, delivery schedule), and relationships between logging firms and independent power generators designed a new flow of feedstock that were unimportant before 2008.

Figure 1 sketches the structure of the wood value chain in Michigan once biomass transactions started to perform. Blue solid arrows represent transactions of log-derived throughputs. Green dashed arrows represent transactions of biomass feedstock. The dark arrow represents service agreements between LCLs and logging firms where timber and biomass ownership is maintained by LCLs after harvest. The grey shaded area indicates that saw mills and fine processing firms might be vertically integrated. Each box includes, to the best of the data available, the number of operating facilities and the aggregated capacity of value generation as of 2011 (NAICS[5], 2011). Secondary transactions of saw milling residue were deliberately omitted.

[5] North American Industrial Classification System. A single firm might own or control multiple facilities.

Figure 1: Scheme of the wood value chain in Michigan



Source: Developed by the authors. Dollar figures in thousands.
For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation

The emergence of biomass feedstock related transactions – those represented as green dashed and dark solid arrows in figure 1 – requests research on whether parties have chosen to govern transactions as TCE theory would predict. For this study, Williamson's framework (1996) is employed and begins with a comprehensive assessment of the underlying attributes of transactions (i.e. asset-specificity, uncertainty, complexity, and frequency).

The concept of asset specificity, the central concept in the TCE literature, has been understood as the degree at which an asset can be redeployed to alternative uses or by alternative users without sacrifice of productive value (Peterson et al. 2001). Uncertainty refers to the fact that economic agents live only by knowing something about the future (Knight 1921); and that the occurrence of certain events cannot be modeled through the assumption of a probability distribution. The concept of complexity refers to the difficulty level of programming activities associated in the transaction (Mahoney 1992). As complexity increases, exchange partners tend to be more vulnerable to contract breaches and therefore, are likely to incur additional safeguards in order to protect specific assets. Masten (1984) suggests that the greater the complexity of a transaction, the greater the likelihood of a party being bound to an inappropriate action of the counterparty. Frequency, the fourth attribute of transaction modeled by Williamson (1985, 1996), refers to how often a given transaction happens.

Based on a discrete categorization of these attributes, TCE predicts the coordination mechanism that is efficient in the sense of minimizing transaction costs as well as safeguarding specific assets against expropriation of quasi-rents (Klein et al. 1978; Shelanski and Klein 1995, Williamson 1998). Theory predictions are then compared to the strategies adopted in the market place.

3.1. Transactions between small-scale private landowners (SPLs) and logging firms

The first attribute to be considered is the specificity of productive assets. From the SPLs side, forestland is the asset dedicated to production of biomass. Focus group interviewees indicate that land has low specificity because any potential change of activities compromises little productive value. Interviewees in fact highlight that recreation (i.e. hunting games, vacation property) tends to be the primary use of SPLs' land, and that little effort is put into production of wood and biomass by the owners (focus group interviews, 2011). From the logging firms' perspective, chippers have low specificity as these assets might be utilized for numerous transactions. In other words, reallocating chippers from a transaction with SPL A to a transaction with SPL B incurs little cost to logging firms.

Uncertainty, the second attribute of transaction, is associated with procurement efforts, price discovery, and log/biomass productivity. As transactions are infrequent for the reasons discussed below, parties must exert some effort to discover potential partners and stumpage[6] prices, which tends to influence uncertainty of supply. Focus group representatives of logging firms also indicate that there is a considerable variation of production yield for both logs and biomass in SPLs' land. The low effort dedicated to production has been argued as the main factor causing production variation. Focus group interviewees, nevertheless, mention that there is little uncertainty of demand for the biomass harvested at SPLs' land, and that is primarily associated with the relative small amount of biomass collected. Hence, uncertainty seems to reach moderate levels for transactions between SPLs and logging firms.

Transactions were identified as of low complexity. Once trading parties agree on service schedule and payment methods, logging firms have little difficulties to program operational

[6] Stumpage refers to standing trees selected for harvest. Professional "foresters" (consultant agents) are often consulted by landowners to assist on price discovery and valuation.

activities. Putting it differently, once parties settle an agreement, harvesting activities become task-programmable and can be executed without major concerns to either trading party. Frequency of transactions between SPLs and logging firms, however, are occasional. According to focus group responses, SPLs are "unlikely to trade harvest rights more than once or twice in their lifetime". Some participants believe that infrequent transactions are closely related to the nature of forest plants and the size of SPLs' properties in the UP of Michigan. As trees take many years to mature and sophisticated management systems are unfeasible on small properties, frequency of transactions between SPLs and logging firms turns out to be occasional.

Based on Williamson's framework, it is plausible to predict that a spot market is the most efficient strategy to govern transactions in which assets are nonspecific, uncertainty reaches moderate levels, complexity is low, and frequency is occasional. Looking to reality, SPLs and logging firms seem to adopt the same coordination strategy: "most agreements [between SPLs and] loggers are one-time formal written agreements although handshake agreements are not uncommon" (focus group interview 2011). Trading parties, therefore, choose the most efficient coordination mechanism as predicted through Williamson's transaction cost economics model (1985 p.79, 1996). Table 1 summarizes the transaction between SPLs and logging firms and highlights both predicted and observed governance strategies.

Table 1: Predicted versus adopted governance structure and the underlying Williamson's attributes (1996)

Parties		Asset-Specificity	Uncertainty	Complexity	Frequency	Governance Structure	
						Predicted	Observed
SPLs	Logging companies	Low	Moderate	Low	Occasional	Spot Mkt.	Spot Mkt.
LCLs	Logging companies	Moderate	Low	Moderate	Recurrent	Prod. Ctr.	Prod. Ctr. or Spot Mkt.
F & S parks	Logging companies	Low	Low/moderate	Moderate	Moderate	Spot Mkt.	Spot Mkt. and Prod. Ctr.
LCLs	Biomass processors	Moderate/high	Low	High	Recurrent	Str. Alliance	Prod. Ctr.
Logging companies	Biomass processors	High/low	Low/moderate	High	Moderate	Str. Alliance	Prod. Ctr.

3.2. Transactions between large-scale commercial landowners (LCLs) and logging firms

Transactions between LCLs and logging firms are considerably different from transactions between SPLs and logging firms. Although chippers continue to be categorized as nonspecific assets for the reasons mentioned above – redeployment to an alternative exchange would cause little loss of productive value – forestland is now moderately specific to wood and biomass production. Differently from above, LCLs adopt numerous agricultural practices and exert high effort to enhance production efficiency. Focus group interviewees agree, therefore, that reallocating LCLs' forestland to a different use sacrifices productive value but such move would not reach prohibitive values. In that sense, LCLs forestland reaches a moderate degree of asset specificity.

Transactions between logging firms and LCLs are exposed to low levels of uncertainty. Focus group interviewees suggest that certain characteristics of LCLs' forestland such as high productivity and large extensions are factors lowering uncertainty of supply. Productivity of wood and biomass tends to be high and consistent because of the management practices often employed in LCLs' land and absent in SPL's land. Large production scale also facilitates procurement and discovery of counterparties. Additionally, both logging firms and LCLs are frequently well informed about stumpage prices, facilitating negotiation and decreasing uncertainty of supply (focus group interviews 2011).

Higher efficiency and expertise of LCLs, however, tends to increase complexity of transactions. Logging firms must follow a set of administrative and operational procedures if wood and biomass are to be harvested from LCLs' land. Focus group representatives of logging firms, however, demonstrate preference in trading with LCLs rather than SPLs even though the programmability of activities is more complex. "Loggers want to harvest from LCLs forestland in order to decrease uncertainty exposure associated with procurement" (...), even if a set of operational standards are required (focus group interview 2011).

Finally, property size also affects frequency of transactions. Logging firms and LCLs conduct recurrent transactions because production plots and operations are managed to allow frequent cuts. With moderate asset idiosyncrasy, low uncertainty, moderate complexity, and recurrent transactions Williamson's framework (1985 p. 79, 1996) plausibly suggests that production contracts would suffice to minimize transaction costs and safeguard moderately specific assets. Production contracts are superior because parties must devise enforceable conditions for exchange in order to coordinate moderately complex transactions and to prevent expropriation of quasi-rents.

Focus group interviewees indicate that actual transactions are often governed through production contracts, but spot market relationships are not unusual. Large-scale commercial landowners tend to maintain ownership over cut trees and biomass regardless of the coordination mechanism adopted (focus group interviews 2011). The use of spot markets might be explained by implementability constraints (Peterson et al. 2001) faced by LCLs. Although LCLs understand that production contracts return higher transaction efficiency, the absence of compatible partners (due to low operational skills or inability to follow operational standards, for example) prevents LCLs from using the optimal mechanism for all transactions with logging firms. Table 1 summarizes the underlying characteristics of transactions between LCLs and logging firms as well as the predicted and observed coordination strategies

3.3. Transactions between public parks and logging firms

When stumpage and biomass are traded between public parks and logging firms, asset specificity returns to low levels. Public land is primarily dedicated to environmental protection and recreation, so wood and biomass production are not prioritized (focus group interview 2011). In that sense, land as a productive asset has low specificity because any failure to trading wood and biomass would have minor impact on the value of public parks. Chippers, the piece of equipment used by logging firms to cut and gather biomass, are also unspecific as redeployment to a different harvest job would cause little loss of rents.

Uncertainty reaches low-to-moderate levels for transactions between public parks and logging firms. Due to the large extension of public parks in the UP of Michigan[7], harvest services are often in need. Discovery of stumpage prices require low effort as transactions are relatively frequent for agents on either trading side, leading to low uncertainty. Productivity and quality of stumpage, however, are variable and induce some uncertainty of supply. Once again, these facts are related to the low use of agricultural practices in public parks given that wood and biomass production are secondary objectives for this sub-group of landowners. Uncertainty of demand is of little concern because managers at logging firms are often willing to collect biomass: "the additional cost of running the chipper is lower than the value generated from selling biomass" (focus group interview 2011).

Considerable attention is given to operational procedures. When wood harvest is necessary such service must be performed with great care to avoid anthropic impact on protected areas: "requests for logging firms to use specific routes and forest tracks are not unusual" (focus group interview 2011). Harvest activities are programmable but certain requests to minimize

[7] State and federal land account for 49% of the total forest land in the UP of Michigan.

environmental interference introduce some degree of complexity. Finally, frequency of transactions is not as recurrent as transactions with LCLs, but tends to be more frequent than transactions between loggers and SPLs due to the extension of public parks.

Transaction cost economics indicates that spot markets should be used to coordinate transactions when assets carry little specificity, trades are relatively recurrent, and uncertainty is low-to-moderate. When transactions are complex, however, theory suggests that greater involvement should be preferred so parties may monitor *ex post* behavior and avoid unwanted outcomes (i.e. excessive environmental disturbance). Interestingly, actual transactions show that parties devise agreements that match theory predictions. Public parks appoint logging firms through reverse auctions, a classic example of spot market coordination, but draft performance contracts in which monitoring provisions are clearly specified.

Transactions unfold as follows: pre-specified contracts are firstly made available to logging firms; auctions are sequentially held among those who agree on contract terms; the logging firm with the lowest bid is the auction winner; the winner and park manager formally sign the harvesting agreement. Logging firms have incentive to behave as determined in contracts because park managers can monitor behavior and block participation of deviators in future auctions (focus group interviews 2011). The coordination mechanism adopted by public parks and logging firms is therefore unlikely to inflict problems to the development of the biomass value chain in Michigan as TCE prediction and parties' coordination strategies are aligned. Table 1 summaries transaction attributes, predicted governance mechanisms and implemented coordination strategies.

3.4. Transactions between large-scale commercial landowners (LCLs) and biomass processors

Specificity of assets takes a different set of arguments when biomass processors are involved in the transaction. If agreements with large-scale biomass suppliers breach, independent power generators incur losses associated with two main facts. First, the inability to generate steady supply of renewable electricity triggers expensive penalties imposed by distribution utilities. Because the latter group has a tight schedule to distribute clean electricity through the state, agreements often count with incentive provisions (fines) to motivate optimal behavior (personal interview 2011). Second, without stable access to biomass – coming primarily from LCLs – the value of assets used for electricity generation would be drastically expropriated. Power generation units tend to be meticulously designed to the type of input used: material density, granularity, moisture content, and temporal availability of biomass are some of the technical factors affecting specificity. This second fact alone indicates that power generating units are dedicated assets, a type of investment that would not be undertaken but for the prospect of selling significant amount of electricity.

Similar reasons would trigger losses at manufacturing firms (e.g. paper and pulp companies) that have invested in renewable electricity generators. Although these companies do not usually have downstream partners to trade electricity, and hence do not face potential penalties in case of short electricity supply, they also require steady generation of power. Their reason is rather maintain efficient levels of industrial operations and minimize usage of more expensive inputs (i.e. electricity acquired from distribution utilities).

Once biomass is the adopted input for in-house power generation, managers at manufacturing plants rely on its supply and optimize operational activities accordingly. But if unstable supply of biomass leads to recurrent power shortages, operations become compromised as manufacturing equipment lose productive efficiency (personal interview 2011). Managers may still consider backup plans such as generating coal-based electricity or acquiring electricity from the local utility. Such plans are, however, more expensive than generating continuous flows of biomass-based electricity. Moreover, neither plan is easily implementable because switching from one electricity source to the next involves a precise procedure that may damage manufacturing equipment if not properly performed (personal interview 2011). In the other end of the transaction, forestland dedicated to production of wood and biomass in LCLs' properties continues to be of moderate specificity for the reasons mentioned above. In that sense, the assets utilized in these transactions reach moderate-to-high degrees of specificity.

Uncertainty levels are low for biomass transactions between LCLs and processors. Quantity and quality of biomass tend to be consistent because of high efforts exerted by LCLs. Agricultural practices, for instance, lead to higher production efficiency and lower uncertainty of supply when compared to SPLs and public parks. Uncertainty of demand has been identified as a minor issue by interviewees because of the performance incentives in place (i.e. incentive provisions in contracts with independent power generators and the argument of industrial optimization in the case of manufacturing firms).

Continuous generation of power and steady supply of biomass also influence complexity of transactions between processors and LCLs. Incentive mechanisms are often devised to guarantee stable supply as independent power generators must meet precise contractual terms with distribution utilities. Manufacturing companies also attempt to devise these mechanisms to minimize acquisition of power from distribution grids – often more expensive (focus group interview 2011). Therefore, harvest activities and transportation schedules must follow specific programs, leading to complex transactions. Representatives of biomass processors indicate that incentives and monitoring mechanisms are well implemented when counterparties are LCLs. Economies of scale and better managerial skills when compared to small suppliers of biomass (i.e. logging firms) are plausible reasons for this argument (remote interviews 2011).

Finally, transactions are frequent between LCLs and biomass processors. That can be explained by the size of operations (and demanding levels of efficiency) in both ends of the transaction. With moderate to high degrees of idiosyncrasy, low uncertainty, high levels of complexity, and recurrent transactions, Williamson's framework would suggest that efficient transactions require hybrid strategies (Williamson 1998), such as relation-based alliance. Peterson et al. (2001) argue that hybrid coordination strategies are in order when *ex post* control are of high importance and courts of justice are incapable to verify parties' behavior, even if provisions are clearly specified in bilateral contracts. Such argument fits well for transactions between LCLs and biomass processors. Parties must not only match quality and quantity specifications but also follow precise schedules in order to maintain steady supply of biomass and generation of electricity. Courts would be unable to verify performance of parties regarding these provisions, even though they might be well stated in bilateral contracts. Relation-based alliances would then suffice as an efficient alternative to minimize negative effects of opportunism.

Actual transactions have been coordinated through specification contracts. Although the misalignment between theory prediction and observation might give birth to frictions, minimal problems have been reported by focus group participants and phone call interviewees. The mutual dependence of parties and the presence of moderate/high idiosyncratic assets in both sides of the trade might be the reasons leading to acceptable performance of specification contracts; especially in the UP of Michigan where there are few LCLs and biomass processors (focus group interviews

2011). Living up to the agreement let parties enjoy rents from specific assets while behaving opportunistically would trigger onerous losses to both trading sides. Table 1 reports the underlying attributes of transactions, the predicted governance mechanism and the strategy actually implemented by trading parties.

3.5. Transactions between logging firms and biomass processors

Transactions between logging firms and biomass processors are marked by an intense difference in the degree of asset specificity. Logging firms, from one side, own highly specific assets (i.e. chippers) for production of renewable electricity input. Specificity here is related to two main factors. First, chippers constitute a type of investment that would not be undertaken but for the prospect of selling large volume of biomass (focus group interview 2011). Interviewees agree on the previous statement especially because alternative uses or alternative users are scarce. Second, there are only three processors acquiring biomass in the UP of Michigan (one independent power generator in the Baraga County, one manufacturing firm in the Delta County, and one manufacturing firm in the Dickinson County), which are relatively far from each other.

The assets controlled by biomass processors in the other end of the transaction have low degrees of specificity. The underlying reason here is associated with the small amount of biomass each logging firm carries. Although biomass-based generators are designed to a specific function, the low volume of biomass hauled by a single firm is unlikely to affect stable generation of electricity and expose biomass processors to expropriation of rents (e.g. penalties from downstream partners, lack of industrial efficiency). In other words, biomass processors incur low costs if reallocation from one logging firm to another takes place. It is worth noting that the latter argument is not valid for relationships between processors and LCLs due to operational size and mutual dependability, as analyzed above.

The nature of operations at logging firms plays an important role to the level of uncertainty faced by trading parties. Logging firms often procure upstream partners because long-lasting relationships are seldom settled (except between LCLs and logging firms). That leads to unstable transactions and relatively uncertain supply of biomass. Moreover, biomass quality tends to be variable because of the lack of agricultural practices undertaken in SPLs' properties and public parks. Uncertainty of demand has been highlighted as of low importance (personal interview 2011). Not different from above, the REP policy and the interest of manufacturing firms to reduce use of expensive inputs maintain demand for biomass at high levels. Therefore, uncertainty levels equilibrate at low-to-moderate levels.

The necessity of processing firms to maintain stable generation of renewable electricity is the main fact leading managers to request stable supply of biomass. Such stability only happens if parties arrange a precise delivery schedule of activities (biomass harvest and transportation). The development of a refined operational plan, however, is of difficult execution because of the nature of operations at logging firms. As these firms must procure upstream partners and conduct harvesting operations without establishing long-lasting agreements, the programmability of activities is considerably compromised. Constrained management capability at logging firms is also a factor favoring high complexity because it tends to influence programmability of operational activities (personal interview 2011). Together these factors indicate that transactions are highly complex. Finally, frequency of transactions between a given pair of logging firm and biomass processor is moderate. Focus group participants explain that it cannot be more frequent than transactions between LCLs and processing firms but it is certainly more frequent than transactions between SPLs and logging firms (focus group interview 2011).

With a considerable difference in the degree of asset specificity between trading parties, low-to-moderate levels of uncertainty, high complexity, and moderately frequent transactions, Williamson's framework indicates that a hybrid alliance is necessary to obtain transaction efficiency. Relation-based alliance is of good use to balance risks and benefits emanating from different degrees of asset specificity (Peterson et al. 2001). Because logging firms are highly dependable on trades with biomass processors while the opposite is not the case, relation-based alliance as a hybrid mode of governance (Williamson 1998) creates room for definition of mutual objectives and safeguards against opportunism. Alliance is also functional to devise *ex post* control and manage uncertainty through a set of programmable tasks.

Actual transactions between logging firms and biomass processors, nevertheless, have used specification contracts instead. In concordance to theory predictions, focus group participants report that such coordination mechanism has not performed efficiently. Representatives of logging firms in particular contend that "contract specification has little meaning (...). A competing logger comes in, undercuts the agreed price and all of a sudden the processing firm offers a new price at its gate" (focus group interview 2011). Besides, biomass processors tend to penalize loggers who decide to take legal action to enforce breached contracts. Penalties take the shape of lock-out strategies and the plaintiff-logger is no longer accepted in future transactions with the defendant-processor. Table 1 summaries the underlying attributes of transactions, the TCE prediction, and the coordination mechanism adopted to govern transactions.

Different from the misalignment analyzed in transactions between biomass processors and LCLs, the misalignment here culminates in hold-up problems as discussed in-depth below. It is plausible to argue that the poor performance of relationships between logging firms and biomass processors is an important factor preventing the renewable electricity industry to develop faster in Michigan. Commentators yet suggest that the unsuccessful attempt of logging firms to supply biomass might have generated skepticism among potential small-scale suppliers located elsewhere in the state.

With a good understanding of where in the woody biomass value chain transactions have struggled to perform, next section introduces a model that pushes discussion further. The private enforcement capital model (Klein 1996) is employed to precisely explain why specification contract is not sufficient to govern sustainable transactions between logging firms and biomass processors. A theory-based mechanism is sequentially proposed to alleviate the existing transaction problem.

4. Private Enforcement Capital Model (Klein 1996)

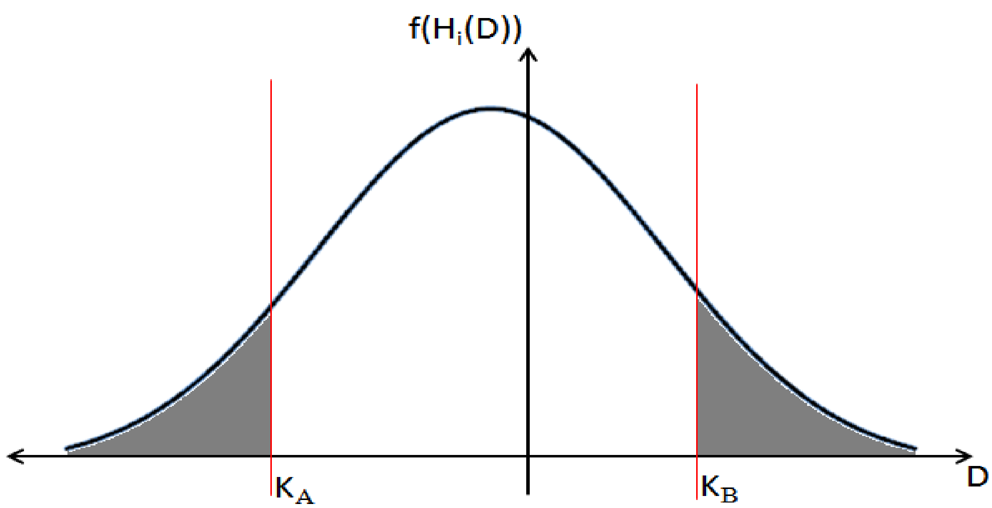
The private enforcement capital model is founded on prior substantial contributions. To mention, the literature of hold-up problems was open for discussion when Benjamin Klein (1996) introduced the concept of 'self-enforcing range' of contractual agreements and developed a framework for minimizing the probability of hold-up potential. In this sense, two concepts and a conditioning factor created foundations for the model of interest: (i) contract incompleteness, (ii) asset-specificity, and (iii) changes in market conditions. For the purpose of context, the concepts and conditioning factor are reviewed below.

Theorists and applied economists have long ago agreed that contracts are at best incomplete (Bolton and Dewatripont 2005) for two behavioral reasons. First, a contractual relationship is the result of interactions among people, and people's minds are constrained to their ability to access all relevant information promptly. Even if we humans were fully capable of doing so, the cost of accessing information and mapping out all potential outcomes and related states of nature would reach uneconomical marks. In other words, contracts are often conditional to 'bounded rationality' (Simon 1978). Second, a given party to trade needs not share strategic information (e.g. costs of production, procurement strategies, and hedging strategies) with its counterparty at the moment of contract negotiation. This latter reason defines the concept of 'asymmetric information' which emerges when one side is better informed about a transaction than the other (Arrow 1963). Together the concepts of bounded rationality and information asymmetry force any contract to be incomplete at its best.

The concept of asset specificity, as applied above, has been understood as the degree at which an asset can be redeployed to alternative uses and by alternative users without sacrifice of productive value (Peterson et al. 2001). Different types of specific-assets have been identified elsewhere (e.g. physical specific asset, dedicated asset, site specific asset) but such refinement of the TCE literature is not necessary for the purposes of Klein's model (1996). Finally, it is well accepted that the occurrence of contractual hold-ups is conditional to changes in market conditions. When changes in market conditions (e.g. unexpected decrease of demand, input scarceness) take place, a party may have incentive to hold up its counterparty in order to expropriate quasi-rents. It is worth mentioning that such change must not be *ex ante* contracted and *ex post* verifiable. That is, changes in market conditions only make a hold-up threat credible if the contract does not explicitly specify the contingency under question. If there are contracted provisions for a given market condition and the state of nature can be verified by courts of justice, the deviator is then subject to punishment. Thus, hold-up is unlikely to happen.

Taking these past contributions into consideration, the private enforcement capital model can then be defined as follows. Let two firms, A and B, be engaged in a transaction in which specification contract is the coordination mechanism. Also, assume that both firms own productive assets with equal or different degrees of specificity. Under the plausible assumption of incomplete contracts, allow decision makers at firms A and B to have expectations about future market conditions and associated gains or losses from hold-ups. For simplicity, assume that *ex post* change in market conditions is represented by a change in aggregate demand of an arbitrary good. Figure 2 illustrates a hypothetical probability distribution of the hold-up potential, $f(H_i(D))$ where *i* = A and B, and hold-up potential is a function of observable *ex post* demand. Moreover, let K_i be a threshold and for any $|k| > |K_i|$, firm *i* will hold up its counterparty.

Figure 2: Probability of hold-up potential



Source: Adapted from Klein (1996).

