Contracting in the Presence of Insurance: A Case of Bioenergy Crop Production

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Abstract

This paper investigates the interaction of crop insurance and contracts in improving the risk management of farmers who produce bioenergy crops. Numerical simulation is conducted for 1,919 U.S. counties east of the 100th Meridian that have yield data for corn and for at least one bioenergy crop yield of miscanthus and switchgrass. County-level yield data, both on low quality land and high quality land, are simulated by using DayCent model, and Copula approach is used to estimate a joint yield-price distribution for each county. We model a representative farmers' optimal choice problem of whether to use their land to grow conventional crops or to use their land for production of bioenergy crops under one of three different contract choices offered by the biorefinery. The terms of these contracts are determined in such a manner that they jointly maximize the net benefits of the refinery and farmers. We do this joint optimization in two scenarios: 'With insurance' and 'Without insurance' for bioenergy crops to see how presence of crop insurance for bioenergy crops will affect the optimal contract design and will affect land allocation under a certain contract type.

Key Words: Bio-Energy Crops, Contracting, Insurance, Miscanthus, Risk, Switchgrass

JEL Code: D81, Q15, Q16

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1. Introduction

The recent Billion-ton study (USDOE 2016) envisions miscanthus and switchgrass as two promising bioenergy crops meeting a dominant share of the billion tons of biomass supply in 2030. Similar to conventional crops, yield and price risks will be prevalent in bioenergy crop production. Moreover, the availability of crop insurance for conventional crops makes the production of energy crops without crop insurance even riskier than otherwise. Therefore, risk management strategies and the need for coordination of biomass supply between farmers and the refinery is likely to necessitate reliance on long term contracts and on insurance programs for bioenergy crops. A few recent studies have investigated contracting for energy crops or the effects of crop insurance on bioenergy crop production (e.g., Yang, Paulson, and Khanna 2014; Miao and Khanna 2014). However, none of these studies considers the interaction between contracting and crop insurance for energy crops. This interaction is of interest because as two major risk management tools in agricultural production, contracting and crop insurance may substitute or complement each other. In this paper, we investigate the interaction of crop insurance and contracts in improving the risk management ability of farmers who produce energy crops. The purpose of this paper is to investigate how crop insurance for energy crops will affect the optimal contract design and land allocation under a certain contract type. There is a general paucity of research on contracting in the presence of insurance or other government supported risk interventions. This paucity may result from less-well developed insurance programs in sectors where contracting farming is a popular industrial organization format. As the demand for government supported insurance is increasing in such sectors, a need to study how the presence of insurance affects the optimal contract design is in order. This study attempts to fill this gap and hence should be useful to economists and policy analysts interested in industrial organization and bioenergy, and concerned with insurance programs.

2. Conceptual framework:

In our paper, we model a representative farmers' optimal choice problem of whether to use their land to grow conventional crops or to use their land for production of bio-energy crops (namely, miscanthus and switchgrass) under one of the three different contract choices offered by the biorefinery. The terms of these three different contracts are determined in such a manner that they jointly maximize the net benefits of the refinery and farmers. Refinery maximizes the net present value of its expected profits whereas farmers maximize their net present value of expected utility from their profits over lifespan (T years) of bioenergy crops.

We consider a biorefinery that offers a menu of contracts to farmers in a region to incentivize them to grow an energy crop or lease land to the refinery to meet its demand for biomass. The refinery sells its ethanol at an uncertain price, which is characterized by a distribution with known mean and variance. The refinery is assumed to be located in a region with a land of varying quality, available for agricultural production in the proximity of the refinery. This agricultural land is currently used to produce conventional row crops (cropland for conventional crops and pasture for CRP), but can be converted to a perennial energy crop that produces biomass.

