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Contract theory and implications for perennial energy crop contracting

Corinne Alexander [a], Rasto Ivanic [b], Stephanie Rosch [a], Wallace Tyner [a], Steven Y. Wu [a,*], Joshua R. Yoder [c]

[a] Department of Agricultural Economics, Purdue University, 403 West State Street, Krannert Building, West Lafayette, Indiana, 47906, USA
[b] Mendel Biotechnology, 3935 Point Eden Way, Hayward, CA 94545, USA
[c] 7050 Butler Avenue, Plain City, OH 43064, USA

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ABSTRACT

This article provides an overview of modern contract theory and discusses the implications of the theory for contracting for perennial dedicated energy crops. We discuss some of the unique challenges of contracting for dedicated energy crops used for the production of advanced biofuels and survey some of the relevant concepts and research from the contract theory literature to address these challenges. We focus primarily on the "mechanism design" or "complete contracts" approach to contracting, which involves optimizing some objective function (e.g. profits, costs, etc.) with respect to contract terms, subject to important incentive constraints. The solution to these optimization problems typically highlight important tradeoffs that a contract designer needs to consider in order to maximize profits and/or minimize costs.

1. Introduction

This article provides a selected survey of modern contract theory, highlighting specific concepts that can be useful for framing important issues related to dedicated energy crop contracting. Many dedicated energy crops, such as switchgrass or miscanthus, have little commercial history and production cycles that can last for over ten years. This creates some unique challenges for biofuels plants that will rely on feedstocks produced from perennial dedicated energy crops. At the same time, an increasing amount of public resources are being devoted toward developing renewable fuels in the U.S. For example, the federal Biomass Crop Assistance Program provides a subsidy of up to $45 per dry ton to producers of advanced biofuels. Thus, understanding the economic principles that motivate the tradeoffs for dedicated energy crop supply chains is important and will become more so over time.

According to the academic literature, contracts are written because there are transactions costs, information barriers or lack of standardization that precludes the existence of well-functioning markets. As such, contracts tend to be highly specialized and transaction specific so standardization will be the exception rather than the rule. Given the specific nature of a typical contract, it is very difficult to evaluate the economic virtues of a contract by using empirical studies that are based on cross-section comparisons of different contracts. Consequently, the design of effective contracts cannot rely on surveys or case studies alone, but should also be grounded in economic theory, which provides general principles for determining whether insights gathered from one setting can be generalized to new settings.

To provide some background for the discussion, note that over the last ten years, surges in fuel prices and concerns over carbon emissions have induced increased political and financial support for research and investment in alternative energy in the U.S. In particular, the U.S. biofuels industry has experienced significant growth spurred on in part by renewable fuel mandates that promulgate the use of biofuels. This growth in biofuels production has primarily occurred through corn-based ethanol. Using corn as a feedstock for ethanol production, however, is not without its limitations. First, existing supplies of corn do not have enough potential to meet current domestic energy demand. In 2005, the combined energy potential of the entire U.S. corn crop only accounted for 9% of the embodied energy of U.S. net crude oil imports (Epplin et al., 2007). Second, there might be alternative feedstocks that yield relative reductions in greenhouse gas (GHG) emissions, suggesting that it may be more desirable for future growth in biofuels production to be derived from alternative feedstocks that fall into the category of advanced biofuels (Koonin, 2006). U.S. energy policy has already moved in this direction, mandating that production of advanced biofuels grow to 21 billion gallons per year by 2022 through the renewable fuel standard (RFS).

* Corresponding author. Tel.: +1 765 494 4299; fax: +1 494 9176.
E-mail address: sywu@purdue.edu (S.Y. Wu).

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Advanced biofuels are defined as biofuels derived from renewable sources other than corn starch. Cellulosic biofuels are a specific subset of advanced biofuels created from cellulose, hemicellulose, or lignin derived from renewable sources. Sources for advanced and cellulosic biofuels range from wood wastes, to crop residues, to dedicated energy crops such as switchgrass and miscanthus. To meet current mandates for advanced biofuels, production will ultimately need to be derived from a variety of feedstocks including dedicated energy crops. Nonetheless, there are significant barriers to commercial viability of dedicated energy crops today. First, the cost of building cellulosic ethanol plants can be three to four times higher than the cost of building corn ethanol plants (Coyle, 2010). Second, markets and infrastructure for the production, harvesting, storage, and delivery of dedicated energy crops are largely underdeveloped (Epplin et al., 2007). Since a significant determinant of a biorefinery's cost will be how much the refinery has to pay farmers to produce, harvest, store and/or deliver biomass, this creates tremendous uncertainty about the total cost of biomass feedstocks over time. Given potentially high costs and risks, people are unlikely to invest in new biofuels refineries unless they can secure commitments from growers to produce and deliver feedstock.