Intuitively, $|K_i|$ is the limiting market condition at which the contractual relationship sustains. It represents the zero net value between gains and losses of breaching the contract. More specifically, gains are returns a firm may have by holding up its counterparty; and losses include not only the loss of future rents but also the reputation loss in the marketplace. Hence, for any market condition k' falling between K_A and K_B (i.e. self-enforcing range), it is more costly than beneficial for either party to breach the contract so parties have incentive to live up to the agreement. For any market condition $k"$ falling in the outer region ($k" < K_A$ or $k" > K_B$), firm A has incentive to hold up B or firm B has incentive to hold up A, respectively. That is, there are more gains than losses in breaching the contract and holding up the counterparty. Therefore, the probability of firm A hold up B is $\int_{-\infty}^{K_A} f\big(H_A(D)\big)dD$. Similarly, the probability of firm B hold up A is $\int_{K_B}^{\infty} f(H_B(D))dD$.

In the lines of the model, the probability of hold-up can be changed by shifting K_A and K_B. That can be done by either increasing gains or decreasing losses at every transaction period. Numerous studies have discussed ways to shift thresholds K_A and K_B (Williamson 1983, Klein 1996, Hueth et al. 1999, Gow and Swinnen 2001, Shanoyan 2011). Next section explains why the use of credible commitments (Williamson 1983) could be used to minimize the probability of hold-up problems and, along with collective action, might increase transaction efficiency for biomass trading between loggers and processors in the UP of Michigan.

4.1. The Private Enforcement Capital Model, Applied

It is worthwhile to identify in the case the concepts of 'asset-specificity' and 'contract incompleteness' and the conditioning factor (i.e. change in market conditions). Once these pieces are recognized, it can be argued that logging firms are likely to hold up biomass processors if a given set of market conditions take place. The same argument can be used for biomass processors: managers at biomass processing firms are likely to hold up loggers if another set of market conditions emerge.

Logging firms and biomass processors have decided to invest in new productive assets (i.e. chippers and power generating equipment, respectively) as they expected that demand for renewable electricity would sharply increase once the REP was enacted in 2008. The expectation over demand for renewable electricity was so optimistic that new logging firms invested in chippers and entered the market seeking positive rents through sales of biomass feedstock[8]. Although entry did not happen in the processing side due to impeditive investment costs, a large expansion project took place in the UP of Michigan. More interestingly, parties invested in new assets without taking under consideration potential collaboration regarding supply chain issues; perhaps because of distrust already in place.

The intensive entry in the logging side and the expansion in the processing side ended up altering the initial degrees of asset-specificity and unbalancing probabilities of hold-ups. Investments made by biomass processors became less specific as new logging firms entered in the opposite side of business. Managers at processing firms could then easily redeploy a given contract from one logger to another without sacrificing the productive value of electricity generators. Conversely, logging firms that had also invested in specific physical assets became dedicated firms with few alternative uses for their chippers. As a result, investments undertaken by logging firms were not only specific to a certain operational activity but also became dedicated to a reduced number of biomass processors[9].

With investments in place, loggers and biomass processors drafted specification contracts for trading biomass. Focus group responses allow us to plausibly argue that contracts were drafted

[8] Exit started to occur when logging firms experienced opportunism from counterparties (focus group interviews 2011). In total, eight firms entered business between 2008 and 2011 and six firms exited during the same period (Manufacturers News Inc., 2013).
[9] As of 2011, there were three biomass processors in the UP of Michigan – two manufacturing firms and one independent power generator (EIA, 2013).

without either party having a good understanding of demand prospects for biomass-based electricity (focus group interview 2011). Contractual agreements were settled based on optimistic expectations of demand and without specifying how parties would behave (or how contracts should perform) if negative scenarios emerged. In light of the private enforcement capital model, trading parties ended up engaging in (incomplete) contracts in which incompleteness is represented by the absence of specific terms regarding demand for biomass-based electricity.

Figure 3 illustrates the situation in which loggers (L) and biomass processors (B) placed themselves. Aggregate demand (D) for renewable electricity is in the x-axis and probability of hold-up potential, $f(H_i(D))$, is in the y-axis. *Ex ante* expected demand for renewable electricity is represented by k^0.

Figure 3: Scenario preceding contract performance

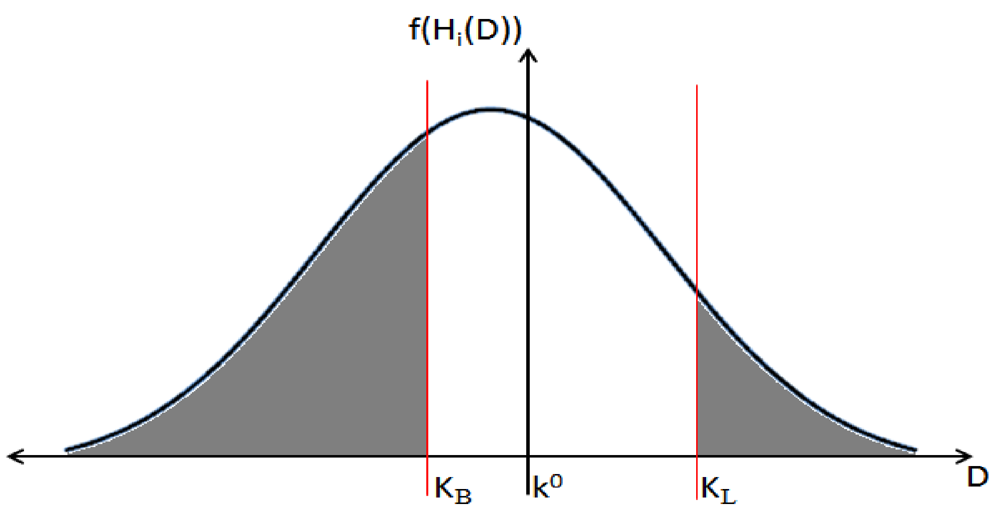


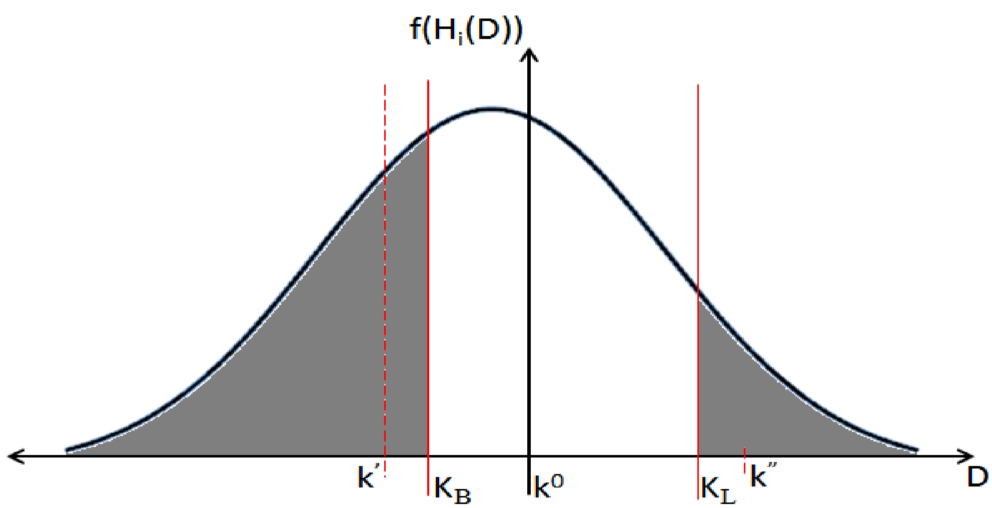
Figure 3 shows that parties set the arena for potential hold-up problems. Logging firms owned specific assets, which were exposed to expropriation of quasi-rents because the agreed contract carried little information of how parties should perform if future demand did not follow optimistic expectations. Therefore, K_B represents the minimum aggregate demand for renewable electricity that prevents a biomass processor from behaving opportunistically. Similarly, K_L represents the maximum demand for renewable electricity that maintains a logger loyal to the agreed contract.

The self-enforcing range (i.e. area below the probability density function and between K_B and K_L) is relatively small as neither party requested additional specifications nor used alternative mechanisms to enlarge or shift that range. Additionally, the probability of loggers to push hold-up threats forward was relatively small when compared to the probability of threats that biomass processors could impose over loggers. The first and main reason is related to the intensive entry in the logging sector and limited entry in the processing sector. Logging firms were highly exposed to expropriation of quasi-rents due to increased degree of asset-specificity of their investments. Conversely, biomass processors were less exposed to hold-up threats because contracts for biomass could be redeployed amongst numerous logging firms. Three additional reasons justify the relatively small capability of logging firms to hold up biomass processors: (i) constrained capacity of production; (ii) managerial independence; and (iii) lack of collective action.

The first reason suggests that the capacity of producing forest residue at a given logging firm falls far below the quantity demanded by any average-sized biomass-based electricity generator, which suggests that a logging firm alone has low bargaining power and low probability to hold up its counterparty. This is true unless the demand for renewable electricity downstream in the supply chain was exceptionally high and managers could not afford giving up any agreement of feedstock supply. The second and third reasons imply that numerous logging firms compete to supply biomass to a limited number of processors. As stated by a focus group participant, "logging firms are autonomous and seldom coordinate actions collectively" (focus group interview 2011).

Once contracts of supply started performing, parties realized that the real demand for renewable electricity was not as much as they expected ($k' < k^0$). In fact, such realization led participants to suggest that "(loggers) spent a lot of money to gear up for something that never showed up" (focus group interview 2011). 'Something that never showed up' refers to the optimistic demand that loggers were expecting. This aspect of the case can be analyzed as the change in market condition; the conditioning factor that turns hold-ups into credible threats. Figure 4 represents the real demand (k') such that $k' < K_B$. As mentioned above, a biomass processor holds up a logger because: (i) transactions have been conducted through incomplete contracts; (ii) the logger owns assets with high degree of idiosyncrasy; and (iii) the real demand for biomass-based electricity is below the K_B threshold.

Figure 4: Scenario once contracts started performing



Under this new scenario, commentators ask why trading parties were so optimistic about demand of renewable electricity in the first place; or what loggers failed to consider that could have otherwise led them to better estimates of demand. As mentioned by focus group interviewees, the REP and the existence of subsidies for renewable electricity motivated existing loggers (and entrant firms) to settle bilateral contracts without considering the use of alternative enforcing mechanisms to limit the probability of opportunistic behavior of biomass processors. In addition, decision makers at logging firms might have failed to observe the existence of substitute technologies that fulfill REP standards and are also eligible to receive subsidies. Windmills, for instance, have demonstrated to be more cost-effective than biomass-based generators in Michigan. The Michigan Public Service Commission (MPSC) reports that average contract price for wind-based electricity is $80.32/MWh against $98.94/MWh for biomass-based electricity (Quackenbush et al. 2013 p.26). Although, these prices are not conclusive about generation costs, they are strong indicators of cost effectiveness.

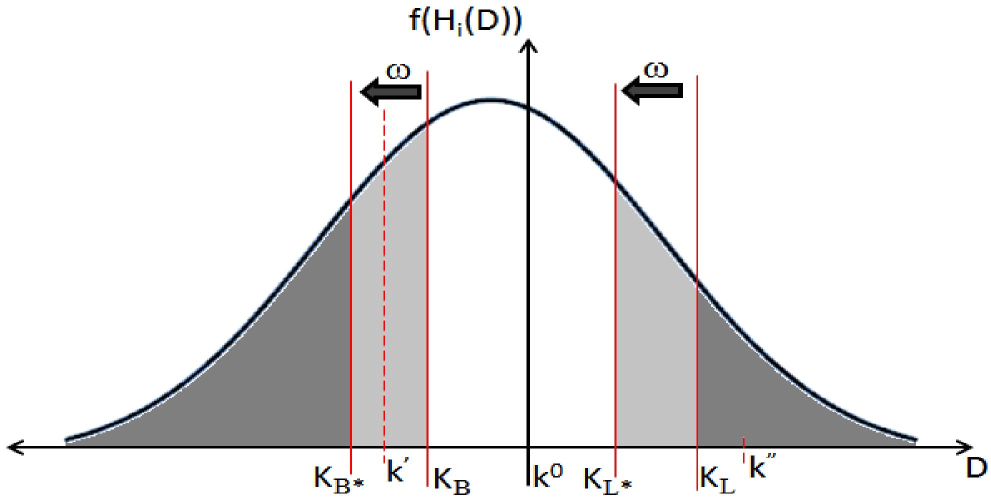
These supporting numbers let us reasonably argue that distribution utilities are likely to start procuring the most cost-effective technology, leaving the residual demand to be supplied by less cost-effective technologies. Decision makers at logging firms should therefore have considered the existence of substitute technologies and have drafted sale contracts based on the expected residual demand (i.e. the expected demand for biomass-based electricity) rather than the expected aggregate demand for renewable electricity.

An interesting conjecture is that if biomass-based electricity was the most cost-effective technology available in Michigan, and thereby real demand was just as high as the optimistic expectation of loggers; biomass processors would have honored contracts previously specified. A theoretical justification behind this argument is that the demand for biomass-based electricity would fall into the self-enforcing range and biomass processors would have little incentive to hold up loggers. Still, loggers would be likely to threaten biomass processors if demand for biomass-based electricity overcame the upper threshold K_L (i.e. $k" > K_L$) in picture 4. In this latter scenario biomass processors would, in turn, submit to the credible threat in order to maintain stable generation of renewable power and meet contractual specifications defined downstream with distribution utilities.

4.2. The Use of a Credible Commitment Mechanism: a necessary but not sufficient condition

Despite the fact that managers at logging firms could have decreased the probability of hold-up problems to occur by noticing the existence of more cost-effective technologies, and therefore having set their entry strategies based on the residual demand for biomass-based electricity; the expose to opportunism could be decreased if logging firms had requested credible commitments from biomass processors. Williamson (1983) refers to these commitments as 'hostages' because they force biomass processors to behave as agreed for the duration of the contract. In his words, credible commitments create reciprocity and serve to equalize the exposure of the parties, thereby reducing the incentive of the buyer to defect from the exchange (Williamson 1983 p. 531). The imposition of a hostage (ω) over biomass processors would shift thresholds K_B and K_L, and consequently re-set the self-enforcing range as follows in figure 5.

Figure 5: Potential scenario if hostages (ω) were *ex ante* implemented



With implementation of a credible commitment mechanism, a given biomass processor would have lower incentive to hold up the logger because hostages decrease his gains from doing so. Likewise, a given logger has less to lose if the biomass processor unfairly holds her up. Kreps and Wilson (1982) and Williamson (1983, 1998) suggest that the use of hostages enhance contractual efficiency by introducing mutual dependence between logger and biomass processor. In the case under analysis, hostages might represent upfront payments from biomass processors to logging firms; or even partial acquisition of the specific machinery used for collecting biomass. Klein (1996) suggests that the ideal size of hostages occurs when the probability of hold-up potential is equal for the logging firm and biomass processor.

However, even if a single strategist-logger had tried to request credible commitments from the biomass processor, the problem of hold-up potential would not have been entirely managed. The processor related in the transaction would have had little incentive to agree on paying a hostage to the strategist-logger knowing that other, less cautious, loggers did not use the same strategy.

It turns out that the biomass processor could still behave opportunistically (i.e. undercut feedstock prices) given that loggers play under almost perfect competitive conditions. A likely equilibrium for this strategy game is as follows: the biomass processor would have rejected the contract provision requested by the strategist-logger; instead, the processor would have signed contracts of supply with less cautious loggers who did not request credible commitments; the strategist-logger would not have entered into business; and the biomass processor would still expropriate quasi-rents from less cautious loggers by holding up their contracts. Therefore, the strategy of requesting credible commitments can be analyzed as a necessary but not sufficient condition to improve overall transaction efficiency in this emerging industry.

A sufficient condition would only obtain if loggers behaved collectively to adopt the strategy discussed above (i.e. request payment of hostages from the biomass processor). If loggers meet the definition of agricultural producers under the Capper-Volstead Act (1922), then they would be allowed to organize themselves as a cooperative, a type of hybrid mode of governance (Williamson 1998). Loggers would need to give up some managerial independence in order to share a common contract term regarding payment of hostages. If such collective action was in place before individual contracts were signed between loggers and biomass processors, a given processor would have little alternative but accept the request imposed by the cooperative. Acquiring feedstock outside the cooperative – perhaps from new entrants – would not be optimal because the cooperative might punish the processor by expropriating hostages (e.g. gain full ownership over the chippers). Cooperative members would also have little incentive to trade directly with biomass processor, especially because biomass feedstock is a homogeneous input.

It is worth to mention that collective action alone would be insufficient for improving contractual efficiency if loggers did not agree upon a solid hostage provision. That is, if loggers had formed a cooperative with the sole objective of defining a common sales price, biomass processors would still have incentive to acquire biomass from outsiders at lower prices, and consequently, hold up cooperative members. This observation rises against a remark (usually addressed by the classic industrial organization school of thought) that improving bargaining power implies better contractual outcome.

A similar argument fits if transactions between biomass processors and LCLs are taken as example. Although parties have traded biomass using specification contract (in which credible commitment provisions are omitted) it does not guarantee that they will continue to perform until expiration. Transactions are performing well merely because of the mutual dependence generated from moderate-to-high degrees of asset-specificity. However, if biomass processors could identify other large-scale suppliers capable of delivering a stable flow of biomass hold-up problems or other types of credible treats could still occur. Negative effects of opportunistic behavior would be minimized only if LCLs and biomass processors agreed on a credible commitment clause. Thus, collective action or large productive scale would imply higher transaction efficiency only if the correct set of strategies was agreed in the first place.

In the case of loggers, higher transaction efficiency would have obtained if loggers had not only organized themselves as a cooperative but also requested payment of hostages from the counterparty. This result meets the criticism once expressed by Goldberg and Erickson (1987 p.371): propositions [invoking market power] have impeded research on complex exchanges by providing superficially appealing answers that have discouraged search along more fruitful lines.

5. Conclusion

This paper conducts a qualitative analysis of biomass transactions in the emerging renewable electricity industry in Michigan. Through the lenses of TCE (Williamson 1985) and based on focus group/personal interviews, the four underlying attributes of transactions (i.e. asset-specificity, uncertainty, complexity and frequency) are examined to predict the most efficient coordination strategy. Predictions are then compared to actual coordination mechanisms for five biomass-related transactions. Our analysis indicates that while four sets of transactions seem to perform efficiently, transactions between logging firms and biomass processors do not. These trading parties face hold-up problems because specification contracts have been adopted to govern biomass transactions while TCE predicts that hybrid strategies (i.e. relation-based alliance or equity-based alliance) should be used instead.

We sequentially utilize Klein's private enforcement capital model (1996) to examine why specification contracts have exposed logging firms to hold-up problems. The generalized model is adjusted to represent multiple contractual relations between logging firms and biomass processors. We identify for the biomass transaction under question the concepts of idiosyncratic assets and incomplete contracts, two fundamental factors for the occurrence of hold-ups. The mismatch between expected aggregate demand for renewable electricity and real demand for biomass-based electricity is interpreted as the conditioning factor trigging hold-up problems.

It is then argued that the use of a credible commitment mechanism as defined in the literature (Williamson 1983) is a necessary but not sufficient condition to minimize probability of hold-up potential, and thereby improve contractual efficiency. The sufficient condition would only take place if such strategy was taken as a collective action – plausibly under a strategic alliance as allowed by the Capper-Volstead Act – by loggers. If that scenario emerged, biomass processors would have little gain from offering incentives to suppliers outside the alliance; alliance members would not be willing to trade directly with the biomass processor; and new entrants would have undercut prices rejected by the processor due to credible commitments made with the alliance. For that to happen, however, loggers would need to set aside some competitive behavior and engage in a collaborative action in order to improve transaction efficiency.

The case study of biomass trading in the UP of Michigan has also provided evidence to support the usefulness of the private enforcement capital model (Klein 1996). Although Williamson's framework suffices to indicate that logging firms and biomass processors should adopt a strategic alliance rather than specification contracts to govern transactions, it provides little guidance of how to implement the most efficient strategy. The private enforcement capital model (Klein 1996) complements Williamson's framework in the sense of creating grounds for implementing the new strategy. As one would expect, the analyses conducted through either model indicates that hybrid coordination strategy is superior to specification contract. Results derived from Klein's model nevertheless push discussion further and indicate that a sufficient solution for long-lasting relationships also requires credible commitments from the biomass processor.

Although the analyses conducted in this article do not intend to solve hold-up problems faced by logging firms, we hope it adequately explains how parties should conduct *ex ante* negotiations in order to devise stable relationships and efficient markets. Structured assessment of transaction attributes and holistic understanding of value chain relationships are essential for the development of solid coordination strategies. That is especially true when practitioners examine opportunities in emerging markets as it is demonstrated to be the case of the renewable energy industry in Michigan.

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ESSAY 2: ASSESSING FARMERS' WILLINGNESS TO PRODUCE ENERGY CROPS IN THE U.S. MIDWEST

1. Introduction

Governments have exerted effort to develop renewable energy industries in several countries around the globe. The public stimuli often take shape in mandates, as in the European Union (EU) and in the United States (US). In the EU, mandatory national targets consisting of 20% share of energy from renewable sources were implemented and are due by 2020. In the US, the Renewable Portfolio Standards (RPS) regulation – perhaps the most important measure taken in the country to promote clean energy – defines proportion goals of renewable electricity for 30 states with multiple deadlines.

As policy unfolds academics conduct research to assess its efficiency (Menz 2005, Palmer and Burtraw 2005, Lewis and Wiser 2007, Sanya 2009, Yin and Powers 2010, Bird et al. 2011, Palmer et al. 2011) and to discuss successful and unsuccessful cases (Goldemberg et al. 2004, Blok 2006, Zoellner et al. 2008, Fava Neves and Conejero 2010). Some results, nevertheless, indicate that the use of renewable sources for electric power generation has fallen short of expectations (Roos et al. 1999).

American states provide supporting examples for the reference above. The US states of Michigan and Wisconsin have mandated that power distribution utilities must supply end-consumers with 10% of renewable electricity (i.e. electricity based on renewable sources such as solar, wind, geothermal, micro-hydro[10], and biomass) by 2015. As of 2013, Michigan authorities

[10] with capacity of less than 60 megawatts.

reported that renewable electricity distributed within the state has barely reached half of the RPS mandate (MPSC 2014). Illinois and Minnesota have even higher goals. Utilities in these states are expected to distribute 25% renewable electricity by 2025.

The disparity between real and expected participation of renewables in the electricity portfolio of US states is associated with multiple deterring factors (Roos et al. 1999, Paulrud and Laitila 2010). Among those factors, farmland conversion and entry barriers for feedstock producers appear to play major roles in the establishment of sustainable relationships with upstream supply chain players (e.g. transactions between utilities of generation and suppliers of biomass feedstock). Previous research points out that uncertainty of biomass-based electricity demand, asymmetric information, and idiosyncratic assets turned initial attempts to trade renewable energy feedstock into hold-up problems with difficult solutions (Signorini et al. *forthcoming*). Factors related to downstream relationships seem less concerning. Transactions between biomass-based generating facilities and distribution utilities are likely to unfold smoothly because state authorities recognize the inability of renewable electricity to compete in price with electricity generated from traditional sources such as coal and petroleum. Hence, distribution utilities are often granted some leeway to surcharge end consumers in order to acquire less price-competitive power and meet federal requirements[11].

Contributions from two recent studies indicate that hesitation and skepticism among potential biomass suppliers might be important underlying reasons to these deterring factors. Using a double-hurdle modeling approach, Qualls et al. (2012) find significant effects of hesitation on willingness to grow switchgrass and convert farmland. Using similar analytical methods, Hayden (2013) concludes that only one third of the sampled population of landowners would be willing to

[11] Residential customers in Lansing, MI have $2.50 of surcharge added to their monthly bills. Residential customers in Milwaukee, WI might voluntarily subscribe to a renewable energy program starting at $4.50 per month.

rent out marginal land at $300 per acre to grow bioenergy crops. Such rates, however, far exceed rental rates being offered for conventional field crops in the analyzed region. Skepticism has also become an important driver of producers' lack of interest for energy crops (Rossi and Hinrichs 2011), especially because hold-up problems experienced by some tend to spread over broader populations. In the context of the developing biomass-based electricity industry, we borrow the definition of hesitation from Qualls et al. (2012): hesitation is the reluctance to adopt new production methods or crops until one sees them working for others. To draw unbiased estimates of agricultural producers' willingness to grow energy crops and to identify the underlying causes of skepticism and hesitation, this study proposes an estimating approach different from those found in the literature.

Much of the analysis of agricultural producers' willingness to change land use and willingness to supply biomass feedstock utilize simulation methods (Scheffran and BenDor 2009, Bocquého and Jacquet 2010, Sherrington and Moran 2010, Griffith et al. 2012) or survey-based choice experiments (Rahmani et al. 1996, Paulrud and Laitila 2010, Caldas et al. 2014). Other scholars examine farmers' intentions toward energy crops by analyzing focus group or structured interview responses (Mattison and Norris 2007, Sherrington et al. 2008, Villamil et al. 2008). Despite great contributions, these studies either simulate decisions using a 'representative farm' or estimate coefficients using data from randomly selected respondents. Our major concern is that results drawn from these approaches produce weak approximation of reality and little effective guidance to decision makers. That is because these results are often extrapolated to broad regions and important factors such as regional specificities and heterogeneity of farming operations tend to be neglected. The present study overcomes these limitations by conducting a choice experiment while recognizing that regional characteristics and types of operation lead to different potentials to convert conventional cropping systems into acres of energy crops.