Three different types of contracts are offered by the refinery. Under contract type 1 (Land Leasing Contract), farmers are offered a fixed rental rate ω_t per acre per year for the contract period $t = 1, 2, ...T$ to lease their land to the refinery to produce bioenergy crops. Under this contract type, the refinery pays all costs and takes on all risks associated with bioenergy crop production, and the farmer receives a risk-free return each year during the lease. Under contract type 2 (Fixed Price Contract), the farmer is offered a fixed price P_y per ton of biomass to produce the energy crop on his land and deliver a guaranteed amount of biomass Y_b per acre (equal to per acre average yield of miscanthus or switchgrass) to the biorefinery. In case of switchgrass, the farmer is supposed to deliver 100% of the guaranteed amount of biomass from year 1 onwards, whereas in case of miscanthus, the farmer is supposed to deliver 0% of the guaranteed amount of biomass in year 1 and 100% of the guaranteed amount of biomass from year 2 onwards. Under this contract, the farmer assumes all biomass yield risk, but is guaranteed a fixed-price from the refinery. Farmer also pays the one-time establishment cost F_b per acre, annual fixed production cost F_p per acre, and annual variable cost V_b per acre in this contract. Under contract type 3 (Revenue Sharing Contract), the biorefinery pays a price indexed to its revenue for delivering a guaranteed amount of biomass Y_b per acre (equal to per acre average yield of miscanthus or switchgrass) to the biorefinery (as in fixed price contract). The price is a pre-specified α percent of its revenue $P_{et}G$ generated per ton of biomass supplied by the farmer and converted to G gallons of ethanol that is sold at the price P_{et} per gallon. Under the revenue sharing contract, the farmer is exposed to biomass production risk and price risk. Under fixed price contract and revenue sharing contract, if the harvest of biomass exceeds/falls short of the committed amount, the farmer sells the surplus/buys the deficit from the spot market, whereas in case of land leasing contract, the refinery itself sells the surplus/buys the deficit from the spot market.

We assume that a spot market for biomass exists and biomass can be bought and sold in this spot market at a stochastic and exogenous price P_{bt} per ton. If the harvest of biomass exceeds/falls short of the committed amount, the grower (farmer or refinery) sells the surplus/buys the deficit from the spot market at a price of $\overline{P_{bt} \mp W}$ per ton, where W represents an average biomass transportation cost for grower to/from spot market (assumed as $10 per ton of biomass, Yang et al. 2016). We have assumed that spot market exists outside the contracting region, and one has to incur transportation cost in order to buy/sell biomass on the spot market. In addition to transportation cost for grower to/from spot market, one additional type of transportation cost may also be involved i.e. transportation cost from farm-gate to refinery. For simplicity, we have assumed that size of the contracting region is small enough such that the transportation cost of delivering biomass from farm-gate to refinery within the contracting region is negligible. Thus, spot market serves as the last resort for the refinery to buy biomass, as we have assumed that there is no transportation cost from the farm-gate to the refinery, however there is a transportation cost of obtaining or selling biomass on the spot market.

3. Simulation Approach and Data

Numerical simulation is conducted for 1,919 U.S. counties east of the 100th Meridian that have yield data for corn and for at least one bioenergy crop yield of miscanthus and switchgrass. Each county is assumed to be represented by a farmer who optimally chooses one of the four options (i.e., original land use and three types of contracts). County-level yield data, both on low quality land and high quality land, are simulated by using DayCent model, and Copula approach is used to estimate a joint yield-price distribution for each county. We find 15,548 different combinations according to a range of three contract terms and term every such unique combination a ‘menu’ of contract terms. Range of Fixed Price per ton of biomass is taken from $50 to $100, with a step of $2 per ton of biomass, range of revenue sharing is taken from 20% to 70%, fixed % of revenue generated per ton of biomass, step by 2%, and range of rent is taken from \$40 to \$150 per acre per year, with a step of \$5 per acre per year. For every menu, farmer will first calculate her profits in all four options and then will calculate expected utility from these profits by using a constant absolute risk aversion (CARA) utility function with functional form $U(\pi_{it}) = 1 - e^{-\alpha\pi_{it}}$. Then out of these four options, farmer will choose the option having maximum net present value of above mentioned expected utilities over the lifespan of energy crops *T* years. Thus in this farmer's optimization problem, the choice variables will be the four discrete choices for each decision-making land unit (i.e. county level) denoted by l_1, l_2, l_3, l_4, each of which is equal to 1 if that option is chosen and zero otherwise and $l_1 + l_2 + l_3 + l_4 = 1$. Thus, as a result we have one selected optimal option among the four options for each of the county. From these results, we calculate total acreage for energy crops and total biomass production level for all counties taken together. On basis of this information, we calculate the profits of biorefinery for that particular menu of contract terms. This whole process is undertaken for all possible menus of contract terms. Thus, we have the refinery profits for all possible menus of contract terms. Refinery will also undertake its optimization problem by choosing the menu with highest profits. We do this joint optimization in two scenarios: 'With energy crop insurance' and 'Without energy crop insurance' for bioenergy crops to see how presence of energy crop insurance will affect the optimal contract design and will affect land allocation under a certain contract type.