At the same time, it is not easy to secure commitments from growers as the production cycle for switchgrass and miscanthus can last as long as ten to fifteen years, with an initial two year establishment period that produces very little yield. This implies that the refinery may have to convince growers to commit to long-term contracts that may initially have very low payoffs. The refinery may face additional barriers such as growers' uncertainty about the profitability of the crop and growers' lack of knowledge about the technical aspects of producing, harvesting, and storing a new commercial crop. Thus, a typical biorefinery faces significant barriers in inducing growers to "participate" in the contracts. In addition to inducing participation, contracts must also contain incentives to ensure performance (e.g. biomass of adequate quantity and quality) and must be flexible enough to entice growers to remain in their contracts even when there are adverse changes in market conditions. Broadly speaking, contracts must ensure *participation*, be *incentive compatible*, and must be *renegotiation proof.* These are major concepts in modern contract theory.

Before proceeding further, we point out that contract theory is an active area of research and the literature is vast, making it impossible to cover the entire field in one survey article. Moreover, there are methodological divides between those who advocate the "complete contracts" versus the "incomplete contracts" approaches to contract theory (Hart and Moore, 1999; Maskin, 2002; Tirole, 1999). Our discussion of the theory will be biased toward the "complete contracts" approach which is based on implementation theory or mechanism design. We chose this bias because mechanism design is primarily concerned with contract or incentive design, which is the focus of this article.[1] The mechanism design approach to contracting is concerned with designing contracts that are "optimal" in the sense that contract terms will be structured in order to optimize some objective function subject to important constraints. In order to reach a broad audience, we do not rely heavily on mathematics and discuss the theory with constant reference to practical problems that a biorefinery might face. While this article is light on mathematics, we try to remain true to the spirit of the theory by preserving the logic and intuition of the models in our discussion.

The mechanism design or the "complete contracts" approach relies on the *Revelation Principle* (Myerson, 1981). The Revelation Principle states that the contract designer can obtain an optimal contract simply by choosing contract terms that optimizes the biorefinery's objective function (e.g. maximize profit or minimize cost) subject to *incentive compatibility constraints*. A contract that satisfies this simple criterion is optimal. Even if one were to devise excessively fancy and complex schemes, it would not be possible to find a contract that can outperform the incentive compatible optimal contract. Thus, the Revelation Principle has tremendous practical usefulness because it reduces the set of contracts that need to be considered when one is searching for optimal contracts. We will highlight the important economic insights and principles that emerge from solutions based on the Revelation Principle. While the Revelation Principle and the concept of incentive compatibility are usually presented rather abstractly in the research literature thereby making these concepts difficult to grasp even for well-trained economists, we try to illustrate these concepts using simple explanations and examples.

Incentive compatibility typically refers to the idea that well-designed contracts will contain good incentives. For example, to motivate farmers to meet certain quality or yield objectives, a contract might contain performance bonuses for meeting these objectives. However, if the incentives are weak so that the bonuses fail to cover the increased costs of meeting objectives, then it may not make economic sense for a farmer to produce the extra quality or yield. Thus, the contract fails to be incentive compatible. Incentive compatibility constraints are set up specifically to ensure that a farmer operating under the contract has more to gain from meeting contract objectives than not meeting the objectives.

While incentive compatibility constraints ensure that the contract will contain adequate pay-for-performance provisions, the biorefinery also has to design a contract that farmers will accept, meaning that the contract must also satisfy a *participation constraint*. The participation constraint requires that the contract compensate the farmer in such a way that his/her payoff from producing the energy crop will be at least as high as the payoff from the next best use of the land. The payoff from the next best use of the land is typically referred to as the *reservation payoff* or *reservation utility*. Participation is a critical issue for dedicated energy crops as farmers have expressed concerns about signing contracts for crops that have little commercial history and face significant market, technological and logistical uncertainties (Alexander et al., 2010).

Because a biorefinery plant is expensive to build, it is critical that a steady supply of feedstock can be guaranteed for a sufficiently long period of time (e.g. ten or more years). This means that biomass feedstock contracts will have to be long term contracts. Over a long enough time horizon, market conditions and technological uncertainties could change how the parties value the contracts. These changes increase the likelihood that either the refinery or farmers will attempt to renegotiate or default on their agreements. To reduce the likelihood of defaults, contracts must also contain incentives for both parties to stick to their agreements in the face of adverse market conditions and discourage them from renegotiating their contracts. If parties expect that a contract will be renegotiated, then it erodes the credibility of the initial contract. Therefore, an optimal contract should be *renegotiation proof*.

Enforceability of a contract over a long period can also be problematic. Contract law and arbitration work imperfectly. As a consequence it is rare in practice to have all the important aspects of performance be governed by a legalistic contract. Real world contracts typically involve a mixture of legalistic components along with tacit expectations, verbal agreements and implicit understandings. These types of contracts are called *relational contracts* in the economics literature.

Participation constraints, incentive compatibility constraints, renegotiation proof constraints, and relational contracting form the bedrock of modern contract theory. They also have substantial practical implications for the design of cost-minimizing supply contracts. In this overview paper, we will discuss each of these concepts in detail and provide a rationale for why they are important

[1] Had we had a different focus for this paper, such as explaining vertical integration issues or the problem of asset allocation, we might have chosen to focus on the incomplete contracts approach.