In the realm of the developing bioelectricity industry in the US, the objective of this study is to refine past attempts to assess agricultural producers' willingness to grow energy crops. Specific objectives are to identify locations within six Midwestern states with RPS mandates (i.e. Illinois, Michigan, Minnesota, Missouri, Ohio, and Wisconsin) where energy crops have competitive advantages over conventional cropping systems; and to examine agricultural producers' preferences for cropping system attributes conditional on location and type of farming operation. This study uses a discrete choice experiment and incorporates agricultural producers' preference heterogeneity into two adapted versions of the random utility maximization (RUM) model (McFadden 1974). This study also compares the models in terms of relative performance as suggested by Fiebig et al. (2010). We design an unlabeled choice experiment that includes expected net margins along with other characterizing attributes of hypothetical cropping systems. The following sections explain how regions and types of farming operations were categorized according to energy crops substitution potential.

2. Identifying Regional Categories

Production regions are categorized by comparing predictions of net margins from a conventional cropping system to net margins that might be obtained from growing energy crops. As this study focuses on Midwestern states, corn-soybean rotation is assumed to be our conventional cropping system. Such assumption is reasonable since corn-soybean rotation is the most common cropping system in the Midwest United States. Corn and soybean together correspond to 79 percent of the total area planted in the states under analysis. The state of Illinois leads the rank with the highest share of farmland covered with corn or soybean (93 percent in 2013), followed by Ohio (82 percent), Minnesota (79 percent), Michigan and Wisconsin (70 percent), and finally Missouri (64 percent) (USDA/NASS 2014).

Because switchgrass (*Panicum virgatum*) is considered by some scholars the 'model biomass feedstock' (McLaughlin and Kszos 2005), we base our introductory analysis in estimates obtained elsewhere for this crop. We use public multi-level data from the United States Department of Agriculture (USDA) (i.e. National Agricultural Statistics Service (NASS) and Economic Research Service (ERS)) and from the Food and Agricultural Policy Research Institute (FAPRI/MU) to estimate net margins from corn-soybean rotation. Expected net margin (ENM) from switchgrass is based on results of highly cited research papers. Table 2 summarizes time granularity, spatial granularity, and sources for all data.

Table 2: Summary of data

	Time Granularity	**Spatial Granularity**	**Sources**
Corn-Soybean Rotation			
Yield	annual: 2007-2012	county-level	NASS QuickStats
Price forecast	annual: 2014-2019	national-level	FAPRI/MU
Farm Revenue	-		
Operating Costs	annual: 2007-2012	ERS farm resource regions	ERS Costs and Returns
Net Margin	-		
Switchgrass			
Farm Revenue			Griffith et al. (2012)
Operating Costs			Perrin et al. (2008)
Net Margin	-		

Corn and soybean yields (bushels/acre) are disaggregated at county-level. We assume that farms within a given county obtain production yields similar to those obtained in the past six years.

Price forecast ($/bushel) for corn and soybean is at best available for the country[12]. Hence, agricultural producers are assumed to receive the prices forecasted by FAPRI/MU for the next six years, regardless of the location. Farm revenue from corn-soybean rotation (dollars per acre) is computed based on the assumption that revenue comes half from corn sales and half from soybean sales. On the expenses side, operating cost (dollars per acre) is assumed to include expenditures for seed, fertilizer, chemicals, custom operations, fuel, lubricants, electricity, repairs, and interest on operating capital; and is available at the level of major production regions[13]. We also assume that operating costs (dollars per acre) reported by USDA/ERS remain stable for the next six years. Half of the operating costs are assumed to come from corn production and half comes from soybean production. Finally, ENM is computed based on the data and assumptions described above, corresponding to farm revenue minus operating cost.

Switchgrass farm revenue is assumed to be the same as the compensation offered to Eastern Tennessee agricultural producers engaged in the University of Tennessee Biofuels Initiative (UTBI). The UTBI contract compensates producers with an annual payment of $450 per acre (Griffith et al. 2012). Operating cost is retrieved from Perrin et al. (2008) and is assumed to be similar for all agricultural producers regardless of the location. The annualized cost per acre includes seed and planting operations, fertilizer and operations, weed control, harvesting operations, and rent. Estimates indicate that commercial-scale fields have an annualized cost of $133 per acre. The ENM from switchgrass is then calculated to be $317 per acre for all locations.

[12] Aggregated commodities prices should not be too concerning, however. The average of differences between highest and lowest state prices (as reported by USDA/NASS for 2007-2012) is $0.58 per bushel of corn and $0.62 per bushel of soybean. Such difference affects farm revenue in plus or minus $25 per acre.
[13] See US farm resource regions link for more information: http://webarchives.cdlib.org/sw1wp9v27r/http://ers.usda.gov/briefing/arms/resourceregions/resourceregions.htm

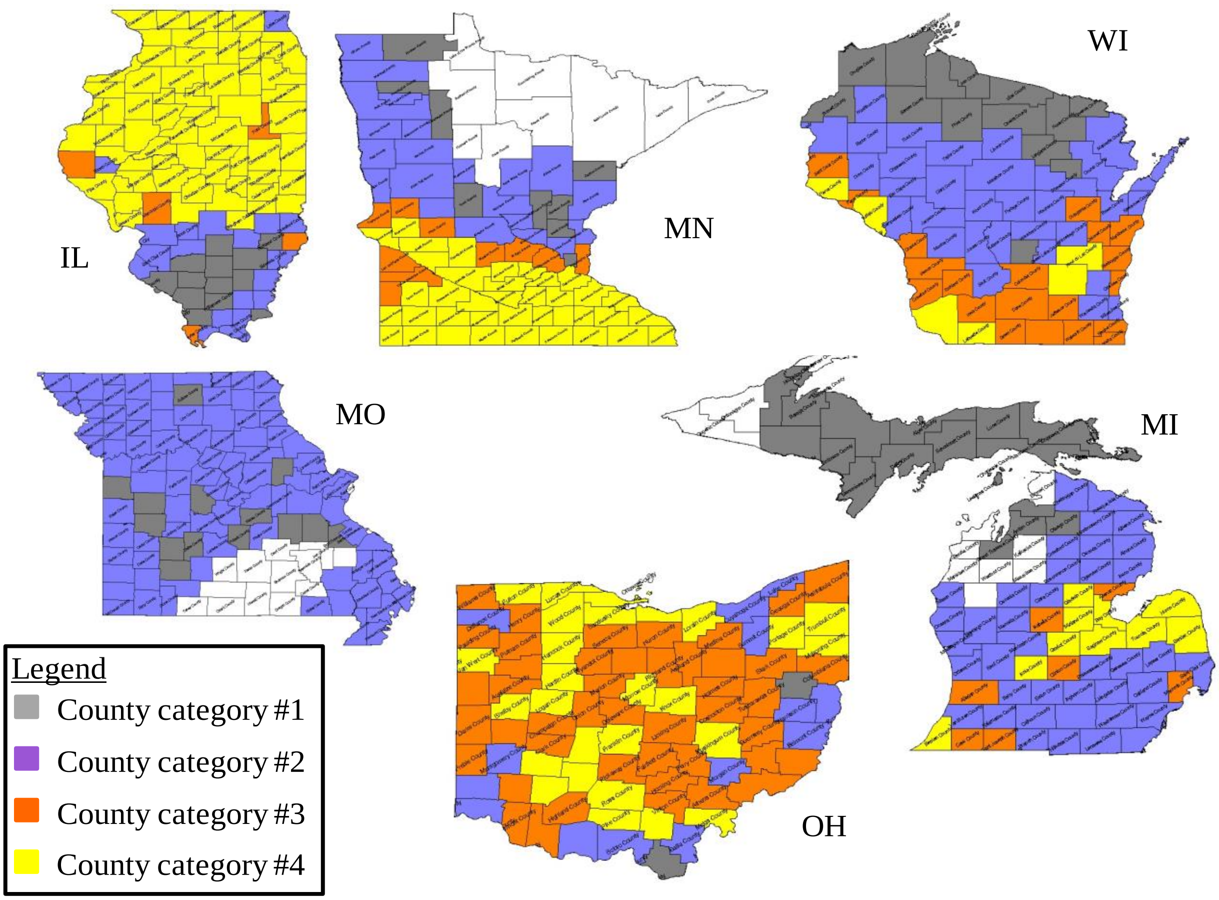
With expected county-level net margin values from corn-soybean rotation and expected net margin from switchgrass, a comparative analysis can be undertaken. Counties are divided into four categories: (1) counties that have ENM (over the next six years) from corn-soybean rotation 30 percent below state average; (2) those with ENM higher than 70 percent of state average but lower than ENM from switchgrass; (3) those with ENM from corn-soybean rotation above ENM from switchgrass but with two or more annual net margins from corn-soybean rotation below ENM from switchgrass; and (4) counties with at most one annual net margin from corn-soybean rotation below ENM from switchgrass. Table 3 summarizes the frequency of county categories per state and figure 6 displays their location within states.

Table 3: Expected Net Margin from corn-soybean rotation by State and by category (2014-2019). Frequency of county categories per state

	Corn-soybean rotation ENM by State	Categories (frequency)			
		(1)	(2)	(3)	(4)
Illinois	374.33	13	20	5	64
Michigan	295.79	9	35	7	10
Minnesota	353.89	8	22	10	38
Missouri	172.38	16	85	0	0
Ohio	355.02	2	13	43	28
Wisconsin	299.31	7	32	20	6
Sum of counties		55	207	85	146
ENM by category		173.65	241.01	351.53	410.52

In this study we hypothesize that agricultural producers’ willingness to dedicate farmland to energy crops is higher in regions where switchgrass presents comparative advantage over corn-soybean rotation systems for the next six years. More precisely, agricultural producers’ preference for energy crops is higher in counties categorized as (1) when compared to other county categories. The underlying reason here is that producers located in 1-counties might be searching for a cropping system with greater economic returns than corn-soybean rotation. Exceptions might occur in regions where such transition has already happened, such as in Northwest Michigan (fruit orchards), Central Missouri (livestock production), and Northeast Minnesota (timber and wood pulp production).

Figure 6: County categories per state



Source: Designed by the authors.

For similar reasons, we hypothesize that agricultural producers located in 2-counties or 3-counties will be more willing to grow switchgrass than producers located in 4-counties. That is, switchgrass will have lower probability of entering counties where corn-soybean systems generate high and stable annual revenues to growers. Our next hypothesis suggests that farmers located in counties categorized as (2) will have higher interest in growing switchgrass than farmers located in 3-counties. The reason here is that farmers exposed to low average returns from corn and soybean might be more willing to grow switchgrass than farmers who will trade stable returns from energy crops for slightly higher but volatile annual revenues from corn and soybean. Table 4 summarizes these null hypotheses.

Table 4: Null hypotheses: Willingness-to-grow (WTG)

H_o:
$WTG_1 > WTG_2 > WTG_3 > WTG_4$

3. Identifying Categories of Farming Operations

Farming operations are categorized based on agricultural producers' responses to the 2012 census of agriculture administered by USDA/NASS. Answers to section 29 ('Machinery and Equipment') of the census are used as proxy for farming capability. From these responses, agricultural producers are grouped depending on the ownership status over machinery – self-propelled grain combines and self-propelled forage harvesters or a set of three equipment to harvest forage (mower/rake/baler). Agricultural producers were grouped as follows: (A) those who own equipment to harvest grain as well as forage; (B) those who own equipment to harvest grain only; (C) those who own equipment to harvest forage only; and (D) those who own neither type of equipment. This categorization is only possible because the questionnaire used in this study was administered by USDA/NASS[14].

With farm operations categorized according to production capabilities, we hypothesize that agricultural producers who need to acquire machinery to grow energy crops are less willing to

[14] The agency did not disclose private information from census respondents but allowed us to sort the population of producers as described above.

dedicate farmland to switchgrass. The ultimate goal here is to test whether certain characteristics of farming operations such as ownership of machinery have significant effect on the likelihood of growing energy crops.

4. Research Methodology

Choice experiments simulate real-world situations in order to examine how individuals – in our case, agricultural producers – make decisions over available alternatives with varying characteristics. Agricultural producers derive net margin expectations and make production decisions based on past experience, peer influence, household constraints, agronomic characteristic of cropping systems, and market information available *ex ante* (Ross and Signorini 2013). In our context, cropping systems can be interpreted as sets of attributes which express value to decision makers. Previous focus group interviews with agricultural producers in Michigan (Ross and Signorini 2013) highlight six multi-level pecuniary and non-pecuniary attributes with major impact on how agricultural producers make planting decisions. Those attributes are: expected net margin per acre per year, net margin variance, intensity of production practices (e.g. tillage, fertilization, pest control, and irrigation), coordination arrangement, whether the crop under analysis requires acquisition of machinery, and choice of neighbor farmers.

In the choice experiment, ENM takes four levels: \$200/acre/year, \$260/acre/year, \$320/acre/year, or \$400/acre/year. These values attempt to cover the most likely range of ENM from conventional cropping systems and switchgrass in Midwestern states. Revenue variance takes three levels: '± 40%', '± 25%', or '± 10%'. Intensity of production practices takes two levels: 'High' or 'Low'. Coordination arrangement takes three levels: 'Cooperative', 'Production

Contract', or 'Spot Market'. The choice made by neighbor producers takes two levels: 'Crop A' or 'Crop B'. Finally, requirement of machinery is included in the choice experiment but its levels do not vary randomly. The levels are rather adjusted depending on the respondent's category of farming operation. Table 5 outlines the attributes and levels used in the experiment.

Table 5: Attributes and levels used in the choice experiment

Attributes	Levels
Revenue per acre per year	\$200/acre/year \$260/acre/year \$320/acre/year \$400/acre/year
Revenue variance	$\pm$ 40% $\pm$ 25% $\pm$ 10%
Intensity of production practices	High Low
Vertical coordination	Cooperative Production Contract Spot Market
Choice of neighbor producers	Crop A Crop B
Requires acquisition of specific machinery[15]	Yes No

Differently from other studies using choice experiment to examine producers' willingness to grow energy crops, this study takes an unlabeled approach. Without stating the crops' name, agricultural producers are requested to respond in a more abstract fashion, leading to skepticism-free estimates. Switchgrass and corn-soybean rotation can be identified from the attribute levels, however. The literature in place points out that switchgrass requires less intensive production practices when compared to corn and soybean crops (Khanna et al. 2008). FAPRI data corroborates

[15] The levels for this attribute do not vary randomly. They rather vary in function of the respondents' production capabilities and levels of 'intensity of production practices'.

with this fact and indicates that forage crops (e.g. Alfalfa – *Medicago sativa*) require 31% less labor time and effort to reach average yield than corn-soybean rotation does. Hence, we use the 'intensity of production practices' attribute as an indicator of the cropping systems included in a given choice scenario: a system characterized with 'low' intensity of production practices connotes switchgrass and a system qualified with 'high' intensity of practices implicitly refers to corn/soybean rotation.

Using this identification and the machinery ownership status of agricultural producers, surveys are adjusted to capture realistic preferences. For example if the questionnaire is to be answered by a producer who falls into category B (i.e. owns equipment to harvest grain only), the crop alternative characterized by 'low' intensity of production practices (i.e. representing switchgrass) should always have a 'yes' for 'requires acquisition of machinery' and a 'no' if the intensity of production practices indicates 'high'. Likewise, if the questionnaire is to be answered by an A-producer (i.e. owns equipment to harvest grain as well as forage), there should be a 'no' for 'requires acquisition of machinery' regardless of the alternative crop.

The unlabeled experiment uses an efficient fractional factorial design, which accounts for two-way interactions between county category dummies and cropping system attributes. The OPTEX procedure in SAS was used to define 36 choice scenarios and divide them into four blocks[16]. The blocking strategy was defined to decrease the number of scenarios presented to agricultural producers and reduce bias due to fatigue. Hence, each survey respondent was presented with nine different choice scenarios featuring two generic cropping systems (labeled 'crop rotation A' and 'crop rotation B') and an opt-out alternative (labeled 'neither'). By including the opt-out alternative, we remove the market participation assumption and recognize that

[16] The experimental design obtained an optimal D-efficiency value of 97.92.

agricultural producers might choose not to farm if they are restricted to choose from the alternatives presented (Adamowicz et al. 1998). Figure 7 (appendix A) provides an example of choice scenario used in the experiment.

The data used in this study was collected from a mail survey administered through USDA/NASS. The survey was sent to 4,216 agricultural producers who met the following criteria. First, producers must have responded to the 2012 Census of Agriculture. This criterion implies that the producer is listed in the USDA/NASS data bank. Second, agricultural producers must have reported farm income of $10,000.00 or more in 2012 to be eligible as survey respondents. This criterion limits the population of producers to professional individuals and excludes those who grow crops for leisure. Although researchers use different techniques to obtain representative responses from professional producers, such criterion is also found in other survey-based studies (Jensen et al. 2007, Paulrud and Laitila 2010, Hayden 2013). Third, agricultural producers must have reported 'value of sales' above $5,000.00 in section 6 ('field crops') and/or section 7 ('hay and forage crops') of the 2012 census. This criterion seeks to include farmers who produce grains and/or forage crops aiming economic gains while excluding those focused on other businesses. This criterion also tries to exclude large dairy facilities, for example, that might obtain some profit from selling leftover hay bales. Finally, the amount of grain and/or forage produced in 2012 and reported in the Census must have been produced within the counties of interest. All these criteria were precisely verified prior to the first mailing of the survey.

Eligible producers were randomly selected by the USDA/NASS within each county category rather than randomly selected across the entire region under analysis. The objective here is to obtain a balanced dataset with similar number of observations for each county category, leading to a consistent statistical analysis of agricultural producers' preferences while controlling for regional specificities. Descriptive statistics of demographic characteristics for the survey sample and for the population of farmers, who meet the three research criteria mentioned above, are presented in Table 6.

In total each agricultural producer received two letters in the mail and a phone call. The first correspondence contained a cover letter explaining the purpose of the study and a copy of the survey with the choice experiment. The second correspondence was sent two weeks after the first aiming to reinforce the importance of the study. It included a new copy of the cover letter and a new copy of the survey. Finally, phone calls were made a week after the second mailing to those participants who had not yet returned the surveys. In total 294 valid surveys were obtained, leading to a 7% response rate[17]. Almost all returned surveys were filled completely, yielding a statistical sample of 2519 observations (294 surveys X 9 choice scenarios, approximately). Survey sample is available from the authors upon request. The dataset is distributed across county categories as follows: 21% of the choices over cropping systems were stated by agricultural producers located in 1-counties; 29% from producers located in county category 2; 26% were made by producers from county category 3; and 24% from agricultural producers located in county category 4.

It is worth noting that the obtained sample appears to be a good representation of the population. Table 6 below indicates that the summary statistics of experience, age, farm income participation, gender, retirement status, and engagement of producers in renewable energy enterprises are similar for sample and population. There are slight divergences for harvested acres, however. While the sample has an overall mean of 390 acres harvested in 2012, the population seems to have harvested 16% more land on average. Except for producers sampled in county category 2, survey respondents appear to have harvested fewer acres than the population of their

[17] The response rate achieved here is comparable to other studies. Looking at a similar research question Khanna et al. (2014) obtained 424 usable responses from 4800 surveys, leading to 8.8% response rate.

corresponding counties. The distribution of harvested acres is also more disperse for the population than it is for the sample.

Table 6: Demographic statistics

	Sample	Population		Obs.
Size	294 *(persons)*	656,917		2519 *(n)*
- county cat. 1	63	56,852		535
- county cat. 2	84	278,816		740
- county cat. 3	77	134,056		647
- county cat. 4	70	187,193		597
Net Margin Revealed	229.90 (mean)			
- county cat. 1	152.69			
- county cat. 2	211.60			
- county cat. 3	276.12			
- county cat. 4	264.73			
Regional Rent Price	147.93 (mean)			
- county cat. 1	83.85			
- county cat. 2	135.42			
- county cat. 3	175.70			
- county cat. 4	197.29			
Acreage	390.2 ± 585.9	451.98 ±746.37	(mean ± st. dev.)	
- county cat. 1	246.53	357.87		
- county cat. 2	460.09	450.69		
- county cat. 3	385.13	427.70		
- county cat. 4	446.90	518.39		
Experience (years)	29.6 ± 15.7	30.3 ±15.06	(mean ± st. dev.)	
- county cat. 1	30.33	30.45		
- county cat. 2	29.23	30.14		
- county cat. 3	31.94	30.52		
- county cat. 4	26.90	30.35		
Age	58.4 ± 13.9	59.79 ±13.31	(mean ± st. dev.)	
- county cat. 1	58.91	60.40		
- county cat. 2	60.48	60.14		
- county cat. 3	58.06	59.45		
- county cat. 4	55.99	59.31		

Table 6 (cont'd)

	Sample	Population		Obs.
Farm Income %	47% ± 35%	48% ±36%	(mean ± st. dev.)	
- county cat. 1	38%	40%		
- county cat. 2	48%	46%		
- county cat. 3	53%	49%		
- county cat. 4	50%	54%		
Gender				
- male	96.6%	96.1%		
- female	3.4%	3.9%		
Retired?				
- yes	18%	19.6%		

4.1. The Model

The statistical model used in this article to analyze decision data relies on random utility theory (McFadden 1974, 1981). Agricultural producers are assumed to maximize utility by choosing from a hypothetical set of two cropping systems available to them before the planting season. Following Lancaster (1966), system alternatives are comprised of a number of attributes that both agricultural producers and analyst can observe. Let S_{it} denote the set of system alternatives (indexed *j*) available to agricultural producer i in choice scenario t. Let $\boldsymbol{x}_{ijt}$ be the vector of attributes that take on various levels for each system alternative j in choice scenario t. Also, let U_{ijt} be the utility function of agricultural producer i from choosing cropping system $j \in S_{it}$ in choice scenario t.

The utility function is assumed to be of the following form:

$$U_{ijt} = v_{ijt} + \varepsilon_{ijt}, \tag{1}$$

where v_{ijt} is the deterministic term and ε_{ijt} is the stochastic term. While the latter captures cropping system attributes observed by agricultural producer i but unobserved by the analyst, the former contains attributes observed by both producer and analyst. The stochastic term is assumed to be independent of v_{ijt} and can be argued as agricultural producers' heterogeneity in preferences (Keane 1997) for unobserved characteristics of cropping systems. Regarding the deterministic term, agricultural producer i has preferences for net margins, risk exposure, and other non-pecuniary attributes. Let v_{ijt} be linear in parameters as follows:

$$v_{ijt} = \boldsymbol{\beta}\boldsymbol{x}_{ijt}, \tag{2}$$

where $\boldsymbol{\beta}$ is a vector of utility weights measuring N, and $\boldsymbol{x}_{ijt}$ a vector of equal length N measuring the levels of each attribute for cropping system j. Plugging (2) into (1) we have:

$$U_{ijt} = \boldsymbol{\beta}\boldsymbol{x}_{ijt} + \varepsilon_{ijt}, \tag{3}$$

Hence, agricultural producer i chooses from a set of alternative cropping systems in order to maximize utility. But because the analyst cannot observe ε_{ijt}, an informed assumption regarding its distribution must be made so estimates resulting from stated decisions can be obtained. A convenient and often made set of assumptions regarding ε_{ijt} is that it is distributed identically and independently across individuals and follows a Glumbel distribution (ε_{ijt} ~ i.i.d. Glumbel or extreme value type I, in short). The basic multinomial logit (MNL) model (McFadden 1974) for the probability that agricultural producer i chooses cropping alternative c when presented with scenario t can be written as:

$$P_{ict} = Pr\left\{U_{ict} = \max_{j \in S} U_{ijt}\right\} = \frac{exp\,(\boldsymbol{\beta}\boldsymbol{x}_{ict})}{\sum_{j \in S} exp\,(\boldsymbol{\beta}\boldsymbol{x}_{ijt})} \tag{4}$$

The literature in place has, however, sought to refine McFadden's seminal model in three main fronts: (i) addition of heterogeneity in preferences for observed attributes; (ii) inclusion of preference heterogeneity for unobserved attributes (Keane 1997); and (iii) correlation of observed attributes[18]. The first concern has led scholars to propose and apply the random parameters logit (RPL) model, which is appealing to practitioners due to its ease of use (Fiebig et al. 2010). In this case utility weights are assumed to be random variables following a pre-determined distribution. When applied, the RPL model modifies equation 3 as follows:

$$U_{ijt} = (\boldsymbol{\beta} + \boldsymbol{\gamma}_i)\boldsymbol{x}_{ijt} + \varepsilon_{ijt}, \tag{5}$$

where $\boldsymbol{\beta}$ is the vector of mean utility weights and $\boldsymbol{\gamma}_i$ is the vector of individual i-specific deviations from the mean weight. It is worth to note that the utility weight on net margin is commonly kept as a fixed variable rather than random (Goett et al. 2000, Morey and Rossmann 2003). Such restriction has to do with identification of WTA estimates, calculated subsequently to model estimation. The second concern serves as motivation for the scaled multinomial logit (S-MNL) model, which modifies equation 3 as below:

$$U_{ijt} = \boldsymbol{\beta}\boldsymbol{x}_{ijt} + {}^{\varepsilon_{ijt}}/_{\sigma_i}, \tag{6}$$

where σ_i varies across agricultural producers and represents individual-specific scale in the stochastic term. The scale parameter σ is commonly normalized to 1 in order to allow model estimation. The S-MNL model takes the following form:

$$U_{ijt} = (\boldsymbol{\beta}\sigma_i)\boldsymbol{x}_{ijt} + \varepsilon_{ijt} \tag{7}$$

[18] Other refinements to McFadden's original MNL model have recently been proposed such as relaxing the linear utility assumption or estimating preference models in WTP-space. Although we recognize the importance of these advances, the purpose of our argument is to call attention to refinements that have been tested in several empirical studies and are now widely accepted in the literature.

The third and final concern regarding McFadden's model is whether or not observed attributes should be correlated (Revelt and Train 1998, Scarpa and Del Giudice 2004). While most scholars argue that adding this flexibility tends to enhance goodness of fit, others explain that complex models may prevent its implementation due to the rapid increase in number of parameters (Louviere et al. 2000, Train 2009). In other words, allowing parameters to correlate freely in complex models forces the number of parameters to increase rather fast, turning estimation unfeasible.