To facilitate potential cellulosic biorefinery investors to decide about their plant locations, we have divided the entire area under analysis into four different regions and every region is assumed to be represented by a biorefinery who sets the terms for each of the three contract types to maximize the net present value of its expected profits. By doing this, study will also be able to look at the regional difference on contracting and contracting's interaction with insurance. In what follows of this section we describe the data and parameters used in the simulation.

Crop yields

Due to the lack of large scale commercial production, we obtain county-level yield data, both on low quality land and high quality land, for miscanthus over the same temporal and geographical range by using DayCent model. DayCent is the daily time-step version of the CENTURY biogeochemical model that is widely used to simulate plant growth based on information of precipitation, temperature, soil nutrient availability, and land-use practice (Del Grosso et al. 2011, 2012; Davis et al. 2012). We also utilize DayCent to obtain simulated yields for corn grain, corn stover, and soybean grain on both high and low quality land even though historical data on these crops is available from National Agricultural Statistics Service (NASS). This ensures consistency in methods underlying yield estimates across the various crops considered here. Additionally, use of DayCent-simulated corn and soybean yields implies that we do not need to rely on arbitrary assumptions that are used in previous studies to obtain corn and soybean yields on low quality land, or to obtain corn stover yield.

In DayCent model, the high quality land is approximated by land under crop production whereas the low quality land is approximated by land under pasture. Together with land management practice and observed daily weather information, properties of dominant soil type of cropland and pasture land in each county are used in input files to simulate crop yields on high quality land and low quality land, respectively. These properties of dominant soil type include percentage sand, percentage silt, percentage clay, pH, and soil depth. Overall, when compared with high quality land, low quality land has lower pH value (6.12 vs. 6.24) and has smaller soil depth (173.5cm vs. 177cm). Due to the lack of knowledge of how technology advances or learning in crop management will improve energy crop yields, we do not include an upward yield trend for miscanthus in the simulations. Introducing a yield trend parameter will add another layer of uncertainty to the results. Accordingly, to assure consistency we do not assume a yield trend for conventional crops either.

Corn is either grown in rotation with soybeans or in continuous corn. For counties that do not produce soybean (as evident by the lack of data on soybean yield in the dataset), we assume that corn is grown continuously. Since we assume that miscanthus has a 15-year lifespan, we consider a 15-year period land tenure in which miscanthus completes one lifecycle. Miscanthus is assumed to have no harvestable yield in the first year, 100% of mature yield in the second year, and onward within a lifecycle.

Crop Prices

Three types of prices of corn and soybeans are used in the simulation: received prices, projected futures prices, and harvest futures prices. We use the state-level received prices from NASS to calculate realized profit of corn and soybean. Projected futures prices and harvest futures prices are used to calculate crop insurance indemnity for corn and soybeans. These futures prices are determined by following RMA (2011) rules based on Chicago Board of Trade (CBOT) futures prices. The CBOT futures prices of corn and soybeans over 1980-2010 are obtained from Barchart.com. We convert all prices to 2010 dollars using the Gross Domestic Product implicit deflator. Biomass price is calculated from the ethanol prices on the assumption that profit of the biorefinery is zero. For simplicity we consider farm-gate biomass prices which do not include transportation cost from farms to bio refineries. We also assume that prices in each year are draws from the same price-yield joint distribution and do not consider the autocorrelation of prices across years. We expect that relaxing this assumption will not affect qualitative insights but will make analysis more complicated and less transparent.