Besides these three research fronts, it is worth mentioning that choice behavior specialists have been quite active developing new models and discussing new approaches. A model that has received recent attention is the generalized multinomial logit (G-MNL) model (Fiebig et al. 2010) which incorporates individual deviations to utility weights – as in the RPL model – and individual specific scale heterogeneity – as in the S-MNL model – into the same model. More specifically, the G-MNL model combines equations 5 and 7 and is presented in equation 8.

$$U_{ijt} = [\boldsymbol{\beta}\boldsymbol{\sigma}_i + \delta\boldsymbol{\gamma}_i + (1-\delta)\boldsymbol{\gamma}_i\boldsymbol{\sigma}_i]\boldsymbol{x}_{ijt} + \varepsilon_{ijt} \tag{8}$$

Scale factor σ_i and the deviations to mean utility weights $\boldsymbol{\gamma}_i$ take the same descriptions provided above. The new variable δ captures the proportions of preference heterogeneity associated with scale factor σ or individual-specific deviation γ[19].

There are strong criticisms against the models presented in equations 5, 7 and 8, however. Authors argue that the utility weight on net margin (or revenue) should be treated as random variables, just as the utility weights related to other attributes are. The underlying reason is that unobserved socioeconomic characteristics are likely to influence individuals to respond differently

[19] For a comprehensive treatment of the G-MNL model, please refer to Fiebig et al. (2010).

to revenue (or expense in case of WTP estimation) (Fiebig et al. 2010). Train (2009) contends that models with all-random coefficients can be empirically unidentified. Yet, it is also known that WTA/WTP estimates derived from two random coefficients do not converge to identifiable distributions. In this present study we agree with the latter set of concerns and assume net margin attribute as non-random variables.

In a different study Hess and Rose (2012) express concern to the G-MNL model exclusively. The authors argue that scale heterogeneity is equivalent to heterogeneity in individual utility weights; and including both types of heterogeneity into the same model (as in equation 8) is misleading. They explain that the relative gain in fit obtained through the G-MNL model – when compared to the RPL model – is primarily associated with using more flexible distributions, rather than capturing scale heterogeneity. Louviere et al. (2008) also criticize the G-MNL model. In their empirical application, they have found that heterogeneity in preferences is better captured by S-MNL than by G-MNL.

In this study two econometric models – random parameters logit (RPL) and scaled multinomial logit (S-MNL) – are used to estimate preferences over cropping system attributes. Both of these models have meaningful advantage over the traditional MNL model because they recognize that subjects are heterogeneous and might have different appreciation for specific attributes. The modeling question that remains unanswered is how to incorporate agricultural producers' preference heterogeneity for cropping system attributes – through individual-specific deviations from the mean utility weight or though scale factor. Following the method proposed by Fiebig et al. (2010), we assess model performance by examining the likelihood improvement that is attained by including deviations from mean utility weights or individual scale factors into the seminal MNL model proposed by McFadden's (1974).

The RPL model assumes that utility weights are random parameters and follow a predetermined distribution (Train 2009). Based on equation 5, the probability that agricultural producer i chooses cropping alternative c when presented with scenario t becomes:

$$P_{ict} = \int \frac{exp(\boldsymbol{\beta x}_{ict})}{\sum_{j \in S} exp(\boldsymbol{\beta x}_{ijt})} g(\beta) d\beta \tag{9}$$

where the distribution of random parameters $g(\cdot)$ is normal and $\boldsymbol{\beta} = \boldsymbol{\beta} + \boldsymbol{\gamma}_i$[20].

The S-MNL model assumes that utility weights are scaled proportionately across agricultural producers. Based on equation 7, the probability of agricultural producer i choosing cropping system c is:

$$P_{ict} = \frac{exp\ (\boldsymbol{\beta x}_{ict})}{\sum_{j \in S} exp\ (\boldsymbol{\beta x}_{ijt})} \tag{10}$$

where $\boldsymbol{\beta} = \boldsymbol{\beta}\sigma_i$, $\sigma_i = exp\left(-\tau^2/_2 + \tau\omega_i\right)$ and ω_i takes the standard normal distribution.

Correlation of coefficients was assumed absent due to the complexity of the model. Given the objective of the study (i.e. to examine whether regional characteristics and farming capability influence decision), two-way interaction effects bring the total number of parameters to 52 and 29 (RPL and S-MNL, respectively) as opposed to 13 in the main effects RPL and 8 in the main effects S-MNL. Hence, allowing correlation of coefficients in the model with two-way interactions would add over 200 parameters to be estimated which is computationally unfeasible. The next section analyzes the results derived from these models.

Willingness to accept (WTA) values for cropping system attributes are sequentially computed for each county category by taking the ratio of the estimated coefficient on the observed

[20] Normal distribution is assumed because it provides the best fit to our data.

attribute to the net margin coefficient, times two due to effects coding (Lusk et al. 2003). Statistical variability in WTA estimates are calculated using the parametric bootstrapping technique as proposed by Krinsky and Robb (1986). For each crop attribute, WTA estimates are compared across county categories using the complete combinatorial method proposed by Poe, Giraud, and Loomis (2005).

5. Empirical Results

The estimates for two RPL models and two S-MNL models are reported in Tables 7 and 8, respectively. While column 2 presents estimates for the entire region of interest (main effects models), column 3 presents county category-specific estimates (two-way interactions models).

Table 7: Random Parameter Logit Estimates for Cropping Systems

Variable	RPL Model	RPL model (partitioned by county category)	Standard Deviations
Net margin per acre per year	1.390 (0.074)**		-
- county cat.#1		1.279 (0.174)**	-
- county cat.#2		1.249 (0.120)**	-
- county cat.#3		1.495 (0.142)**	-
- county cat.#4		1.586 (0.160)**	-
Variance of net margin	-1.546 (0.325)**		1.901 (0.567)**
- county cat.#1		-2.41 (0.837)**	2.623 (1.244)*
- county cat.#2		-0.632 (0.551)	0.885 (1.229)
- county cat.#3		-1.972 (0.665)**	2.475 (0.958)**
- county cat.#4		-1.894 (0.715)**	2.569 (0.939)**
Does not require acquisition	0.714 (0.097)**		0.713 (0.126)**
- county cat.#1		1.237 (0.212)**	0.091 (0.335)
- county cat.#2		0.375 (0.135)**	0.508 (0.177)**
- county cat.#3		0.634 (0.180)**	0.672 (0.348)
- county cat.#4		0.772 (0.238)**	0.935 (0.248)**

Table 7 (cont'd)

Variable	RPL Model	RPL model (partitioned by county category)	Standard Deviations
Low intensity of practices	0.540 (0.060)**		0.402 (0.101)**
- county cat.#1		0.855 (0.149)**	0.390 (0.219)
- county cat.#2		0.510 (0.091)**	0.179 (0.192)
- county cat.#3		0.471 (0.117)**	0.509 (0.171)**
- county cat.#4		0.428 (0.142)**	0.435 (0.176)*
Cooperative	-0.189 (0.063)**		0.511 (0.085)**
- county cat.#1		-0.245 (0.173)	0.813 (0.206)**
- county cat.#2		-0.187 (0.1)	0.353 (0.154)*
- county cat.#3		-0.068 (0.109)	0.127 (0.389)
- county cat.#4		-0.264 (0.153)	0.752 (0.176)**
Specification Contract	-0.248 (0.056)**		0.457 (0.08)**
- county cat.#1		-0.321 (0.146)*	0.607 (0.178)**
- county cat.#2		-0.171 (0.096)	0.451 (0.134)**
- county cat.#3		-0.134 (0.098)	0.242 (0.172)
- county cat.#4		-0.415 (0.125)**	0.519 (0.169)**
Opt out	1.858 (0.325)**		3.442 (0.28)**
- county cat.#1		2.152 (0.815)**	5.906 (1.096)**
- county cat.#2		2.060 (0.538)**	3.282 (0.464)**
- county cat.#3		1.858 (0.546)**	2.668 (0.428)**
- county cat.#4		1.689 (0.607)**	2.051 (0.44)**
Log likelihood function	-1915.63	-1878.10	
AIC	3857.3	3860.2	

Notes: The models were estimated using Nlogit 5.0, with Halton draws and 800 replications for simulated probability. Standard errors are reported in parentheses.
* and ** indicate statistical significance at 5% and 1% level respectively.

Table 8: Scaled Multinomial Logit Estimates for Cropping Systems

Variable	S-MNL Model	S-MNL model (partitioned by county category)
Net margin per acre per year	1.441 (0.221)**	
- county cat.#1		1.038 (0.239)**
- county cat.#2		1.356 (0.269)**
- county cat.#3		1.953 (0.473)**
- county cat.#4		1.849 (0.509)**

Table 8 (cont'd)

Variable	S-MNL Model	S-MNL model (partitioned by county category)
Variance of net margin	-1.546 (0.350)**	
- county cat.#1		-2.474 (0.843)**
- county cat.#2		-0.388 (0.462)
- county cat.#3		-1.842 (0.665)**
- county cat.#4		-0.994 (0.805)
Does not require acquisition	0.681 (0.117)**	
- county cat.#1		0.899 (0.218)**
- county cat.#2		0.391 (0.131)**
- county cat.#3		0.687 (0.218)**
- county cat.#4		1.078 (0.366)**
Low intensity of practices	0.592 (0.099)**	
- county cat.#1		0.697 (0.164)**
- county cat.#2		0.538 (0.135)**
- county cat.#3		0.630 (0.182)**
- county cat.#4		0.648 (0.169)**
Cooperative	-0.173 (0.068)*	
- county cat.#1		-0.096 (0.131)
- county cat.#2		-0.256 (0.102)*
- county cat.#3		-0.073 (0.127)
- county cat.#4		-0.064 (0.141)
Specification Contract	-0.176 (0.056)**	
- county cat.#1		-0.048 (0.110)
- county cat.#2		-0.302 (0.100)**
- county cat.#3		-0.132 (0.116)
- county cat.#4		-0.299 (0.122)*
Opt out	2.302 (0.448)**	
- county cat.#1		1.920 (0.619)**
- county cat.#2		2.727 (0.627)**
- county cat.#3		3.371 (0.975)**
- county cat.#4		1.958 (0.700)**
τ		1.095 (0.153)**
σ		0.97613 (1.314)
Log likelihood function	-2245.00	-2213.89
AIC	4506.0	4485.8

Notes: The models were estimated using Nlogit 5.0, with Halton draws and 800 replications for simulated probability. Standard errors are reported in parentheses.
* and ** indicate statistical significance at 5% and 1% level respectively.

The main effects RPL model shows that all attributes included in the experiment influence utility and drive agricultural producers' preferences for crop attributes. As expected, the estimates on net margin, absence of machinery acquisition, and low intensity of production practices are valuable and increase agricultural producers' utility; variance of annual net margins and use of hybrid governance strategies (i.e. specification contract or cooperative), on the other hand, tend to decrease utility. The model indicates, however, that there is strong heterogeneity in agricultural producers' preferences for all experimented cropping system attributes. Although the main effects S-MNL model obtains similar estimates, deviations from mean utility weights seem to accommodate preference heterogeneity far better than the scale factor. Departing from the basic MNL model simple calculations indicates that inclusion of individual deviations improves goodness of fit by 18.8% while inclusion of scale factors improves fit by 4.8%.

Two-way interactions refine the initial model and allow one to examine whether regional specificities capture heterogeneity in preferences. Results derived from the RPL model indicate that some heterogeneity is indeed related to county categories. Variance of net margins, for example, is less of a concern for agricultural producers located in county category 2. Agricultural producers located in county categories 1 and 3 have homogeneous preference for cropping systems that do not require acquisition of machinery. Cropping systems that require low intensity of production practices are homogeneously preferred to producers located in county categories 1 and 2. While producers located in 3-counties seem to be indifferent of the coordination arrangement used to govern transactions with buyers, producers from 2-counties have heterogeneous preferences without a typical preference.

Results derived from the S-MNL model are similar. Variance of net margins appears not to influence decisions of agricultural producers located in county categories 2 and 4. Requirement of machinery acquisition and intensity of production practices necessary to obtain average yields influence planting decisions in all county categories. Producers located in 1-counties and 3-counties seem to derive little value from the type of coordination arrangement in place. Producers located in county category 4 are, on one hand, indifferent between trading via spot markets or cooperatives; but on the other, are less willing to accept a hypothetical engagement offer if the related coordination arrangement is specification contract. County category 2 farmers are less willing to adopt a cropping system if the associated coordination arrangement is different from spot market.

It is worth noting that the inclusion of preference heterogeneity via individual deviations from mean utility weights improves model performance faster than via scale factors. Taking the MNL model as base for comparison, RPL with interactions improves fit by 18.63% while S-MNL improves fit by 4.09%.

In any case interpreting the magnitudes of coefficients is discouraged because only relative parameter values matter (Scarpa and Del Giudice 2004). The conventional alternative in these circumstances is to estimate agricultural producers' willingness to accept (WTA) based on model estimates. Due to the substantial difference in model performance, Table 9 reports mean WTA estimates, 95% confidence intervals, and statistical evidence of differences amongst county categories derived from the RPL model only.

Table 9: Mean Willingness-to-accept (WTA) and 95% confidence intervals

Variable	Mean WTA [95% CI]		*1
Variance of net margin	-222.54 [-313.87, -133.79]		
- county cat. 1		-380.19 [-659.01, -118.54]	△
- county cat. 2		-101.20 [-278.82, 73.82]	△
- county cat. 3		-263.74 [-438.57, -93.58]	△
- county cat. 4		-239.34 [-410.67, -65.82]	△
Does not require acquisition	102.92 [75.35, 131.07]		
- county cat. 1		196.00 [132.21, 273.15]	△
- county cat. 2		60.83 [17.46, 106.86]	☐
- county cat. 3		85.43 [38.94, 135.52]	☐
- county cat. 4		97.85 [39.67, 160.54]	☐
Low intensity of practices	77.85 [61.32, 95.06]		
- county cat. 1		135.06 [90.83, 186.89]	△
- county cat. 2		82.01 [54.15, 113.05]	☐
- county cat. 3		63.02 [33.02, 93.63]	☐
- county cat. 4		54.12 [18.98, 91.65]	☐
Cooperative	-27.18 [-44.68, -9.38]		
- county cat. 1		-38.66 [-91.94, 14.99]	△
- county cat. 2		-30.06 [-61.11, 1.27]	△
- county cat. 3		-9.00 [-37.33, 19.99]	△
- county cat. 4		-33.24 [-70.98, 4.94]	△
Specification Contract	-35.69 [-51.70, -19.89]		
- county cat. 1		-50.57 [-97.79, -5.70]	△☐
- county cat. 2		-27.65 [-58.06, 3.03]	△☐
- county cat. 3		-17.87 [-43.72, 7.76]	△
- county cat. 4		-52.34 [-83.22, -21.98]	☐

Notes: Different symbols in the final column indicate statistical difference at 5% confidence level within each attribute.
*1: Complete combinatorial test results.

The estimates of WTA for variance of net margins differ across county categories. Agricultural producers located in county category 1 show the highest aversion to variable annual returns. These producers would be willing to adopt a cropping system with high variance of returns if the expected net margin was on average $380.19 higher than the average net margin of a cropping system characterized by low variance of returns, maintaining all other attributes fixed. This result might be associated with revealed net margins (from the survey). Producers located in county category 1 reported the thinnest net margins ($152.69/acre/year – Table 5), which is 33.6%

lower than the average revealed net margin ($229.90/acre/year). Therefore, it is reasonable that 1-county producers demand such high returns because any unexpected reduction of net margins could lead to desertion or bankruptcy of farms in extreme cases. Producers located in county category 2 present the lowest aversion to variable net margins. These producers would adopt a cropping system with variable returns if its expected net margin was $101.20/acre/year higher than returns from a crop with low variance of net margins, *ceteris paribus*. For comparison, producers located in county categories 3 and 4 would need additional $263.74/acre/year and $239.34/acre/year respectively to adopt a cropping system with high variance of returns, keeping other attributes equal. These results should be used with caution, however, since the mean estimates of WTA for net margin variance are not statistically different (Table 9).

The absence of specific investments in machinery is preferable to most producers, regardless of the location. Estimates of WTA for investment requirements computed from coefficients of the two-way interactions RPL model presented on Table 6 indicate that producers would be willing to accept $102.92/acre/year less, on average, to adopt a cropping system that does not require acquisition of new machinery, *ceteris paribus*. There are differences across county categories, however. Producers from 1-counties would be willing to give up $196/acre/year to adopt a crop or set of crops that do not require investment in machinery. Producers located in county categories 2, 3, and 4 would request additional $60.83, $85.43, and $97.85/acre/year respectively to engage in a given cropping system that does require investment in machinery, leaving other attributes unaltered.

It is interesting to observe that economies of scale seem to correlate with preference for investments in machinery. While producers located in county category 2 operate the largest production fields in the sample (460 acres on average – Table 6), they also require the lowest ‘fee’ to engage in a cropping system that requires acquisition of machinery. On the other hand, producers located in 1-counties have the highest WTA estimates because of the relative small size of production fields (246.53 acres on average – Table 6). In addition to small production fields, agricultural producers from 1-counties also demonstrate little ability to afford investments due to the thinnest revealed net margins, leading to the highest WTA estimate. In fact, the WTA estimate for producers located in 1-counties is statistically different at 5% confidence level from estimates computed for producers located elsewhere.

Producers expressed overall preference for crops that require low intensity of production practices. The mean WTA for a low intensity cropping system is $77.85/acre/year. Looking into specific counties, agricultural producers from 1-counties require $135.06/acre/year to engage in a high intensity cropping system. Producers located in counties 2, 3, and 4 would demand additional $82, $63, and $54.13/acre/year to cultivate high intensity crops. An underlying factor leading to this difference across county categories might be farm income participation in the total household income. Because producers from 1-counties are less dependent on farm income and consequently more dependent on off-farm returns (farm income participation of 38% – Table 6), crops with moderate production practices give them more flexibility to seek full-time positions outside the farm. Producers located in 3-counties and 4-counties, on the other hand, are more attached to farm work (average farm income participation of 53% and 50% respectively – Table 6), making them accept a considerably lower 'fee' for a high intensity crop (less than 50% the amount producers from 1-counties would be willing to accept).

When it comes to coordination arrangements, agricultural producers indicate strong preference for spot markets. Regardless of the location, producers would be willing to accept an additional of $27.18/acre/year to trade via cooperatives and an additional of $35.69 to trade via specification contracts. Producers from county category 3 are the least averse to trading through hybrid governances (i.e. specification contracts or cooperatives). County-3 farmers would be willing to join a cooperative if the expected net margin was on average \$9/acre/year higher than trading via spot markets; or willing to sign a specification contract if the expected net margin was \$17.87/acre/year more than trading through spot markets. Producers from county category 1 are the most averse to joining a cooperative while producers from county category 4 are the most averse to signing production contracts. The former group would require an additional net margin of \$38.66/acre/year to become a cooperative member and the latter group would demand \$52.34/acre/year net to sign a written agreement of supply.

Stated preferences for crop attributes indicate that agricultural producers behave as we initially expected in regards to net margins. The summary statistics presented in Table 10 (appendix B) shows that the probability of a crop being chosen increases with net margin, over all counties as well as for each separate county category. Preferences for high net margins, however, seem to increase in county categories as the trend line approximation indicates. Agricultural producers located in 3-counties and 4-counties, for example, show stronger preference for high net margins when compared to agricultural producers located elsewhere. This result makes sense in light of regional rent prices and revealed net margins. Producers located in 3-counties and 4-counties operate in regions where farmland rent prices are the second and first highest across all county categories (\$175.70 and \$197.29, respectively – Table 6). Producers located in these counties also have the highest and second highest revealed net margins, suggesting that they are used to higher compensations when compared to producers located in 1-counties and 2-counties.

Finally, hypothetical choices made by peers seem to influence the decisions of producers located in 1-counties differently from producers located elsewhere. While producers located in 1-

counties tend to show competitive attitude and adopt cropping systems that differ from neighbor producers, producers from other counties are likely to adopt the same cropping system, evidencing collaboration. This result comes hand and hand to the fact that cooperative leads to little value loss for producers located in 3-counties (additional $9/acre/year), where producers show collaborative posture. Conversely, producers tend to show competitive behavior in 1-counties (Table 10) where cropping systems with cooperative coordination arrangement would be accepted for extra $38.66/acre/year, *ceteris paribus*.

6. Implications for Energy Crops

Agricultural producers located in all county categories show considerable preference for low intensity cropping systems; and as expected, WTA decreases from 1-counties to 4-counties. This result can translate into agricultural producers' willingness to grow energy crops given that switchgrass resembles a low intensity crop while corn/soybean resemble high intensity ones. Therefore, our original hypotheses hold in light of our empirical results – willingness to grow energy crops (low intensity crops) is greater than willingness to grow conventional row crops (high intensity crops) and willingness to grow decreases orderly from county category 1 to county category 4.

These results are promising for extension initiatives wishing to incentivize energy crop production. As producers become aware of agronomic characteristics of switchgrass (i.e. it requires 31% less labor time and effort to obtain average yield than conventional crops), appreciation for low intensity of agricultural practices is likely to broaden, and the low intensity characteristic to become a source of differentiation leading to opportunities for switchgrass expansion and crop substitution in Midwestern states. Expansion of energy crops might unfold relatively faster in county category 1 than in other county categories since WTA for low intensity crops is statistically higher in this county category. It means that well-aligned extension initiatives can motivate farmland conversion into switchgrass faster in 1-counties than in other county categories. Nevertheless, all county categories have presented opportunities for crop substitution and switchgrass expansion.

Producer WTA for machinery acquisition requirement also follows our original hypothesis. If a given cropping system does not require acquisition of machinery, producers would be more willing to adopt that system. This result is of great importance for bioelectricity investors because building a biomass processing plant in regions where few producers own forage harvester or forage mower/rake/baler (or have expensive access to them) would make switchgrass lose value associated with its low intensity of production practices. A better strategy would be to first enter regions where most producers have productive capability for cultivating forage crops, which can be adapted for switchgrass and production of biomass. In fact, targeting producers who own harvesting capabilities in addition to educational sessions would boost crop substitution potential and expansion of energy crops across the Mid-West United States.

That is especially the case if switchgrass enters commercial farms using a contract specification similar to that used in the University of Tennessee Biofuels Initiative (UTBI). As presented above, the UTBI contract has a net margin of $317/acre/year, which overcomes average net margin revealed for all county categories. A combined entry strategy with extension sessions targeting agricultural producers who own desirable farming capability and net margin of $317/acre/year should generate enough value to producers so they move away from the preferred coordination arrangement (i.e. spot market) and sign biomass production contracts.

County category 2 in particular shows great opportunities for emergence of the energy crop industry in Midwestern states if such entry strategy is put forward. Differently from other regions, the UTBI net margin of $317/acre/year appears to be large enough to offset revealed net margins in that county category as well as the negative values associated with machinery acquisition and engagement in specification contract. More specifically, the UTBI net margin overcomes revealed net margin in county category 2 by $105.40/acre/year, which can be conjectured as sufficient to cover machinery acquisition – valued at $60.83/acre/year on average – as well as engagement of producers in specification contracts – averaged at $27.65/acre/year. Nevertheless, utility weights obtained from the RPL model with two-way interactions indicate that producers in 2-counties have heterogeneous preferences for machinery acquisition and coordination arrangements; which emphasizes the importance of extension sessions in an effective entry strategy.

These implications must be used with discretion because WTA estimates rely on the notion of *ceteris paribus*. In other words, WTA estimates should be interpreted while maintaining other factors constant since one cannot guarantee that the effect of two or more attributes combined is equal to the sum of the individual effects. Additionally, the revealed net margin value of $211.60/acre/year for producers from 2-counties is averaged across survey respondents, which does not take dispersion or variance into account. We recognize these points as limitations to our approach but our results are the first of its kind and can be used to motivate expansion of energy crops in the Mid-west United States. If past empirical studies have identified hesitation and skepticism (Rossi and Hinrichs 2011, Qualls et al. 2012, Hayden 2013) from agricultural producers in regards to energy crops, this article shows that producers are interested in growing crops with key characteristics found in switchgrass. A good extension initiative could benefit expansion of energy crops because it would not only inform producers that switchgrass possesses characteristics they value, but it would also minimize the negative effects of hesitation and skepticism.

7. Conclusions

Despite government efforts to develop renewable electricity industries, hesitation and skepticism of decision makers in upstream links of the supply chain have been identified as deterring factors for expansion and farmland conversion. This article utilizes an innovative choice experiment to estimate willingness to grow energy crops. Based on choice data collected throughout Midwestern states with RPS mandates in place, results indicate that agricultural producers value (i) cropping systems that require low intensity of production practices to obtain average yield; (ii) absence of required investments in machinery; (iii) low variance of net margins; and (iv) coordinating transactions through spot markets.

While recognizing that regional specificities cause preference for cropping system attributes to vary, results point out that producers located in places where conventional cropping systems (e.g. corn-soybean rotation) are less competitive to switchgrass tend to prefer crop characteristics found in switchgrass. In other words, low intensity of production practices have diminishing WTA as one moves from county category 1 to county category 4.

Farming capabilities also influence preference for cropping system attributes. As one would plausibly suggest, producers value crops that do not require investment in machinery. The present study refines this notion and estimates magnitudes for such preference. Results indicate that absence of investment not only places first in the rank of preferable attributes but also identify locations across the Mid-west where producers would be less concerned to purchase machinery for cultivating a desirable crop. Producers located in county category 2 would be considerably less concerned with acquiring equipment whereas producers in county category 1 would be highly concerned.

Combining these results and taking into consideration agricultural producers' demographic characteristics, we show that \$317/acre/year (same as the UTBI net margin) might suffice to motivate farmland conversion and adoption of switchgrass in county category 2 – regardless of whether investments in machinery are necessary – or in county categories 1, 3, and 4 if investments are unnecessary. These would hold even if specification contracts must be agreed between producers and biomass processor. However, it is important to take these interpretations with caution given the notion of *ceteris paribus* associated with model estimates and derived WTA calculations. Further refinement of this study to allow precise interpretation of WTA estimates is strongly encouraged.

Finally, this study provides evidence that modeling preference heterogeneity through individual deviations to mean utility weights reaches superior performance than modeling individual scale effects. Results show that log likelihood improves about 18% when RPL model is utilized versus 4% improvement when S-MNL model is used, regardless of whether county categories are specified.

This article leaves an important question unattended. Although it has been observed that producers from county category 2 and 3 do not have homogeneous preference for coordination arrangements while producers from counties 1 and 4 do, this study does not address how contract provision or cooperative membership should be drafted. It might be important to assess agricultural producers' preferences for provisions or cooperative membership rules as these points may have substantial influence on producers' cropping system adoption. Essay 3 of this dissertation tackles this question in a comprehensive manner.

APPENDICES

APPENDIX A Sample choice scenario used in the unlabeled experiment

Figure 7: Sample choice scenario used in the unlabeled experiment

Choice Scenario #1 of 9: Which crop rotation would you prefer?

System Attributes	**Crop Rotation A**	**Crop Rotation B**	**Neither**
Net margin/acre/year	$260	$400	I would not farm if A and B were the only alternatives available
Net margin variance	± 10% (± $40)	± 40% (± $160)	
Requires acquisition of machinery	No	Yes	
Intensity of production practices*	Low	High	
Marketing arrangement	Cooperative	Spot Market	
My neighbors are choosing	-------- Crop Rotation B --------		
I would grow:	☐	☐	☐

* cropping systems with LOW intensity of production practices require 31% less labor time and effort to obtain average yield than cropping systems with HIGH intensity of production practices.

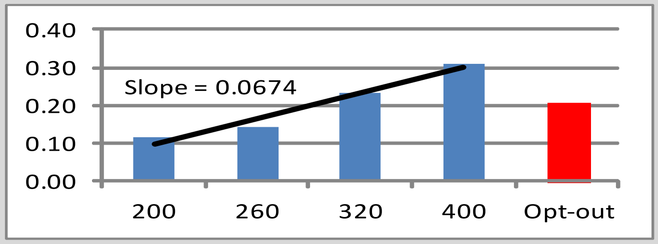
APPENDIX B Summary statistics – aggregate counties and individual county categories

Table 10: Summary statistics - all counties and separate county categories

Prob(Net Margin)

All counties

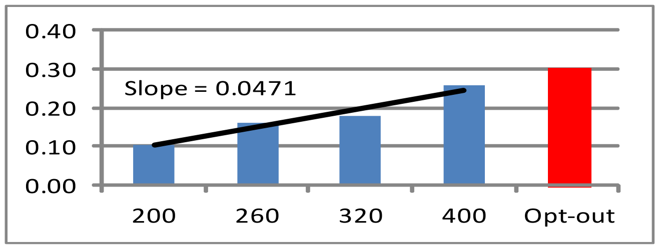
Net Margins	Abs. Obs.	Freq.
200	288	0.11
260	357	0.14
320	582	0.23
400	779	0.31
Opt-out	513	0.20
Total (n)	2519	



Weighted average of margins: **$257.35**

County Category #1

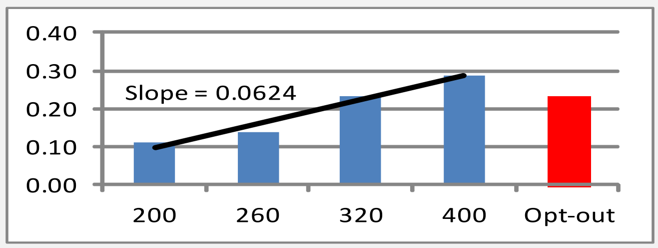
Net Margins	Abs. Obs.	Freq.
200	56	0.10
260	86	0.16
320	95	0.18
400	137	0.26
Opt-out	161	0.30
Total (n)	535	



Weighted average of margins: **$221.98**

County Category #2

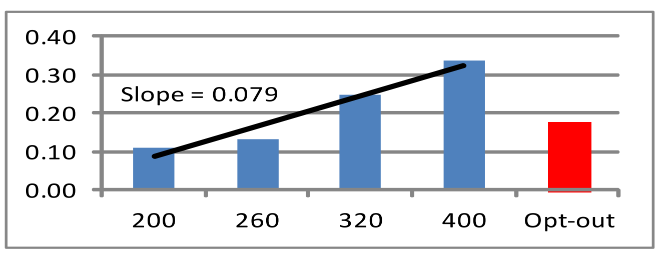
Net Margins	Abs. Obs.	Freq.
200	81	0.11
260	103	0.14
320	172	0.23
400	212	0.29
Opt-out	172	0.23
Total (n)	740	



Weighted average of margins: **$247.05**

County Category #3

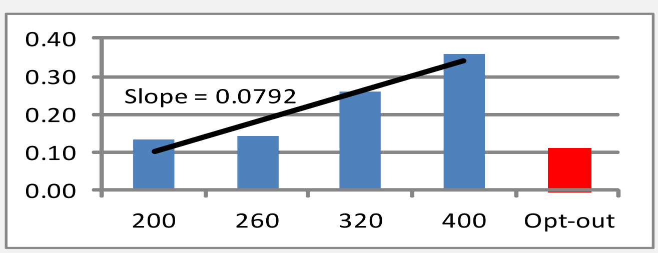
Net Margins	Abs. Obs.	Freq.
200	72	0.11
260	84	0.13
320	160	0.25
400	217	0.34
Opt-out	114	0.18
Total (n)	647	



Weighted average of margins: **$269.30**

County Category #4

Net Margins	Abs. Obs.	Freq.
200	79	0.13
260	84	0.14
320	155	0.26
400	213	0.36
Opt-out	66	0.11
Total (n)	597	



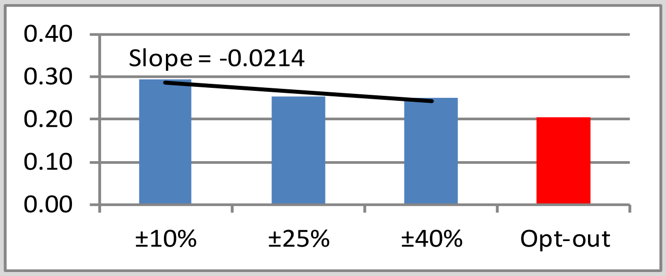
Weighted average of margins: **$288.84**

Table 10 (cont'd)

Prob(Variance of Net Margins)

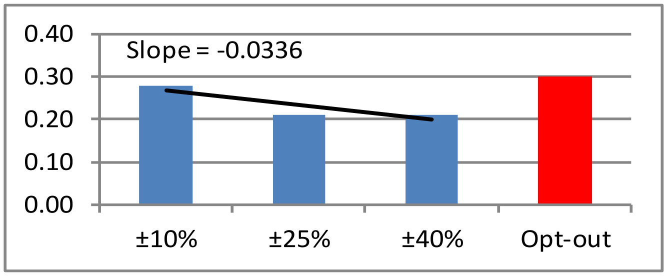
All counties

Variance	Abs. Obs.	Freq.
±10%	737	0.29
±25%	640	0.25
±40%	629	0.25
Opt-out	513	0.20
Total (n)	2519	



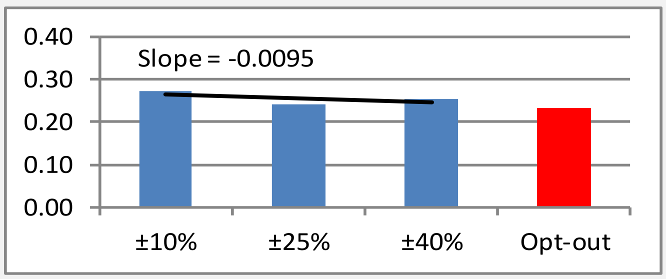
County Category #1

Variance	Abs. Obs.	Freq.
±10%	149	0.28
±25%	112	0.21
±40%	113	0.21
Opt-out	161	0.30
Total (n)	535	



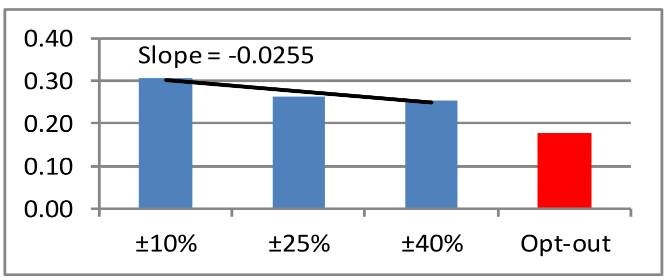
County Category #2

Variance	Abs. Obs.	Freq.
±10%	202	0.27
±25%	178	0.24
±40%	188	0.25
Opt-out	172	0.23
Total (n)	740	



County Category #3

Variance	Abs. Obs.	Freq.
±10%	198	0.31
±25%	170	0.26
±40%	165	0.26
Opt-out	114	0.18
Total (n)	647	



County Category #4

Variance	Abs. Obs.	Freq.
±10%	188	0.31
±25%	180	0.30
±40%	163	0.27
Opt-out	66	0.11
Total (n)	597	

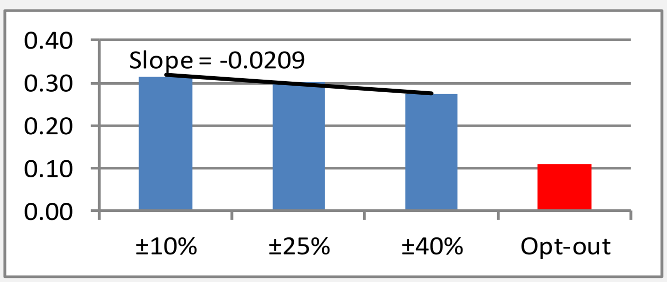
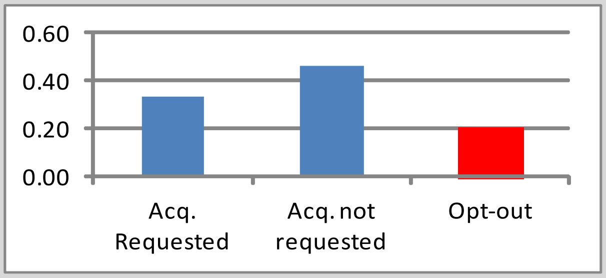


Table 10 (cont'd)

Prob(Requires Acquisition of Machinery)

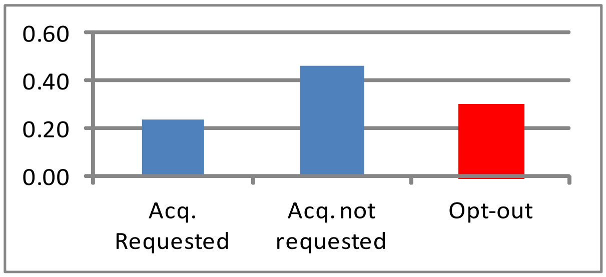
All counties

Acquisition Req.	Abs. Obs.	Freq.
Acq. Requested	833	0.33
Acq. not requested	1173	0.47
Opt-out	513	0.20
	2519	



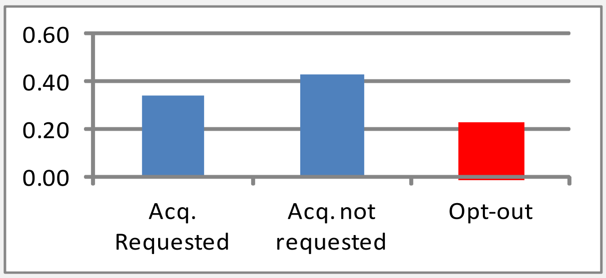
County Category #1

Acquisition Req.	Abs. Obs.	Freq.
Acq. Requested	128	0.24
Acq. not requested	246	0.46
Opt-out	161	0.30
	535	



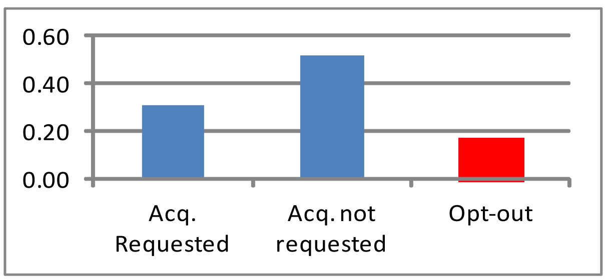
County Category #2

Acquisition Req.	Abs. Obs.	Freq.
Acq. Requested	250	0.34
Acq. not requested	318	0.43
Opt-out	172	0.23
	740	



County Category #3

Acquisition Req.	Abs. Obs.	Freq.
Acq. Requested	200	0.31
Acq. not requested	333	0.51
Opt-out	114	0.18
	647	



County Category#4

Acquisition Req.	Abs. Obs.	Freq.
Acq. Requested	255	0.43
Acq. not requested	276	0.46
Opt-out	66	0.11
	597	

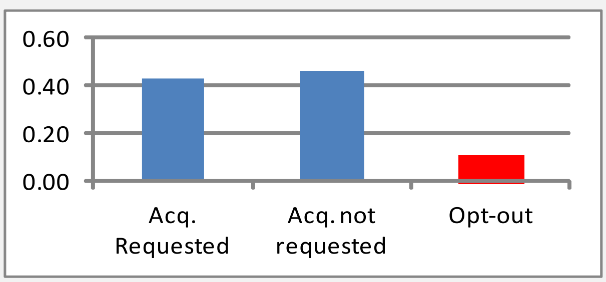
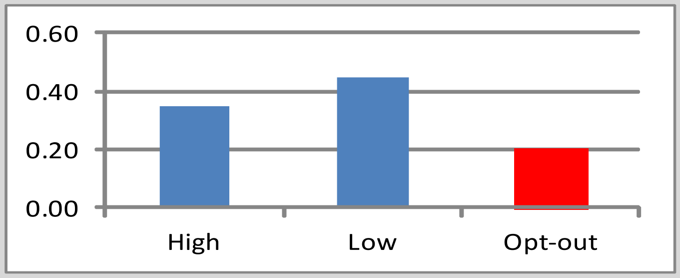


Table 10 (cont'd)

Prob(Intensity of Production Practices)

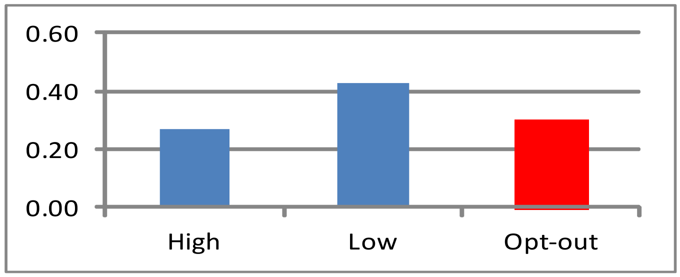
All counties

Intensity	Abs. Obs.	Freq.
High	872	0.35
Low	1134	0.45
Opt-out	513	0.20
Total (n)	2519	



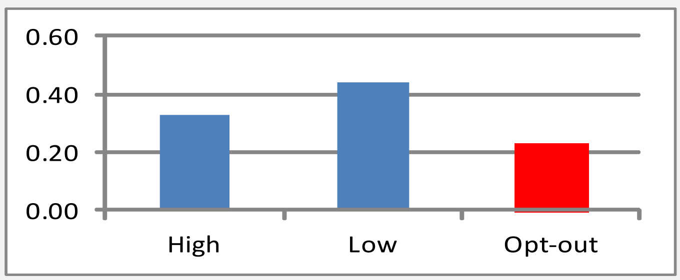
County Category #1

Intensity	Abs. Obs.	Freq.
High	144	0.27
Low	230	0.43
Opt-out	161	0.30
Total (n)	535	



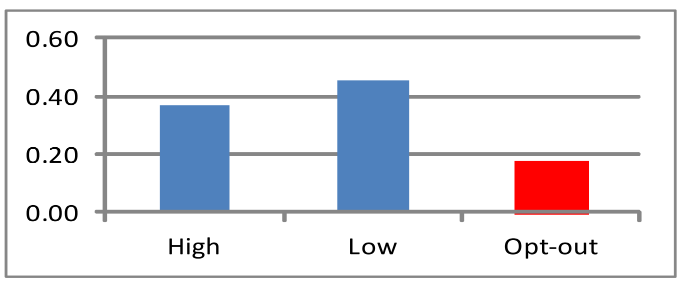
County Category #2

Intensity	Abs. Obs.	Freq.
High	243	0.33
Low	325	0.44
Opt-out	172	0.23
Total (n)	740	



County Category #3

Intensity	Abs. Obs.	Freq.
High	238	0.37
Low	295	0.46
Opt-out	114	0.18
Total (n)	647	



County Category #4

Intensity	Abs. Obs.	Freq.
High	247	0.41
Low	284	0.48
Opt-out	66	0.11
Total (n)	597	

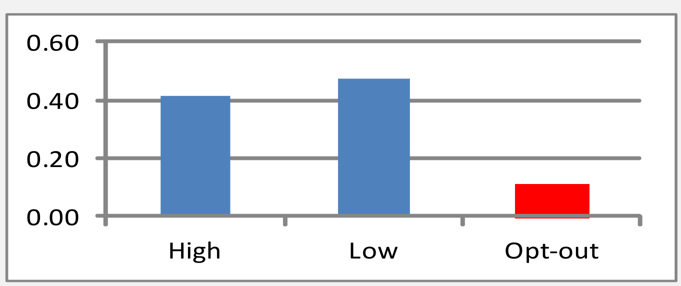
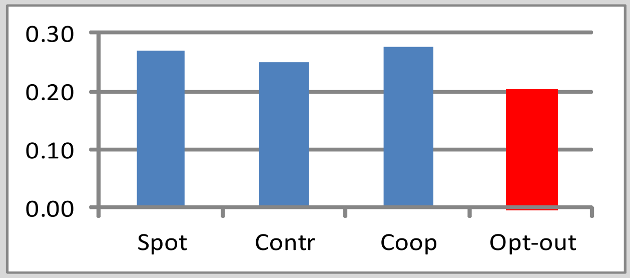


Table 10 (cont'd)

Prob(Vertical Coordination)

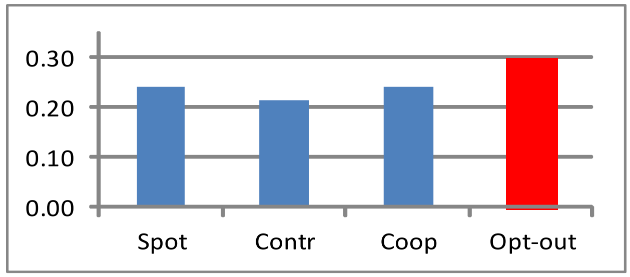
All counties

Coord. Strategy	Abs. Obs.	Freq.
Spot	678	0.27
Contr	632	0.25
Coop	696	0.28
Opt-out	513	0.20
Total (n)	2519	



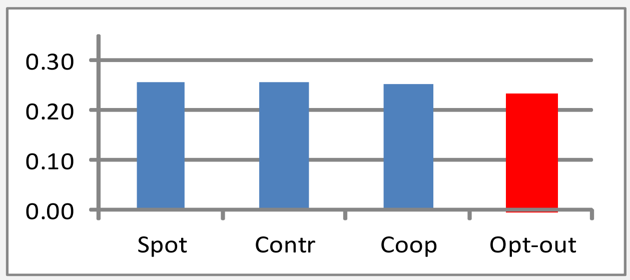
County Category #1

Coord. Strategy	Abs. Obs.	Freq.
Spot	130	0.24
Contr	114	0.21
Coop	130	0.24
Opt-out	161	0.30
Total (n)	535	



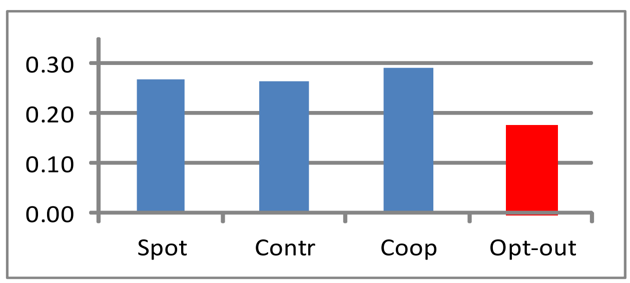
County Category #2

Coord. Strategy	Abs. Obs.	Freq.
Spot	190	0.26
Contr	190	0.26
Coop	188	0.25
Opt-out	172	0.23
Total (n)	740	



County Category #3

Coord. Strategy	Abs. Obs.	Freq.
Spot	173	0.27
Contr	171	0.26
Coop	189	0.29
Opt-out	114	0.18
Total (n)	647	



County Category #4

Coord. Strategy	Abs. Obs.	Freq.
Spot	185	0.31
Contr	157	0.26
Coop	189	0.32
Opt-out	66	0.11
Total (n)	597	

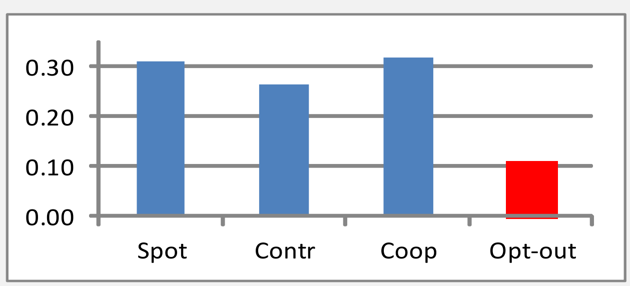
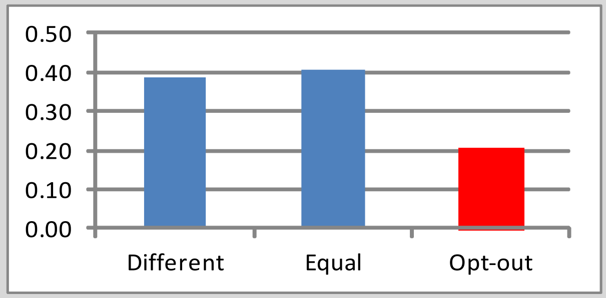


Table 10 (cont'd)

Prob(Neighbor Choice)

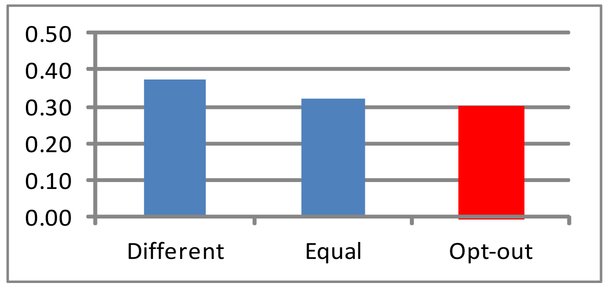
All counties

Neighbor choice	Abs. Obs.	Freq.
Different	978	0.39
Equal	1028	0.41
Opt-out	513	0.20
Total (n)	2519	



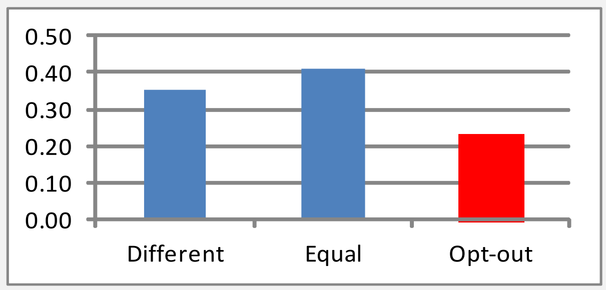
County Category #1

Neighbor choice	Abs. Obs.	Freq.
Different	201	0.38
Equal	173	0.32
Opt-out	161	0.30
Total (n)	535	



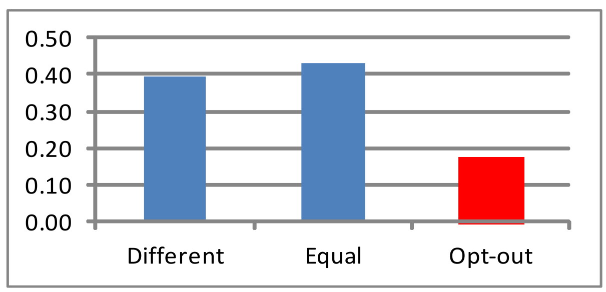
County Category #2

Neighbor choice	Abs. Obs.	Freq.
Different	263	0.36
Equal	305	0.41
Opt-out	172	0.23
Total (n)	740	



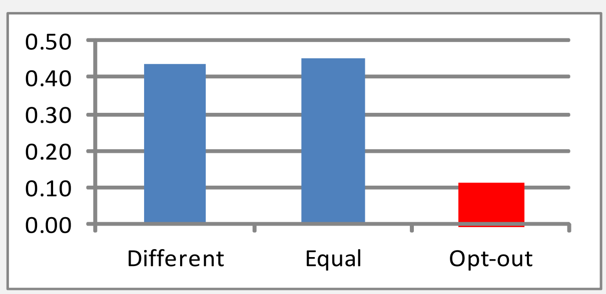
County Category #3

Neighbor choice	Abs. Obs.	Freq.
Different	254	0.39
Equal	279	0.43
Opt-out	114	0.18
Total (n)	647	



County Category #4

Neighbor choice	Abs. Obs.	Freq.
Different	260	0.44
Equal	271	0.45
Opt-out	66	0.11
Total (n)	597	



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ESSAY 3: DOES THEORY PREDICT ADOPTION OF PRODUCTION CONTRACTS? EVIDENCE FROM THE DEVELOPING BIOENERGY INDUSTRY IN U.S. MIDWEST

1. Introduction

Economic theory has developed two distinct routes to deal with issues of market structure and behavior of firms. While the first – recognized as industrial organization – relies on game theory and often justifies firm behavior using arguments of incentive (Tirole 1988); the second – institutional economics – provides justification based on arguments of friction costs, externalities, and opportunism (Williamson 1985). In spite of such distinction, the concepts of information asymmetry, uncertainty and idiosyncratic assets seem to have inspired theorists dedicated to either route, whose contributions originated the rich literature of incomplete contracts.

A central issue in the incomplete contracts literature is the hold-up problem (Williamson 1975, Goldberg 1976, Hart and Moore 1988). From the industrial organization perspective, these problems emerge because observable-but-unverifiable information exists (Bolton and Dewatripont 2005). Information is said to be observable but not verifiable when trading parties can see a given contingency but outsiders (e.g. judges and public jury) cannot (Hart 1995). An institutional economics theorist would conversely argue that hold-ups occur because one party behaves opportunistically to extract quasi-rents from the counterparty when favorable unanticipated market conditions arise.

Occurrence of hold-up problems lead to expropriation of quasi-rents on specific investments made to conduct a transaction. It is especially concerning in emerging industries where uncertainty of future events tends to be high and investments carry high degrees of specificity (i.e. few redeployment options with major losses of productive value). It also concerns emerging industries because the occurrence of hold-ups might hinder future entrepreneurship endeavors in the region or elsewhere.

Regardless of the theoretical interpretation, both routes of economic thought have arrived at solutions to the problem at hand. From the empirical point of view, however, the questions that remain unanswered are whether the offered solutions hold in real-world settings; and if so, which one is preferred by economic agents. Industrial organization theory shows that a 'specific performance contract' with a default option and a penalty for delayed trade suffices to solve hold-up problems and results in the first-best outcome (Aghion et al. 1994). In a similar fashion, Nöldeke and Schmidt (1995) demonstrate that an 'option contract' overcomes hold-ups, leading to efficient idiosyncratic investments and Pareto outcomes. Institutional economics theory argues that the strategic allocation of private enforcement capital minimizes the probability that hold-up problems will occur (Klein 1996). Although the latter contribution does not formally show whether a first-best outcome is obtainable, the author uses multiple real-world case studies to present efficiency enhancing properties. In other words, the use of sufficiently large hostages (Williamson 1983) deters opportunism and increases expected returns to both parties.

When it comes to testing and implementing these solutions applied economists often face a major limitation: access to field data on contractual relationships and strategic alliances. Even with theory shedding light on hold-up issues, predictions of how parties to trade should set strategic partnerships can seldom be tested empirically due to the limited availability of field data. That is not surprising because firms spend resources writing agreements to enhance supply chain efficiencies, which consequently carries strategic information. Under these circumstances firms are often opposed to sharing information that might expose their competitive advantages, even if the data are only used for academic purposes (Just and Wu 2009). Experimental economics, nevertheless, provides an alternative approach to overcome the data problem. Generating data through experiments allows applied economists to test empirical data against theory-based equilibria. More precisely, analyzing how decision makers state their likely behavior when hypothetical market situations are posed to them helps us understand the robustness of theoretical predictions.

The main purpose of this article is to examine what contract designs key economic agents – agricultural producers in this study – involved in an emerging industry prefer when hypothetical market situations are presented. Using the nascent bioelectricity industry in the United States as a case study, this article examines whether theoretical solutions to hold-ups are obtained when decision makers are more or less vulnerable to hold-up problems. Supporting objectives are (i) to inform entrepreneurs of what provisions might cause greater engagement of agricultural producers in the bioelectricity industry; and (ii) to inform extension branches of land grant universities about information barriers that might prevent producers from reaching transaction efficiency.

The developing renewable energy industry provides a fruitful economic environment to test whether theory-based solutions to hold-up problems are available. As previously identified, hold-ups constitute a potential problem in transactions between suppliers of biomass feedstock and generation utilities, especially because idiosyncrasy tends to characterize assets on both trading sides and agreements are unlikely to carry provisions to all future contingencies (Signorini et al. *forthcoming*). In light of these threats, we test whether the contract solutions discussed by theorists (Aghion et al. 1994, Klein 1996) emerge from agricultural producers' stated preferences when facing hypothetical market situations in the bioelectricity industry.

This study uses a discrete choice experiment and incorporates agent heterogeneity into three adapted versions of the random utility maximization (RUM) model (McFadden 1974, 1981). This study also compares the empirical models in terms of relative performance as described by Fiebig et al. (2010). In light of contract theory, we design a choice experiment that includes multiple contract designs and two hypothetical market conditions.

The experiment is conducted with agricultural producers located in six Midwestern states (i.e. Illinois, Michigan, Minnesota, Missouri, Ohio, and Wisconsin) where the development of renewable electricity industries has been pushed by public policies – Renewable Portfolio Standard (RPS) mandate and other state programs[21]. We then examine agricultural producers' willingness to accept (WTA) various contract attributes and contractual designs under two hypothetical market conditions.

The remainder of this article is organized as follows: section 2 reviews three theoretical solutions to hold-up problems; section 3 presents the research methodology; section 4 analyzes empirical results; section 5 discusses implications for bioenergy initiatives; and section 6 concludes.

2. Theoretical Framework

2.1. Industrial Organization Approach to Hold-up Problems

The industrial organization literature suggests that hold-up problems might be overcome with either 'specific performance contracts' (Aghion et al. 1994) or 'option contracts' (Nöldeke and Schmidt 1995). In order to examine these potential solutions, Aghion et al. (1994) examine three variations of the following game:

[21] In Michigan, the Renewable Energy Plan (REP) enacted in 2008 by the Michigan Public Service Commission (MPSC) provides an example for state-level programs.

- in t_0 trading parties agree on initial price p_0, quantity q_0 (called default option), and allocation of bargaining power α, which might or might not be contingent on announcements about the state of nature in period t_3; buyer and seller invest in relationship specific assets (j and i, respectively)
- in period t_1 state of nature θ is realized
- in t_2 trading parties observe θ, j, and i
- in t_3 both parties announce a "state" (i', j' and θ') and renegotiate price and quantity if necessary; trade occurs.

Aghion et al. (1994) consider three scenarios: (i) parties are risk-neutral and investments are present, (ii) parties are risk-averse and investments are absent, and (iii) parties are risk-averse and investments are present. They show that two contractual instruments are necessary and sufficient to reach Pareto efficiency. The first instrument is the adequate choice of the default option (p_0, q_0), which applies whenever ex post renegotiation fails (in t_3). The second is the allocation of all bargaining power to one party by making the default option sufficiently attractive to the other party for all j, i, and θ. For instance, allocating full bargaining power to the seller can be achieved by penalizing the buyer if trade is delayed.

Renegotiation in period t_3 ensures ex post efficiency because information symmetry prevails (i.e. parties have made investments j and i and state of nature θ has realized). At this stage renegotiation follows the bargaining model with discounting in which either party can unilaterally impose a pre-specified trade (the default option) as in Binmore et al. (1986). Besides, monetary penalties take place if no trade occurs until a pre-specified deadline. Aghion et al. (1994) add that a given party has little incentive to deviate and announce a “state” different from the realized. They show that a simple contract in which price, quantity, and allocation of bargaining power are not contingent on announcements suffices to implement Pareto efficiency when parties are risk-neutral. Conversely, a complex contract with a revelation mechanism (Maskin 1999) is necessary to implement the first-best solution when parties are risk-averse, either in the presence or in absence of specific investments.

Nöldeke and Schmidt (1995) use a different approach to reach the same conclusions as Aghion et al. (1994). The authors demonstrate that every option contract results in the allocation of all bargaining power to the buyer, meeting the second condition proposed by Aghion et al. (1994). The first condition is obtained by appropriately choosing the option price $k = p_1 - p_0$, where p_0 is the no-trade payment and p_1 is the trade price to be paid by the buyer if seller supplies quantity q. The game unfolds as follows:

- parties sign the initial option contract (p_0, p_1, q) in period t_0
- buyer and seller make investment decisions and state of nature is realized in period t_1; contract can be renegotiated at the end of period t_1 once parties observe investment decisions and state of nature
- in period t_2 buyer and seller decide whether to present renegotiation offers to the court in order to adjust the initial option contract; trade occurs.

The authors demonstrate that renegotiation at the end of period t_1 happens only if the private decision of the seller is not socially optimal. If socially optimal, both parties are better off sticking to the original agreement. If not socially optimal, the buyer has all the bargaining power in the renegotiation game (i.e. any offer made by the seller can be withheld in period t_2). Thus, the buyer makes a new offer only if it is under his best interest to do so. The first scenario in which it is profitable for the buyer to make a new offer is when $p_1 - p_0 < c(\theta, i) < v(\theta, j)$, where $c(\cdot,\cdot)$ is the seller's production cost and $v(\cdot,\cdot)$ is the buyer's value for the good. In this case, the buyer maintains the no-trade price at p_0 and raises the trade payment to $\tilde{p}_1 = p_0 + c + \varepsilon$ ($\varepsilon \rightarrow 0$ in equilibrium) in order to make the seller slightly better off under the new contract. The second scenario is when $p_1 - p_0 > c(\theta, i) > v(\theta, j)$. In this case, trade is inefficient and the buyer must offer a new set of prices to prevent the seller from delivering the good. Hence the seller increases the no-trade price to $\tilde{p}_0 = p_1 - c + \varepsilon$, with ε converging to zero in equilibrium. Following that the renegotiation game is ex post efficient, Nöldeke and Schmidt (1995) also show that there exists an option contract (p_0,k) that implements efficient investment for both parties. This final proof leads to the conclusion that option contracts obtain Pareto efficiency. The downside of this model in comparison to Aghion et al. (1994) is that it reaches Pareto efficiency under risk-neutrality only. Although valid in a limited setting, the model of Nöldeke and Schmidt (1995) also provides a solution to hold-up problems.

2.2. Institutional Economic Approach to Hold-up Problems

Under a different set of lenses, Klein (1996) proposes a mechanism to alleviate hold-up problems. Without formally proving whether Pareto efficiency is obtained, Klein (1996) argues that credible commitments or hostages (Williamson 1983) can be used to maximize the self-enforcing range of contractual relationships. Commitments might represent upfront payments from party A to party B or co-investment in specific assets utilized to conduct B's activity – more generally defined as party A's private enforcement capital. When well implemented, credible commitments expand the self-enforcing range and equalize exposure of parties to unanticipated events. In other words, it broadens the extent to which market conditions can change without making potential hold-up gains larger than returns associated with honoring the agreement.

Starting from the fact that idiosyncratic investments might characterize both sides of a relationship and that parties can seldom draft contingencies for all future states of nature, the author suggests that a sufficiently large credible commitment leads parties to behave as expected for the duration of the contract. Using empirical case studies to explain the usefulness of concepts (e.g. self-enforcing range and private enforcement capital), Klein (1996) argues that the trading party making the credible commitment, say the buyer, has little incentive to hold up its counterparty because his private enforcement capital would be lost otherwise. In the opposite side of the transaction, the seller is better off seeking future benefits rather than acting with guile for one-shot gain plus zero returns thereafter (due to reputation loss). The use of credible commitments along with a repayment mechanism of hostages increases transaction efficiency and minimizes the probability of hold-up potential.

The literature of incomplete contracts has introduced several models illustrating that hold-up problems can be manageable. From the empirical perspective, however, it is still important to evaluate whether any of the proposed solutions is implementable in reality.

3. Research Methodology

This article conducts a choice experiment to test whether agricultural producers' preferences over various contract provisions resemble contract designs capable of overcoming hold-up problems. Using Lancaster's (1996) approach to utility maximization as point of departure, this study assumes that agricultural producers derive utility from various provisions in contracts for trading biomass feedstock with electricity generation utilities. The experiment attempts to reproduce decision situations to examine how individuals trade off provisions and derive value from contract designs under different market conditions.

In the context of a stated preference experiment, we introduce two hypothetical future market conditions for the developing bioelectricity industry. These treatments illustrate potential market conditions such that the expected probability of hold-up problems differs. Namely, the first market condition is characterized by high hold-up potential: entry into the biomass production business implies investing in idiosyncratic assets, crop yield variability is high across seasons, and producers may only trade with a single processor (i.e. little or no commercial alternative for the produced feedstock). Comparatively, the second market condition is characterized by comparatively low potential for hold-up: two processing plants compete for biomass supply, yield expectations are stable across seasons, and redeployment of investments sacrifices little productive value. Table 11 below summarizes the market conditions used in the choice experiment.

Table 11: Hypothetical market conditions

Market conditions	Description
MC#1	There is an electricity generating firm in your region willing to sign a production contract for biomass feedstock. Price for biomass-based electricity between the generating firm and distribution utilities is volatile. Agricultural operations require acquisition of an expensive piece of machinery, which might be redeployed in a future for its salvage value. Switchgrass yield is as variable as corn/soybeans yield over the seasons.
MC#2	There are two electricity generators willing to sign a production contract for biomass feedstock in your region. There is also a well-established cash market for biomass (i.e. fiber pellets manufacturing company), however the expected returns from this market are lower than the expected returns from the electricity market. Price for biomass-based electricity is relatively stable. Agricultural operations require acquisition of an inexpensive piece of machinery, which might be redeployed in a future period without loss of productive value. Variability of switchgrass yield is low in comparison to corn/soybeans yield variation over seasons.

Market conditions are intentionally designed to hold different levels of hold-up potential. Condition one creates high hold-up potential for the sole biomass processing firm to expropriate quasi-rents from feedstock producers in case of changes in market conditions. Without a second-best market and little alternative use for productive assets, the only option available for the engaged feedstock producer to control for hold-up potential is to sign a complex contract *ex ante*. Condition two generates little chances for the processor to hold-up biomass producers. If the processor behaves with guile, producers might trade biomass with alternative buyers (e.g. a fiber pellets manufacturing company, for instance); or even exit the market by liquidating nonspecific productive assets.

As part of the choice experiment setup, a menu of contracts with different capabilities to deal with hold-up issues is offered to agricultural producers. The objective here is to create a quasi-continuum of contracts such that exposure to hold-ups varies as transactions unfold. Two four-level attributes and one two-level attribute were selected to characterize contracts: compensation structure, base payment, and contract length. The levels used for compensation structure are borrowed from the literature of hold-up problems and from habitual practice in agribusiness settings. Base payment is included as a contract term because it might influence agricultural producers engagement decision as well as their willingness to bear more or less exposure to hold-up potential. Length characterizes contract designs because it tends to affect agricultural producers' utility expectations, especially in light of varying degrees of hold-up vulnerability (Crocker and Masten 1988).

Compensation structure takes four levels. 'Structure A' represents the specific performance contract as presented by Aghion et al. (1994), 'Structure B' represents the private enforcement capital contract proposed by Klein (1996), 'Structure C' represents a share-cost contract, and

‘Structure D’ represents an acreage-based contract. Structures C and D were added to the CE because of their frequent use to govern transactions in agribusiness settings.

The base payment term also has four levels: ‘$106/ton’, ‘$125/ton’, ‘$145/ton’, or ‘$170/ton’. These values assume an annualized yield of 2.83Mg/acre (7Mg/ha) as obtained in agronomic tests conducted in multiple experimental stations by Perrin et al. (2008) and are equivalent to annual farm revenues from switchgrass of ‘$330/acre/year’, ‘$390/acre/year’, ‘$450/acre/year’, and ‘$530/acre/year’, respectively. Based on the operating costs for switchgrass obtained by Perrin et al. (2008) and Chen et al. (2014), these farm revenues define an equivalent range of gross returns (i.e. sales minus operating costs) as found from conventional cropping systems in Midwestern states. In other words, we assume that the hypothetical menu of contracts offered to producers is competitive to returns from a corn-soybean rotation system, the most common agriculture practice in the Midwest. Finally, contract length has two levels: ‘five years’, or ‘ten years’. It is worth noting that the attributes and levels detailed above were previously discussed with Michigan agricultural producers in focus group interviews (Ross and Signorini 2013). Table 12 provides further details about contract terms and levels.

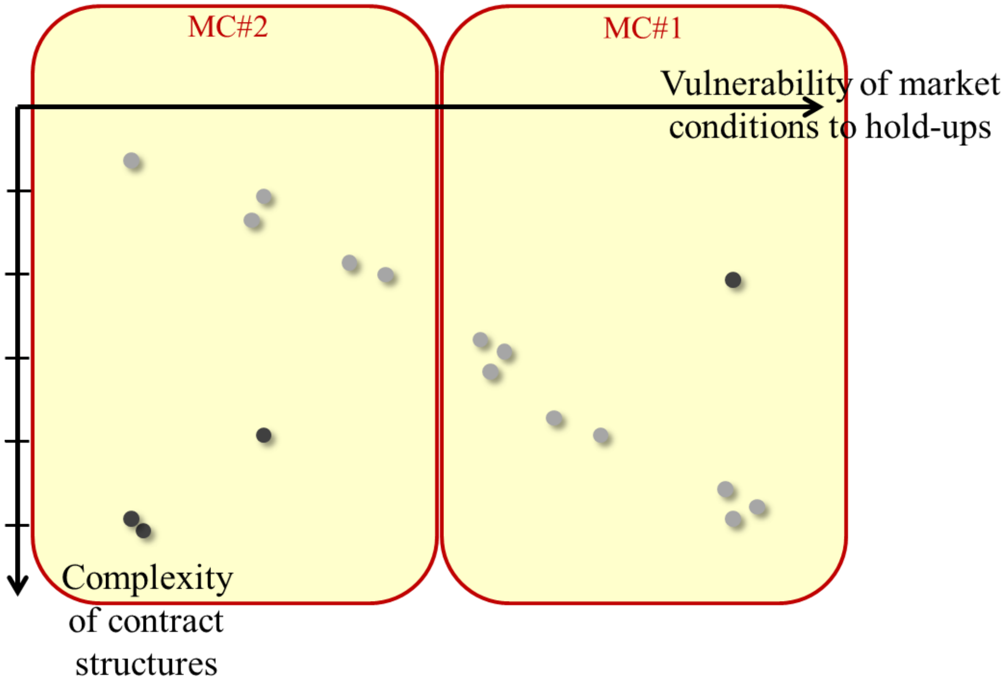
Table 12: Attributes, levels and hypotheses tested in the choice experiment

Contract Terms	Levels	Description (♦) / Expected Effect on stated preferences (◊)
Compensation structure	- Structure A (specific performance)	♦ Parties agree ex ante on price and quantity to be delivered (p_0, q_0) and renegotiate terms (p_1, q_1) after realization of state of nature and investment levels. Producer invests in productive assets if necessary. Biomass processor is penalized if trade is delayed.
	- Structure B (private enforcement capital)	♦ Parties agree ex ante on price and quantity to be delivered. Biomass processor and producer co-invest in productive assets if necessary. Biomass processor loses ownership of assets in case of contract breach due to hold-up.
	- Structure C (share-cost)	♦ Parties agree ex ante on price. Biomass processor and producer share establishment costs equally. Producer invests in productive assets if necessary.
	- Structure D (acreage-based)	♦ Parties agree ex ante on price per acre farmed. Producer invests in productive assets if necessary.
		◊ Preference for complex contracts increases as market situations are more vulnerable to hold-ups.
Base payment	- $106/ton ($330/acre) - $125/ton ($390/acre) - $145/ton ($450/acre) - $170/ton ($530/acre)	◊ Higher base payments induce decision makers to bear more exposure to hold-up problems.
Length of contract	- Five years - Ten years	◊ Short-term contracts are preferable in situations of high variability of yield and prices.

3.1. Hypotheses

Economic theory predicts agricultural producers to recognize that some market conditions are more susceptible to hold-ups than others, and choose contracts accordingly. In concordance with theory, this study hypothesizes that producers choose contract structures that are better equipped to deal with hold-up problems when such problems are more likely to occur as in market condition one. Conversely, we hypothesize that producers choose less complex structures when market condition two (i.e. hold-up problems less likely to occur) characterizes the business environment. We also hypothesize, however, that bounded rationality (Simon 1978) and traditions might lead producers to make inefficient contract choices. Figure 8 below illustrates these hypotheses. Light grey dots depict efficient decisions by agricultural producers and dark grey dots exemplify inefficient choices. While mainstream economic theory suggests that fully rational individuals' preferences move from less to more complex contract structures as hold-up potential increases in market conditions (light grey dots), unorthodox theory proposes that bounded rational individuals might prefer contract structures according to previous experiences and traditions (dark grey dots). Finally, this study hypothesizes that short-term contracts are preferred when market conditions set the stage for hold-up problems to happen. We discuss each hypothesis in depth in the next section. Hypotheses are summarized in table 12.

Figure 8: Primary hypothesis, illustrated



3.2. Survey design, data collection, and data

The experiment uses an optimal design and accounts for two-way interactions between contract design attributes and market condition dummies. The OPTEX procedure in SAS was used to identify 24 choice scenarios and divide them into eight blocks of three scenarios each[22]. The blocking strategy was used to decrease the number of scenarios presented to agricultural producers and to reduce statistical bias due to fatigue (Tonsor et al. 2005). Sequentially, blocks were treated with both market condition one and market condition two such that each respondent faced three choice scenarios under market condition one (high hold-up potential) and three choice scenarios under market condition two (low hold-up potential). The order of market condition appearance was randomized across survey versions to control for potential bias. All choice scenarios featured

[22] The experimental design obtained an optimal D-efficiency value of 95.29.

two contract alternatives and an opt-out alternative. By including the opt-out alternative, we remove the market participation assumption and recognize that agricultural producers might choose not to engage in a production contract for biomass feedstock (Adamowicz et al. 1998). Figures 9 and 10 in the appendix provide examples for the choice scenarios under information treatment one and under information treatment two, respectively.

The data used in this study comes from agricultural producers' responses to a mail survey administered through USDA/NASS. The survey was sent out to 4,176 agricultural producers with operations located in Illinois, Michigan, Minnesota, Missouri, Ohio, or Wisconsin. Prior to the mailing, producers were screened and only those who meet the following three criteria were considered eligible:

1. Producers must have responded to the 2012 Census of Agriculture. This criterion implies that the producer is listed in the USDA/NASS data bank.
2. Agricultural producers must have reported farm income of $10,000.00 or more in 2012 to be eligible as survey respondents. This criterion limits the population of producers to professional individuals and excludes those who grow crops for leisure. Such criterion is widely found in survey-based studies (Jensen et al. 2007, Paulrud and Laitila 2010, Hayden 2013).
3. Producers must have reported 'value of sales' above $5,000.00 in section 6 ('field crops') and/or section 7 ('hay and forage crops') of the 2012 census. This criterion seeks to include in the population farmers who produce grains and/or forage crops and seek economic gains from those activities. It attempts to include diversified farms with multiple business units and exclude non-diversified farms unless the single operation is related to field crops or forage crops.

Eligible producers were randomly selected by USDA/NASS within each state. The objective here was to obtain a balanced dataset, allowing consistent statistical analysis of agricultural producers' preferences and representation across the Midwest. Sampled producers received two letters in the mail and a phone call. The first correspondence contained a cover letter explaining the purpose of the study and a copy of the survey containing the choice experiment as well as demographic questions for characterization of the sample of producers. The second correspondence was sent two weeks after the first mailing with the aim to reinforce the importance of the study. It included copies of the cover letter and the survey that were sent in the first mailing. Finally, phone calls were made a week after the second mailing to those participants who had not yet returned the surveys. In total 439 valid surveys were obtained, leading to a 10.5% response rate. Almost all returned surveys were filled completely, yielding a statistical sample of 2,626 observations (439 X 6 choice scenarios, approximately) – 1,312 for information treatment one and 1,314 for information treatment two[23]. Survey sample is available from the authors upon request.

The dataset is distributed across states as follows: 14.75% of the choices over contract designs were stated by agricultural producers from Illinois; 22.77% from Michigan; 14.55% from Minnesota; 15.16% from Missouri; 14.47% from Ohio; and 18.32% from Wisconsin. Descriptive statistics of demographic characteristics for the survey sample and population of farmers who meet the research criteria are presented in Table 13.

[23] The response rate achieved here is comparable to other studies. Khanna et al. (2014) obtained 424 usable responses from 4800 surveys, leading to 8.8% response rate.

Table 13: Demographic statistics

	Sample	Population		Obs.
Operation size	439 *(persons)*	656,917		2626 *(n)*
- Illinois	63	109,123		387
- Michigan	98	76,095		598
- Minnesota	65	106,537		382
- Missouri	68	138,339		398
- Ohio	64	115,743		380
- Wisconsin	81	111,080		481
Acreage	438.6 ±694.8	451.98 ±746.37	(mean ± st. dev.)	
- Illinois	512.50	617.73		
- Michigan	397.40	419.52		
- Minnesota	531.55	533.85		
- Missouri	280.04	477.12		
- Ohio	522.88	355.81		
- Wisconsin	423.19	318.34		
Experience (years)	30.16 ±14	30.3 ±15.06	(mean ± st. dev.)	
- Illinois	29.13	31.27		
- Michigan	31.88	31.18		
- Minnesota	30.89	29.69		
- Missouri	29.94	30.25		
- Ohio	29.25	30.10		
- Wisconsin	29.19	29.75		
Age	60.07 ±12.35	59.79 ±13.31	(mean ± st. dev.)	
- Illinois	58.63	60.16		
- Michigan	61.77	60.62		
- Minnesota	58.92	58.08		
- Missouri	61.40	61.19		
- Ohio	58.34	59.86		
- Wisconsin	60.32	59.07		
Farm Income Participat.	48% ± 36%	48% ±36%	(mean ± st. dev.)	
- Illinois	51%	52%		
- Michigan	39%	44%		
- Minnesota	61%	56%		
- Missouri	39%	44%		
- Ohio	47%	41%		
- Wisconsin	53%	52%		

Table 13 (cont'd)

	Sample	Population		
Gender				
- male	97%	96%		
- female	3%	3.9%		
Retired?				
- yes	20%	19.6%		
- no	80%	80.4%		
Renewable Energy Enterprise?				
- yes	4%	2.9%		
Familiarity to contracts	*Structure A*	*Structure B*	*Structure C*	*Structure D*
- Never heard	0.59	0.66	0.52	0.50
- Heard but never used	0.27	0.24	0.33	0.30
- Used	0.05	0.00	0.03	0.10
- No response	0.10	0.10	0.12	0.10

It is worth noting that the obtained sample appears to be a good representation of the population. Table 13 above indicates that the summary statistics of experience, age, farm income participation, gender, retirement status, and engagement of producers in renewable energy enterprises are similar for sample and population. There are slight divergences for harvested acres, however. Although sample and population present similar overall mean for harvested acres, sampled farmers from Illinois and Missouri seem to have harvested 21% and 70% less than the population of their corresponding states. Sampled farmers from Ohio and Wisconsin, on the other hand, harvested 32% and 25% more than their respective state populations. These differences in acreage must be considered prior to extrapolating research findings to the entire Midwest region.

Table 13 also reports the level of familiarity with contract structures expressed by survey respondents. The contract structures included in the choice experiment are unknown to at least half of the individuals. Acreage-based contract (structure D) is the most familiar with 40% of the respondents having either heard or used it before. Share-cost contract (structure C) comes second with 36% of familiarity. Specific performance contract (structure A) reaches 32% of familiarity and comes third. Finally, private enforcement capital (structure B) is the most obscure contract type with 24% of the respondents having heard about it but no past users.

3.3. The Model

The three empirical models used to analyze agricultural producers' preference data are based on the random utility maximization (RUM) model (McFadden 1974, 1981). The McFadden model assumes that agricultural producers maximize utility by choosing from a set of finite production contracts when presented with hypothetical decision scenarios. In mathematical notation, let $\boldsymbol{Z}_s$ be the vector of k quantifiable attributes in contract design s and $\boldsymbol{Y}_t$ be a vector of market condition characteristics in decision scenario t. Let utility to agricultural producer i from contract design s in market scenario t be given by the following indirect utility function:

$$V_{ist} = v_{ist}(\boldsymbol{Z}_s \boldsymbol{Y}_t) + \varepsilon_{ist} \tag{1}$$

The first element in the right hand side of equation (1) is a deterministic term representing the set of information available to both decision makers – agricultural producers in this case – and the analyst. The second element is only observable by agricultural producers, and from the analyst's perspective it is equivalent to a stochastic term. Deterministic and stochastic terms are assumed independent where the latter can be argued as decision makers' heterogeneity in preferences (Keane 1997).

Vector $\boldsymbol{Z}_s$ in the deterministic term includes the following k attributes: (i) compensation structure, (ii) base payment, and (iii) length of contract – with randomized levels within contract designs. Vector $\boldsymbol{Y}_t$ includes characteristics of hypothetical market conditions such as (i) number of processing plants in the market, (ii) degree of asset specificity, (iii) expected price variability for biomass feedstock, and (iv) expected yield variation. We use a single dummy variable to capture variation in these attributes across the two market conditions[24]. It is worth stressing that the dummy variable associated with market characteristics is interacted with the vector of contract attributes in the empirical model. The reason for such interaction is to examine whether market conditions and socio-economic characteristics explain preference heterogeneity for contract attributes.

The model also assumes that the deterministic term $v_{iskt}(\boldsymbol{Z}_{sk}\boldsymbol{Y}_t)$ is linear in parameters:

$$v_{ist}(\boldsymbol{Z}_s\boldsymbol{Y}_t) = \boldsymbol{\beta}\boldsymbol{Z}_s\boldsymbol{Y}_t \tag{2}$$

where $\boldsymbol{\beta}$ is a vector of utility weights for interactions between market conditions and contract attributes. Plugging (2) into (1) we have:

$$V_{ist} = \boldsymbol{\beta}\boldsymbol{Z}_s\boldsymbol{Y}_t + \varepsilon_{ist} \tag{3}$$

Therefore, we assume that agricultural producer i chooses the contract alternative s if $V_{is^*t} > V_{ist}\ \forall s^* \neq s$. Consequently, the probability of producer i choosing contract design s is given by:

$$Pr_{is^*t} = Pr(V_{is^*kt} + \varepsilon_{is^*t} > V_{ist} + \varepsilon_{ist}; \forall s^* \neq s) \tag{4}$$

[24] This approach does not harm interpretation of CE results. As the characterizing levels of market conditions are nonrandom across decision scenarios, the use of a dummy variable is appropriate and measures whether agricultural producers' preferences differ between market conditions one and two.

However, because the analyst cannot observe ε_{ist}, an informed assumption regarding its distribution must be made so estimates resulting from stated decisions can be obtained. A convenient and often made set of assumptions regarding ε_{ist} is that it is distributed identically and independently across individuals and follows a Glumbel distribution (ε_{ist} ~ i.i.d. Glumbel or extreme value type I, in short). Thus, the basic multinomial logit (MNL) model (McFadden 1974) for the probability that agricultural producer i chooses contract design s^* when presented with decision scenario t can be written as:

$$Pr_{is^*kt} = \frac{exp\,[\boldsymbol{\alpha}\boldsymbol{Z}_{s^*}\boldsymbol{Y}_t]}{\sum_{s\neq s^*} exp\,[\boldsymbol{\alpha}\boldsymbol{Z}_s\boldsymbol{Y}_t]} \tag{5}$$

3.4. Refinements of the Multinomial Logit Model

The recent discrete choice literature has suggested three main refinements to the McFadden model: (i) addition of heterogeneity in preferences for observed attributes; (ii) inclusion of preference heterogeneity for unobserved attributes (Keane 1997); and (iii) addition of both types of heterogeneity into a model capable of estimating parameters in WTA-space. The first suggestion has led scholars to propose and apply the random parameters logit (RPL) model, which is appealing to practitioners due to its ease of use (Fiebig et al. 2010). In this case, utility weights are assumed to be random variables following a pre-determined distribution. When applied, the RPL model modifies equation 3 as follows:

$$V_{ist} = (\boldsymbol{\beta} + \boldsymbol{\gamma}_i)\boldsymbol{Z}_s\boldsymbol{Y}_t + \varepsilon_{ist}, \tag{6}$$

where $\boldsymbol{\beta}$ become vector of mean utility weights on observed attributes, and $\boldsymbol{\gamma}_i$ is vector of individual i-specific deviations from the mean weight.

The second refinement serves as motivation for the scaled multinomial logit (S-MNL) model, which modifies equation 3 as below:

$$V_{ist} = \boldsymbol{\beta}\boldsymbol{Z}_s\boldsymbol{Y}_t + {}^{\varepsilon_{ist}}/_{\sigma_i}, \tag{7}$$

where σ_i is individual-specific and represents different degrees of unobserved heterogeneity for individual respondents across multiple decision observations (Fifer et al. 2014). The scale parameter σ is commonly normalized to one in order to allow model estimation (Fiebig et al. 2010). The S-MNL model can be re-written in the following form:

$$V_{ist} = (\boldsymbol{\beta}\sigma_i)\boldsymbol{Z}_s\boldsymbol{Y}_t + \varepsilon_{ist} \tag{8}$$

The third refinement to the MNL model has received recent attention in the literature due to its flexibility and capability of allowing estimation in WTA-space. Incorporating both types of preference heterogeneity into the same model – deviations from mean utility weights and i-specific scale heterogeneity – has led scholar to the generalized multinomial logit (G-MNL) model (Fiebig et al. 2010). More specifically, the G-MNL model combines equations 6 and 8 and is presented in equation 9.

$$V_{ist} = [\boldsymbol{\beta}\sigma_i + \delta\boldsymbol{\gamma}_i + (1-\delta)\boldsymbol{\gamma}_i\sigma_i]\boldsymbol{Z}_s\boldsymbol{Y}_t + \varepsilon_{ist} \tag{9}$$

Scale factor σ_i and the deviations to mean utility weights $\boldsymbol{\gamma}_i$ take the same descriptions provided above. The new variable δ captures the proportions of preference heterogeneity associated with individual scale factor σ_i or individual-specific deviation γ_i[25].

[25] For a comprehensive treatment of the G-MNL model, please refer to Fiebig et al. (2010).

In addition to these major refinements, choice behavior specialists have been active in numerous discussion fronts regarding the RPL, S-MNL, and G-MNL models. To mention a few, authors have discussed whether or not observed attributes should be correlated (Revelt and Train 1998, Scarpa and Del Giudice 2004). While most scholars agree that adding this flexibility tends to enhance goodness of fit, others explain that complex models may prevent its implementation due to the rapid increase in number of parameters (Louviere et al. 2000, Train 2009). In other words, allowing parameters to correlate freely in complex models forces the number of parameters to increase rather fast, making estimation computationally infeasible.

Authors have also argued that utility weights on pecuniary parameters should be treated as random variables, just as the weights related to other attributes are in RPL and G-MNL models. The underlying reason is that unobserved characteristics are likely to influence individuals to respond differently to revenue (or to expense in case of willingness-to-pay estimation) (Fiebig et al. 2010). Train (2009) contends that models with all random coefficients can be empirically problematic as WTA/WTP values derived from two random coefficients do not converge to identifiable distributions.

In a different study Hess and Rose (2012) express concerns about the G-MNL model exclusively. The authors argue that scale heterogeneity is equivalent to heterogeneity in individual utility weights, and including both types of heterogeneity into the same model (as in equation 8) is misleading. They explain that the relative gain in fit obtained through the G-MNL model – when compared to the RPL model – is primarily associated with using more flexible distributions, rather than capturing scale heterogeneity. Louviere et al. (2008) also criticize the G-MNL model, as they have found that heterogeneity in preferences is better captured by S-MNL than by G-MNL.

3.5. The Empirical Models

In this study, three empirical models – RPL, S-MNL, and G-MNL – are used to estimate WTA for contract design attributes. Either model has meaningful advantages over the traditional MNL model because they recognize that subjects are heterogeneous and might have different appreciation for specific attributes. The modeling question that remains unanswered is of how to incorporate agricultural producers' preference heterogeneity – through deviations from mean utility weights, through individual-specific scalar, or incorporating both types at once. Following the method proposed by Fiebig et al. (2010), we assess model performance by examining the likelihood improvement that is attained by including preference heterogeneity into the MNL model.

The estimation function derived from the RPL model – equation 5 above – assumes that utility weights on non-pecuniary attributes are random parameters and follow a normal distribution. The utility weight on base payments is assumed to be nonrandom to allow identification of WTA estimates (Goett et al. 2000, Morey and Rossmann 2003). Hence, the probability that agricultural producer i chooses contract design s^* when presented with scenario t becomes:

$$Pr_{is^*t} = \int \frac{exp[\boldsymbol{\beta Z}_{s^*}\boldsymbol{Y}_t]}{\sum_{s\in S} exp[\boldsymbol{\beta Z}_s\boldsymbol{Y}_t]} g(\beta)d\beta \tag{10}$$

where the distribution of random parameters $g(\cdot)$ is normal; $\boldsymbol{\beta} = \boldsymbol{\beta} + \boldsymbol{\gamma_i}$[26].

[26] Normal distribution is assumed because it provides the best fit to our data.

The S-MNL model assumes that utility weights are scaled proportionately across agricultural producers. Based on equation 7, the probability of agricultural producer i choosing contract design s^*in the decision scenario t is:

$$Pr_{is^*t} = \frac{exp\ [\boldsymbol{\beta Z}_{s^*}\boldsymbol{Y}_t]}{\sum_{s\neq s^*} exp\ [\boldsymbol{\alpha Z}_s\boldsymbol{Y}_t]}$$

(11)

where $\boldsymbol{\alpha} = \boldsymbol{\alpha}\sigma_i; \boldsymbol{\beta} = \boldsymbol{\beta}\sigma_i;\ \ \sigma_i = exp\left(-\tau^2/_2 + \tau\omega_i\right)$; and ω_i takes the standard normal distribution.

The G-MNL model incorporates scaled heterogeneity in preferences as well as deviation from mean utility weights. Derived from equation 8, the probability of agricultural producer i choosing contract design s^* in the decision scenario t becomes:

$$Pr_{is^*t} = \int \frac{exp[\boldsymbol{\beta Z}_{s^*}\boldsymbol{Y}_t]}{\sum_{s\in S} exp[\boldsymbol{\beta Z}_s\boldsymbol{Y}_t]} g(\beta)d\beta$$

(12)

where $\boldsymbol{\beta} = \boldsymbol{\beta}\sigma_i + \delta\boldsymbol{\gamma}_i + (1-\delta)\boldsymbol{\gamma}_i\sigma_i$; and δ is a scalar to be estimated. Similar to the RPL model, coefficients on non-pecuniary attributes are assumed to be normally distributed while coefficients on base payments – interacted with dummy variables for market condition one and market condition two – are fixed to allow identification of WTA values. Although choice behavior specialists are enthusiastic with the possibility of estimating preferences in WTA-space, the estimates we derive from the G-MNL model are in the usual preference-space. Because the primary objective of this study is to determine whether market conditions (high vs. low holdup potential) influence preference for industrial organization-related contracts or institutional economics-related contracts, the models contain two interacted parameters for the pecuniary attribute, which cannot be modeled at once for direct estimation of WTA values[27].

Correlation of coefficients is assumed absent due to the complexity of the model. Given that the model considers two-way interaction effects between market conditions and contract design attributes and between demographic characteristics and contract attributes, allowing correlation of coefficients would add 60 plus parameters to be estimated which is computationally infeasible.

Willingness to accept values for contract design attributes are sequentially computed for each hypothetical market condition. Following the literature, WTA values are the ratio of the estimated coefficient on the attribute of interest to the coefficient on base payment, times two due to our use of effects coding (Lusk et al. 2003). Statistical variability in WTA estimates are calculated using the parametric bootstrapping technique as proposed by Krinsky and Robb (1986). For each contract design attribute, WTA estimates are compared across market conditions using the complete combinatorial method proposed by Poe, Giraud, and Loomis (2005).

4. Empirical Results

Estimates for two RPL models are reported in Table 14. The left hand side column presents estimates for the main effects model while the right hand side shows estimates for the model with interactions between contract attributes and market condition dummies. Estimates from the main effects model show that all attributes included in the experiment influence decision over contract

[27] Different strategies were attempted to overcome this limitation. Separating the dataset into two sub-sets - one for each market condition – did not yield a solution. The models do not perform and fail to return robust estimates when sub-sets of the original dataset are utilized.

designs. Base payment is a valuable attribute and tends to increase agricultural producers' utility. Contract structures that resemble specific performance contracts (structure A), private enforcement capital contracts (structure B), or share-cost contracts (structure C) tend to influence agricultural producers' utility negatively when compared to acreage-based contracts (structure D). Finally, long-term contracts (i.e. 10 years long) are less preferred than short-term contracts (i.e. 5 years long). The main effects model also indicates that there is strong heterogeneity in producers' preferences for non-pecuniary attributes, as shown by the statistically significant estimates of 'standard deviation' next to parameter estimates.

Results from the RPL model with two-way interactions between contract attributes and market conditions capture some of the observed heterogeneity. Coefficients on utility weights are significant at 1% confidence level except for share-cost contract structures under high levels of vulnerability. With exception made to share-cost contract structures, non-pecuniary attributes continue to show statistically significant heterogeneity in preferences. Mean utility weights, nevertheless, lead to interesting interpretations. When the contract engagement decision is evaluated in market condition one (high hold-up potential), base payment appears to be slightly less important than it is under conditions of low hold-up potential. Acreage-based contract structure attains agricultural producers' preference regardless of the market condition because of the negative coefficients in alternative contract structures. Coefficients on alternative contract structures also indicate that decision makers are less reluctant to adopt complex contracts if the decision is made under high hold-up potential, and more reluctant if hold-ups do not constitute credible threats. More specifically, parameter estimates reported in Table 14 indicate that mean utility weights on structure A and structure B under high hold-up potential are systematically larger than coefficients on the same structures but under low hold-up potential, suggesting that preference for complex contracts increases in probability of hold-up problems to occur. Agricultural producers also seem indifferent to the possibility of signing share-cost contracts with biomass suppliers when market conditions set the stage for high hold-up potential. Finally, coefficients on contract length are similar and indicate preference for short-term contracts regardless of the market condition.

Despite the clear preference for acreage-based contract structures, these initial results suggest that decision makers weigh market conditions against financial gains and seek appropriate mechanisms to engage in transactions. Results also indicate that one cannot reject the hypothesis that having the possibility of signing a share-cost contract does not influence agricultural producers' preference under market conditions with high hold-up potential, given that its parameter estimate is not significant when high hold-up potential characterizes the market. Under low hold-up potential, however, share-cost structures seems to influence preference. Other parameter estimates provide insights on preferred structures if high hold-up potential characterizes the market condition. Conditional on high potential, producers would give similar consideration to specific performance contract (structure A) or private enforcement capital contract (structure B) to deter opportunism. Statistical difference in parameter magnitude is discouraged at this point (Scarpa and Del Giudice 2004). Statistical difference in preference for complex contracts is discussed below once WTA values are computed.

Table 14: Parameter estimates from RPL models (main effects vs. two-way interactions)

Variable	RPL model	Standard Deviation	RPL model *(partitioned by market condition)*	Standard Deviation
Base Payment	0.032 (0.002)**			
Low hold-up potential			0.033 (0.004)**	
High hold-up potential			0.029 (0.003)**	
Contract Structure				
- Specific Performance	-0.435 (0.071)**	0.626 (0.099)**		
Low hold-up potential			-0.490 (0.098)**	0.524 (0.216)*
High hold-up potential			-0.395 (0.104)**	0.762 (0.191)**
- Private Enforc. Capital	-0.524 (0.074)**	0.820 (0.093)**		
Low hold-up potential			-0.631 (0.103)**	0.672 (0.174)**
High hold-up potential			-0.389 (0.105)**	1.002 (0.172)**
- Share-Cost	-0.226 (0.061)**	0.223 (0.171)		
Low hold-up potential			-0.306 (0.087)**	0.107 (0.567)
High hold-up potential			-0.139 (0.083)	0.103 (0.343)
Long-term length	-0.429 (0.064)**	0.715 (0.083)**		
Low hold-up potential			-0.440 (0.088)**	0.795 (0.159)**
High hold-up potential			-0.465 (0.870)**	0.529 (0.201)**
Opt Out	4.785 (0.427)**	4.246 (0.305)**		
Low hold-up potential			4.839 (0.628)**	4.116 (0407)**
High hold-up potential			4.297 (0.586)**	4.251 (0.423)**
Log likelihood function	-2275.59		-2269.45	
AIC	4116.2		4582.9	

Notes: The models were estimated using Nlogit 5.0, with Halton draws and 1000 replications for simulated probability. Standard errors are reported in parentheses.
* and ** indicate statistical significance at 5% and 1% level respectively.
A likelihood-ratio (LR) test was performed. Preference data fit both models similarly. We cannot reject the main effects model in favor of the two-way interactions model.

Both S-MNL and G-MNL models with two-way interactions show similar relations among coefficients (Table 15). Base payment under high hold-up potential influence utility at a lesser degree than base payment under low hold-up potential. Agricultural producers prefer acreage-based contract structures to any other structure – equipped to deal with hold-ups or not – in either market condition. In contrast to the RPL model, producers appear to consider the share-cost structure a feasible alternative under high hold-up potential. Looking specifically at complex contracts (i.e. structure A vs. structure B) under high potential, S-MNL and G-MNL offer opposite results. While S-MNL suggests that producers prefer private enforcement capital contracts to specific performance contracts, G-MNL shows that producers would be more reluctant to accept the former and more willing to accept the latter. In any case, both models do not reject the hypothesis that producers' preference for complex contracts increases when probability of hold-ups increases (i.e. coefficients on structure A and structure B increase as market conditions change from low to high hold-up potential). Finally, coefficients on contract length confirm that producers prefer shot-term contracts to long-term contracts across all market conditions. Parameter estimates from the S-MNL and G-MNL models are reported in table 15.

Table 15: Parameter estimates from S-MNL and G-MNL models with two-way interactions

Variable	S-MNL model *(partitioned by market conditions)*	G-MNL model *(partitioned by market conditions)*	Standard Deviation
Base Payment			
Low hold-up potential	0.020 (0.002)**	0.033 (0.003)**	
High hold-up potential	0.017 (0.002)**	0.031 (0.003)**	
Contract Structure			
- Specific Performance			
Low hold-up potential	-0.322 (0.056)**	-0.852 (0.219)**	0.814 (0.296)**
High hold-up potential	-0.232 (0.056)**	-0.724 (0.224)**	1.054 (0.307)**
- Private Enforc. Capital			
Low hold-up potential	-0.385 (0.055)**	-1.271 (0.295)**	0.834 (0.281)**
High hold-up potential	-0.199 (0.055)**	-0.826 (0.246)**	1.305 (0.342)**
- Share-cost			
Low hold-up potential	-0.208 (0.059)**	-0.557 (0.189)**	0.158 (0.718)
High hold-up potential	-0.119 (0.059)*	-0.351 (0.164)*	0.003 (4.125)
Long-term length			
Low hold-up potential	-0.256 (0.045)**	-0.725 (0.190)**	0.979 (0.278)**
High hold-up potential	-0.249 (0.044)**	-0.832 (0.192)**	0.582 (0.326)
Opt Out			
Low hold-up potential	3.443 (0.282)**	7.465 (1.201)**	1.195 (2.124)
High hold-up potential	2.885 (0.275)**	7.156 (1.105)**	1.036 (3.274)
τ	0 (0.221)	0.971 (0.111)**	
σ_i	1 (0.005)**	0.988 (1.158)	
Log likelihood function	-2701.29	-2260.28	
AIC	5428.6	4568.6	

Notes: The models were estimated using Nlogit 5.0, with Halton draws and 1000 replications for simulated probability. Standard errors are reported in parentheses.
* and ** indicate statistical significance at 5% and 1% level respectively.

Despite robust findings across the three empirical models, it is important to assess model performance when decision makers exhibit preference heterogeneity. Fiebig et al. (2010) suggest that model performance can be assessed by looking at the percentage log-likelihood improvement in going from the MNL model – where preference homogeneity is assumed – to either RPL, S-MNL, or G-MNL. Including heterogeneity via deviations from mean utility weights improves model performance faster than via individual scale heterogeneity. Taking the MNL model with two-way interactions as base for comparison, RPL improves fit by 16.01% while S-MNL improves fit by 0.03%. Allowing even greater flexibility and modeling both types of heterogeneity – as in the G-MNL – leads to a 16.35% performance improvement. Although results indicate that G-MNL outperforms the other modeling strategies, it is important to consider the argument offered by Hess and Rose (2012) regarding the use of both deviation from mean utility weights and individual scalar at once. As mentioned above the authors explain that G-MNL tends to perform better due to its increased flexibility as opposed to its capability of capturing different types of heterogeneity in preferences. Empirical results obtained here seem to corroborate with Hess and Rose (2012) given minimal performance gain obtained when individual-specific deviation is modeled alone.

In any case interpreting the magnitudes of parameter estimates is discouraged because only relative parameter values matter (Scarpa and Del Giudice 2004). The conventional alternative in this circumstance is to estimate agricultural producers' WTA based on parameter estimates. Tables 16 and 17 report mean WTA values, 95% confidence intervals, and statistical evidence for difference in preferences under market conditions one and two (high hold-up potential and low hold-up potential, respectively).

Table 16: Mean Willingness-to-accept (WTA) and 95% confidence intervals

Variable	RPL main effects	*1	RPL two-way interactions	*1
Contract Structure				
- Specific Performance	-27.01 [-37.42, -17.84]	△		
Low hold-up potential			-29.41 [-42.42, -17.86]	△
High hold-up potential			-26.96 [-42.70, -12.80]	△
- Private Enforc. Capital	-32.48 [-43.78, -22.78]	△		
Low hold-up potential			-37.84 [-50.65, -26.17]	△
High hold-up potential			-26.53 [-42.96, -12.55]	△
- Share-cost	-14.10 [-22.57, -6.53]	☐		
Low hold-up potential			-18.44 [-29.95, -8.35]	△
High hold-up potential			-9.60 [-21.73, 1.77]	△
Long-term length	-26.59 [-35.45, -18.65]			
Low hold-up potential			-31.63 [-44,48, -20.32,]	△
High hold-up potential			-26.43 [-37.18, -16.46,]	△

Notes: Confidence intervals (presented in brackets) were simulated using 1000 Krinsky-Robb replications.
Different symbols indicate statistical difference at 5% confidence level across contract structures (for main-effects RPL) or within attribute (for two-way interactions RPL).
*1: Complete combinatorial test results.

Producers expressed overall preference for acreage-based contracts. Values of WTA for contract structures computed from coefficients of the main effect RPL model presented in Table 6 below indicate that producers would require on average an additional $27.01/ton to sign a specific performance contract. Alternatively, producers would require $32.48/ton extra to engage in a private enforcement capital contract or an additional $14.10/ton to enter in a share-cost contract agreement when compared to an acreage-based contract, *ceteris paribus*. In fact, the WTA estimate for share-cost structure is statistically different at 5% level from estimates computed for complex contract structures. Computations report that WTA values for specific performance structure and private enforcement capital structure are not statistically different at 5% of confidence level when market conditions are not formally modeled.

This result seems well aligned with producers' revealed familiarity to contract types (Table 3), suggesting that bounded rationality (Simon 1978) and habitual practices play important roles in agricultural producers' business decisions. Acreage-based contract was reported as the most familiar contract: 40% of survey respondents have either heard or used this type of contract. Producers have also shown good familiarity to share-cost contracts. Out of 439 subjects, 36% have heard or used this contract structure. When it comes to complex contracts, however, experience with specific performance contract and private enforcement capital contract falls to 32% and 24%, respectively.

Values of WTA differ across market conditions when interactions are modeled. Although producers prefer the contract type that is mostly familiar to them (i.e. acreage-based contract), WTA values indicate increasing acceptance for complex contracts as hold-up potential increases. For specific performance structure, agricultural producers would require $26.96/ton under high hold-up potential and $29.41/ton under low hold-up potential. For private enforcement capital structure, producers would demand $26.53/ton to sign it under high hold-up potential versus $37.84/ton under low hold-up potential. This suggests that producers do understand the importance of using contracts better equipped to deal with hold-up problems when such problems are more likely to happen. The latter result combined with the smaller coefficient on base payment under high hold-up potential (versus low hold-up potential – table 5) leads to interesting interpretations. Survey respondents have not only shown that financial gains have smaller influence on utility when market conditions set the stage for hold-ups, but have also shown that complex contracts are comparatively more attractive under high hold-up potential than they are under low hold-up potential.

Nevertheless, statistical results show that agricultural producers perceive specific performance structure and private enforcement capital structure similarly under high hold-up potential, given that WTA values for these structures are not statistically different. The same comment is valid under low hold-up potential. Willingness to accept for specific performance structure and WTA for private enforcement capital structure are not statistically different at 5% of confidence level.

For the sake of completeness, producers request an additional of $9.60/ton to sign share-cost contract under high hold-up potential and $18.44/ton to sign the same contract structure under low probability of hold-ups to occur. It is worth noting that the 95% confidence interval for the mean WTA of the share-cost contract under hold-up potential includes zero, so the result is not statistically significant.

Regarding contract length, agricultural producers prefer short-term contracts regardless of the market condition. Producers would require $26.59/ton on average to accept a 10-year contract rather than a 5-year. Conditional on hold-up potential, producers would demand an additional $26.43/ton to engage in a 10-year contract under high hold-up potential and $31.63/ton to sign a 10-year contract under low hold-up potential. While these magnitudes are consistent with theory (Crocker and Masten 1988), which indicates that decision makers prefer short-term contracts to protect themselves against high levels of uncertainty; our results should be used with discretion because coefficients are not statistically different under low and high hold-up potential.

Table 17: Mean Willingness-to-accept (WTA) and 95% confidence intervals

Variable	S-MNL Two-way interactions	*1	G-MNL two-way interactions	*1
Contract Structure				
- Specific Performance				
Low hold-up potential	-31.69 [-45.41, -19.82]	△	-51.66 [-79.41, -26.33]	△
High hold-up potential	-27.27 [-42.86, -13.45]	△	-46.52 [-76.73, -18.07]	△
- Private Enforc. Capital				
Low hold-up potential	-37.92 [-52.24, -25.80]	△	-76.94 [-114.51, -42.31]	△
High hold-up potential	-23.50 [-39.02, -10.01]	△	-53.47 [-88.78, -21.36]	△
- Share-cost				
Low hold-up potential	-20.48 [-33.82, -8.51]	△	-33.77 [-56.94, -11.94]	△
High hold-up potential	-14.10 [-29.39, -0.54]	△	-22.80 [-45.04, -2.16]	△
Long-term length				
Low hold-up potential	-25.20 [-34.94, -16.51]	△	-44.03 [-69.15, -21.22]	△
High hold-up potential	-29.27 [-41.33, -18.68]	△	-53.61 [-81.44, -28.23]	△

Notes: Confidence intervals (presented in brackets) were simulated using 1000 Krinsky-Robb replications.
Different symbols indicate statistical difference at 5% confidence level within each attribute.
*1: Complete combinatorial test results.

Table 17 presents the mean estimates of agricultural producers WTA for contract attributes derived from S-MNL and G-MNL coefficients as well as the 95% confidence intervals around those means. The interpretation and discussion that follows consider results obtained from the G-MNL model only because of the relatively low modeling performance of S-MNL.

Results indicate that WTA values calculated from G-MNL estimates are dramatically larger than values calculated from RPL, despite similar performance indicators for the underlying models. Using G-MNL estimates, specific performance structure is consistently preferable to private enforcement capital in either market condition. It would take $46.52/ton to drive preference of producers to specific performance structure and $53.47/ton to stimulate preference for private enforcement capital when high hold-up potential characterizes the marketplace. Under low hold-up potential, agricultural producers would settle for a specific performance structure if $51.66/ton was added to the base payment of an acreage-based contract, or private enforcement capital structure if $76.94/ton was offered in addition to the base payment of an acreage-based structure. The complete combinatorial test (Poe et al. 2005) indicates, nevertheless that WTA values are not statistically different from each other at 5% level. Test were performed to compare specific performance under high hold-up potential versus low hold-up potential; private enforcement capital under high hold-up potential versus low hold-up potential; specific performance versus private enforcement capital under high hold-up potential; and specific performance versus private enforcement capital under low hold-up potential.

Estimate magnitudes, nevertheless, suggest that our original hypothesis about preferences for complex contracts is correct. Preference for complex contracts increases when the probability of hold-up problems to happen also increases. In concordance to the discussion conducted above (based on RPL coefficients), decision makers seem to understand the importance of adopting complex contracts under high potential to hold-ups, despite the overall preference for acreage-based contract structures. On average, producers would give up 10% base payment if market conditions changed from low to high potential and the contract had a specific performance structure. Similarly, decision makers would accept 30.5% less to continue to use a contract derived from the institutional economics literature – private enforcement capital contract – if the probability of hold-up occurrence increased.

Other main results obtained from the RPL model are supported here. Acreage-based contract structure is preferable over any alternative structure, followed by share-cost contracts. Values of WTA for share-cost structure are statistically significant at 5% confidence level or less. The share-cost structure is preferred if producers are offered $22.80/ton on average under high hold-up potential, *ceteris paribus*. Producers would also accept a share-cost contract under low probability of hold-ups to happen if base payment was $33.77/ton higher than acreage-based contract. The complete combinatorial test points out that there is no statistical difference of WTA for share-cost under low hold-up versus high hold-up potential; no statistical difference between share-cost structure and complex structures when probability of hold-ups is low; and mixed results under high hold-up potential. WTA for share-cost structure is statistically different at 5% level from private enforcement capital structure under high hold-up potential; but it is statistically indifferent from specific performance structure also under high-hold-up potential.

The complete combinatorial test also indicates that estimates of WTA for contract length are not statistically different between market conditions with high hold-up potential or low hold-up potential. Producers do prefer short-term contracts regardless of the level of vulnerability to hold-ups. Agricultural producers would sign a 10-year contract under low potential if $44.03/ton on average were added to the amount offered in a short-term contract. Producers would finally require $53.61/ton extra to engage in a long-term contract under high potential of hold-ups.

The hypothesis that producers prefer short-term contracts under high hold-up potential is also confirmed here. Another interesting interpretation is that values of WTA for contract length are increasing in probability of hold-ups, meaning that aversion to long-term contracts increases as market conditions lean towards occurrence of hold-ups. This latter finding also confirms the literature of contract duration (Crocker and Masten 1988).

In light of these results, it is important to emphasize that theoretical predictions regarding contract adoption are partially satisfied at best. Decision makers seem to strongly rely on previous experience and traditions, leading to preferences that might not be appropriate to deal with future transaction problems. Acreage-based structure emerges not only as the most familiar contract type but also as the preferred structure regardless of the hold-up potential. Theoretical predictions are marginally supported when results indicate that WTA for complex contracts increases in exposure to hold-up problems. Results also support the theory that short-term contracts are preferred when high levels of uncertainty characterize the market.

5. Implications for Bioelectricity Initiatives

This study illustrates that Midwest U.S. agricultural producers prefer an acreage-based contract structure and short-term contracts to facilitate transactions in the bioelectricity market. Empirical findings derived from RPL estimates are consistent with our original hypothesis and indicate that preference for complex contracts (i.e. specific performance contracts and private enforcement capital contracts) increases in probability of hold-up occurrence, although not statistically significant at 5% confidence level. Results from G-MNL estimates further support these findings and provide deeper insights. Although not statistically significant, specific performance structure seems preferable to private enforcement capital structure. The estimated WTA for long-term contracts derived from G-MNL coefficients also suggest that aversion to long-term contracts increases from low to high hold-up potential; although WTA values are not statistically different at 5% confidence level.

These results have fundamental implications to the emerging biomass supply chain. Specifically, Midwestern agricultural producers have shown propensity to accept acreage-based contracts, a contract type that has been implemented elsewhere for trading biomass feedstock. Through the University of Tennessee Biofuels Initiative (UTBI), agricultural producers are offered acreage-based contracts to supply biomass to an experimental biorefinery located in Vonore, TN. Producers engaged in this initiative receive an annual payment of $450/acre and face minimal exposure to risk (e.g. price risk, yield risk, and cost of production risk due to provisions concerning volatility of diesel prices). University of Tennessee (UT) extension services provide free switchgrass seeds and technical training to engaged producers (UT Contract 2009).

The propensity to accept acreage-based contracts as demonstrated by Midwestern producers may not lead to the development of a sustainable supply chain for biomass, however. As economic theory suggests, more complex contract structures are needed to sustain exchange relationships when market conditions create opportunities for hold-up behavior (Hueth et al. 1999, Gow and Swinnen 2001, Shanoyan 2011). Therefore, although acceptance of acreage-based contracts might be of assistance to train producers in the short-run and raise awareness about environmental benefits of switchgrass, this structure is unlikely to lead to a sustainable biomass supply chain without intermediation of a facilitator. In Tennessee, the successful use of acreage-based contract has been supported by the constant presence of an impartial facilitator – role played by UT extension (Griffith et al. 2012). The use of this type of contract structure, however, has failed in the absence of UT support. The DuPont-Danisco joint venture (JV), a Tennessee cellulosic ethanol producer, has recently announced that a "stable biomass feedstock supply remains [for the last five years] as the biggest challenge to push renewable energy generation further"[28]. East Tennessee producers have indeed acquired experience with switchgrass crop, promoted through the UTBI engagement, but hesitation to sign supply contracts directly with biomass supplier persists.

From the perspective of this study, hesitation towards energy crops demonstrated by producers is primarily aligned with two factors: (i) transaction uncertainties rather than lack of technical knowledge about switchgrass, and (ii) familiarity or knowledge of different contract

[28] DuPont Danisco Cellulosic Ethanol LLC is a 50/50 JV responsible for the demonstration biorefinery located in Vonore, TN. The JV partnership was forced to review the original plan of turning the facility into a commercial plant given the poor supply chain development (BiofuelsDigest, Nov 2013).

types. Anticipating these challenges, this study estimates agricultural producers' WTA for a broad array of contract structures. Results from RPL estimates indicate that producers would adopt contracts capable of safeguarding against hold-up problems for as low as $26.53/ton/year on average ($83/acre per year, assuming average yield of 3.12 tons/acre as in Perrin et al. 2008) added to the acreage-based contract value, conditional on hold-ups being credible threats. Results from G-MNL estimates suggest a larger 'premium'. Midwestern producers would govern transactions via specific performance contracts under high exposure to hold-up problems if the offered payment was $46.52/ton/year ($145/acre/year) on average higher than acreage-based contract payment.

It is worthwhile to note that WTA estimates computed in this study show strong correlation with familiarity to contract structures, which is a promising result for extension initiatives wishing to incentivize the establishment of stable supply chain relationships for biomass. Our interpretation is that Midwestern producers might feel increasingly comfortable trading through complex contracts (without direct assistance from facilitators) as information barriers regarding complex contract provisions and their effectiveness in case of breach are overcome. To put it in different words, complex contracts should become more acceptable across agricultural producers as extension initiatives lower information barriers.

In that sense, an entry strategy combining forces from entrepreneurs performing investments and extension branches conducting hands-off training with agricultural producers would reduce hesitation among producers. Taking the Tennessee experience as an example, extension activities should tackle agronomic aspects of switchgrass as well as feasible contract designs to govern long-term bilateral transactions. This study focuses on specification contracts and shows that producers seem to understand the importance of using either specific performance contracts or private enforcement capital contracts when opportunism from counterparties is a credible threat. If effective training sessions are put in place and producers gain familiarity with complex contract structures, WTA values are likely to decrease, bringing the biomass-based energy sector a step closer to its sustainable development. It is crucial that producers become comfortable with specific performance contracts or private enforcement capital contracts so they move away from the preferred contract structure (i.e. acreage-based structure), especially when market conditions set the stage for hold-up problems to happen.

6. Conclusions

This essay seeks to estimate agricultural producers' preference for specification contract characteristics and compare the findings with theory-driven predictions. Taking the developing bioelectricity sector as a case, this article utilizes stated choice data on preference for contract provisions collected throughout Midwestern states with RPS mandates in place. The specific objective is to study whether overall preference for contract attributes vary conditional on different levels of hold-up potential. The paper tests whether preferences for contracts better equipped with provisions against opportunistic behavior prevail when the probability of hold-up problems to occur is high. If so, the paper examines whether structures resembling specific performance contracts (derived from the industrial organization literature) or private enforcement capital contracts (derived from the institutional economics literature) are preferable to decision makers. Moreover, empirical results from three models – RPL, S-MNL, and G-MNL – were generated and discussed alongside to contribute to the choice experiment literature.

Results from all three empirical models indicate that producers would prefer acreage-based contract structures to any alternative regardless of the market condition and exposure to hold-ups.

Share-cost contract structure comes second in the preference rank independent of the probability of hold-up problems to happen. On average, a minimum premium of $9.60/ton would stimulate a change from acreage-based contracts to share-cost contracts under high hold-up potential. Under low probability of hold-up occurrence, producers would require a premium of $18.44/ton to adopt a share-cost contract.

Although all three models similarly indicate that complex structures are not preferred to share-cost contracts or acreage-based contracts in any market circumstance, empirical results are mixed when it comes cross-comparing WTA for these structures. While RPL suggests that producers prefer private enforcement capital structure ($26.56/ton premium on average), G-MNL indicate that specific performance structure dominates under high probability of hold-ups ($46.52/ton on average). Under market conditions with low hold-up potential, specific performance structure dominates for all three empirical models (minimum premium of $29.41/ton). The complete combinatorial test (Poe et al. 2005), however, rejects the hypothesis that there is statistical difference in preferences for complex contract structures in either market condition at 5% confidence level.

Parameter estimates also point out that producers prefer short-term contracts (5 years long) to long-term contracts (10 years long) in ether market condition. Sequentially to model estimation and WTA calculation, complete combinatorial tests were conducted and results cannot reject the hypothesis of statistical similarity between WTA for long-term contracts across market conditions.

Results seem to partially satisfy theoretical predictions. Although decision makers heavily rely on traditions to make decisions over contract adoption – generating evidence that plays against predictions driven by mainstream economic theories – WTA estimates point out that complex contracts are more likely to be adopted when they are most needed. Results also corroborate with other studies on contract longevity. Decision makers are not only averse to long-term contracts but such aversion tends to rise when market conditions sets the stage for hold-up problems to occur.

Taking into account the latest developments in Tennessee – perhaps the vanguard state in biomass-based energy generation – this article offers valuable implications to bioelectricity in the Midwest U.S. Transactions between potential Midwest switchgrass growers and biomass processors might unfold via acreage-based contracts in presence of a facilitator (e.g. extension branches of land grant universities). The same specification contract, however, is unlikely to stimulate stable relationships, especially if biomass transactions are conducted without an intermediator. A better set of strategies would be to motivate producers to trade under contracts capable to mitigating opportunism or unexpected breach. Although Midwest producers are somehow averse to complex contracts in either market condition, this article shows that producers' WTA for specific performance contract structure or private enforcement capital contract structure consistently increase in probability of hold-ups (similar for all three empirical models). An entry strategy of biomass-based electricity generators in the Midwest might reach favorable outcomes if combined with hands-off support from extension branches of land grant universities. Without pushing a particular contract structure, educational sessions with agricultural producers ought to demonstrate why complex contracts are effective in market conditions with high hold-up potential. From the results obtained here, such strategy is likely to be effective given the strong correlation between WTA values and revealed familiarity with contract structures. As producers become familiarized with specific performance structure and private enforcement capital structure, it is likely that their WTA for contract structures capable of sustaining relationships in the emerging bioelectricity industry increases.

This article also provides evidence that modeling preference heterogeneity through deviations from mean utility weights performs better than modeling it through individual scale effects. Results show that log-likelihood improves 16.01% when RPL model is utilized versus 0.03% improvement when S-MNL model is used, taking the seminal MNL model as base for comparison. Performance improvement reaches 16.35% when both variations of heterogeneity are incorporated into the G-MNL model.

It is important to interpret our model results with caution, however. First, none of the empirical models used here allowed free correlation across parameters due to the rapid loss in degrees of freedom. That can be interpreted as a weakness of the study given that the choice experiment literature in place would recommend free correlation across attributes. Second, this article is limited to preference-space estimation given our research objective of comparing coefficients and WTA values across two market conditions – leading to two pecuniary attributes. Our attempts to estimate in WTA-space failed to return robust parameter estimates. Refinements of this study to overcome these two main limitations and others are strongly encouraged.

APPENDIX

Example of choice scenarios

Figure 9: Example of a choice scenario under information treatment 1

Assume that YOU are making the decision of what contract to sign under these market conditions:

There is an electricity generating firm in your region willing to sign a production contract for biomass feedstock. Price for biomass-based electricity between the generating firm and distribution utilities is volatile. Agricultural operations require acquisition of an expensive piece of machinery, which might be redeployed in a future for its salvage value. Switchgrass yield is as variable as corn/soybeans yield over the seasons.

Choice Scenario #3 of 6: Which switchgrass contract would you prefer?

Attributes	Contract 1	Contract 2	Neither
Compensation structure	Structure C - Parties agree on price - Grower and biomass processor share establishment costs of crop equally - Grower invests in machinery	Structure A - Parties agree on price and quantity to be delivered - Renegotiation is possible before harvesting season - Grower invests in machinery - Processor is penalized if trade is delayed	I would negotiate different terms with the biomass processor.
Length of contract	5 years	5 year	
Base payment	$145/ton/year	$106/ton/year	

Which contract would you prefer? ☐ ☐ ☐

Figure 10: Example of a choice scenario under information treatment 2

Assume that YOU are making the decision of what contract to sign under these market conditions:

There are two electricity generators willing to sign a production contract for biomass feedstock in your region. There is also a well established cash market for biomass (i.e. fiber pellets manufacturing company), however the expected returns from this market are lower than the expected returns from the electricity market. Price for biomass-based electricity is relatively stable. Agricultural operations require acquisition of an inexpensive piece of machinery, which might be redeployed in a future period without loss of productive value. Variability of switchgrass yield is low in comparison to corn/soybeans yield variation over seasons.

Choice Scenario #4 of 6: Which switchgrass contract would you prefer?

Attributes	Contract 1	Contract 2	Neither
Compensation structure	Structure D - Parties agree on price per acre farmed - Grower invests in machinery	Structure B - Parties agree on price and quantity to be delivered - Grower and biomass processor co-invest in machinery - Processor loses its ownership share in case of contract breach	I would negotiate different terms with the biomass processor.
Length of contract	10 years	5 year	
Base payment	$170/ton/year	$125/ton/year	

Which contract would you prefer? ☐ ☐ ☐

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CONCLUSION

This dissertation constitutes a comprehensive attempt to diagnose deterring factors and propose sustainable relationship mechanisms for the renewable energy supply chain in the U.S. Midwest. It aims at identifying information barriers preventing agricultural producers from engaging in stable transactions with biomass processors and at proposing solutions derived from stated preference data, gathered from producers.

The literature on willingness to convert farmland and produce energy crops has previously identified hesitation and skepticism as two major barriers to conversion (Hayden 2013, Qualls et al. 2012, Rossi and Hinrichs 2011, Kelsey and Franke 2009). Hesitation expressed by agricultural producers has often been associated with the lack of technical or agronomic knowledge about energy crops and can be defined as 'the reluctance to adopt new production methods or crops until one sees them working for others' (Qualls et al. 2012). Essay 1 of this dissertation diagnoses an additional underlying factor that is also leading to agricultural producers' hesitation: transaction problems resulting from inappropriate incentive structures utilized in early attempts to govern biomass transactions.

Using a case study methodology (Yin 2009), essay 1 examines biomass transactions in the Upper Peninsula of Michigan. Five transactions were evaluated through the lenses of transaction cost economics (TCE) theory (Williamson 1985; 1996). Out of the five transactions, the exchange between logging firms and a biomass processor has failed to perform, leading parties to experience hold-up problems. Sequentially, the private enforcement capital model (Klein 1996) served as a framework to inspect the underlying causes of the problem. The exchange based on an incomplete contract (Hart and Moore 1988) and in presence of specific assets (Peterson et al. 2001) created high hold-up potential, which turned into a real problem as changes in market conditions set the stage for the biomass processor to behave opportunistically over logging firms. Essay 1, therefore, suggests that the inability of trading parties to design effective coordination strategies can be considered as a factor causing hesitation across broad populations of agricultural producers.

Combining the results obtained in essay 1 with the argument of agronomic information barriers regarding switchgrass, essays 2 and 3 examine stated preference data to elaborate effective and implementable mechanisms to govern exchange of biomass feedstock. Essay 2 estimates how agricultural producers value general attributes of cropping systems while recognizing regional particularities and differences in farming capabilities. Based on the random utility maximization (RUM) model (McFadden 1974, 1981), the essay implements and compares estimates from two empirical models – Random Parameters Logit (RPL) and Scaled Multinomial Logit (S-MNL). Results indicate that agricultural producers value (i) cropping systems that require low intensity of production practices to obtain average yield, and (ii) low variance of net margins – characteristics that can be found in switchgrass but seldom in conventional cropping systems (e.g. corn-soybean rotation systems). Results also point out that willingness to accept (WTA) for switchgrass characteristics increases as one moves away from counties where conventional cropping systems are competitive to switchgrass. Farming capability also influences preference for cropping system attributes, but WTA for switchgrass characteristics does not decrease linearly in county competitiveness. Instead, producers located in county category 2 (counties where expected net margin from conventional crops is at least 70 percent of state average but lower than expected net margin from switchgrass) would be less reluctant to make specific investments for growing switchgrass than producers located elsewhere.

Having identified regions where energy crops have relatively high acceptance and population segments that are more willing to grow switchgrass, Essay 3 examines how agricultural producers would prefer to draft contract provisions for trading biomass feedstock. The specific objectives are to evaluate (i) whether producers distinguish market conditions with high hold-up potential from market conditions with low hold-up potential, and (ii) whether producers choose contracts better equipped to deal with hold-up problems when those problems are credible threats – as they were discussed in Essay 1. If so, the paper examines whether structures resembling specific performance contracts (derived from the industrial organization literature) or private enforcement capital contracts (derived from the institutional economics literature) are more in line with agricultural producers' preference. The RUM model (McFadden 1974, 1981) is also utilized in Essay 3 and parameter estimates from three empirical models are compared – RPL, S-MNL, and Generalized Multinomial Logit (G-MNL). Results indicate that acreage-based contracts are preferable in any market circumstance. Share-cost contract comes second in the preference rank and is partly dependent on market conditions. Agricultural producers also show increasing acceptance for either complex contract structure as market conditions change from low to high hold-up potential. Producers also seem to rely on traditions to make decisions over contract adoption as preferences for contract structures are closely related to revealed familiarity to contract types. Parameter estimates also point out that producers prefer short-term contracts (5 years long) to long-term contracts (10 years long) in ether market condition.

Essay 3 contends, however, that acreage-based contracts might govern transactions in the presence of a third-party external facilitator, but is unlikely to sustain stable relationships without an intermediary. The argument comes from the rich literature on external facilitation to promote supply chain linkages (Glover and Kusterer 1990, Porter and Phillips-Howard 1997, Shepherd

2007). A better set of strategies would be to motivate producers to trade under contracts capable to mitigating opportunism or unexpected breach when such problems constitute credible threats. An entry strategy of biomass-based electricity generators in the Midwest might reach favorable outcomes if combined with hands-off support from extension branches of land grant universities. Without pushing a particular contract structure, educational sessions with agricultural producers ought to demonstrate why complex contracts are effective in market conditions with high hold-up potential.

Essays 2 and 3 also contribute to the literature of discrete choice by comparing model performance as suggested in Fiebig et al. (2010). The preference data used in essay 2 fit the RPL model better than the S-MNL model. In essay 3, allowing preference heterogeneity via deviation from mean utility weights and individual scale – as in the G-MNL model – was superior to either modelling strategy alone.

Even though the findings of this dissertation suggest a path for the development of the renewable electricity industry in the U.S. Midwest, interpretation of WTA estimates must be conducted with caution. In essay 2, mean estimates of WTA for net margin variance are not statistically different, for example. In essay 3, WTA for specific performance contracts or WTA for private enforcement capital contracts are not statistically different at 5% of confidence. In either essay the statistically significance of standard deviations from mean utility weights (in RPL models or in the G-MNL model) suggests that the mean WTA estimates may not be statistically significant for the entire sample. Further refinements to allow precise interpretation of WTA estimates are strongly encouraged. Finally, our attempts to estimate in WTA-space failed to return robust parameter estimates. Given the growing importance of this latter modeling strategy, refinements of essays 2 and 3 to overcome this limitation are strongly encouraged.

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