Riskiness of Crop Production

To reflect stochastic crop yields, stochastic prices of corn and soybeans, and the correlations among these yields and prices, a joint yield-price distribution is estimated for each county for up to eight yields (i.e., corn grain, corn stover, soybean grain, and miscanthus on both high and low quality land) and three prices (i.e., ethanol prices, corn and soybean grain prices). Since biomass price has been calculated from the ethanol prices, biomass price is not included in the joint yield-price distribution. We utilize the copula approach to model joint distributions due to its flexibility (Yan 2007; Du and Hennessy 2012). For simplicity, we assume that the distribution of conventional crop prices does not change as land is converted to energy crop production; this is not an unreasonable assumption given the relatively small amount of land (and at least a portion of which is of low quality and used for pasture) being used for energy crop production.

Production Costs

The county-specific production costs of the crops considered in this study are the same as those in Chen et al. (2014). The method and assumptions underlying the calculation of county-specific production costs of miscanthus, corn, and soybeans in the rain-fed region are described in Khanna, Dhungana, and Clifton-Brown (2008), Jain *et al*. (2010) and Chen *et al*. (2014). The cost of miscanthus in the first year of establishment includes expenses on rhizomes, planting machinery, fertilizer and land preparation, which is about $3,108/ha. on average. For the second year and onward production costs include expenses on fertilizer, labor, fuel and machinery for harvesting, baling, transportation, and storage. We construct county-specific fixed and variable costs of production as in Chen et al. (2014). For corn stover, the average variable cost ($17.5/MT) is close to that of miscanthus whereas the average fixed cost ($48.5/ha.) is much lower than that of the miscanthus. Regarding conventional crops, the production costs that include fertilizer, chemicals, seeds, harvesting, drying, and storage are collected from crop budgets compiled by state extension services (see Chen et al. 2014). On average, the annual fixed and variable costs for corn are $136.5 per acre and $1.3 per bushel, respectively. The fixed and the variable costs for a crop are assumed to be the same on low and high quality land within a county. The value of risk aversion parameter has been taken as 0.0001 and 0.00005, and value of discount rate has been taken as 2% and 10%.

4. Farmers' optimization

For a given menu of contract terms, a farmer chooses the crop and contract to maximize his net present value of utility from the profits over *T* years as follows:

$$Max_{\{l_1,l_2,l_3,l_4\}} \sum_t \left(\frac{1}{1+r}\right)^{t-1} \mathrm{E}(\mathrm{U}(\pi_{it})) \tag{1}$$

Where $E(\pi_{it}) = \mathrm{l}_1\mathrm{E}\pi_{1it} + \mathrm{l}_2\mathrm{E}\pi_{2it} + \mathrm{l}_3\mathrm{E}\pi_{3it} + \mathrm{l}_4\mathrm{E}\pi_{cit}$

and $l_1 + \mathrm{l}_2 + \mathrm{l}_3 + \mathrm{l}_4 = 1$.

The Profit under each of the 4 options is as below:

Under option 1 (Land leasing Contract), the per-acre profit from the land leasing contract is:

$$\pi_{1t} = \text{Rent} = \omega \qquad for \;\; t = 1, 2, \ldots T \tag{2}$$

Under option 2 (Fixed Price Contract), with fixed contract price per ton of biomass P_y, guaranteed biomass per acre (equal to average per acre Biomass Yield) Y_b, random per acre biomass yield Y_{bt}, establishment cost of bioenergy crops ($/Acre) F_b, variable production cost of bioenergy crops ($/Acre) V_b, fixed production cost ($/Acre) F_p, and spot market transaction

$$(SM) = \mathrm{I}[(\mathrm{P}_{bt} - \mathrm{W})(\mathrm{Y}_{bt} - \mathrm{Y}_b)] + (\mathrm{I} - 1)[(\mathrm{P}_{bt} + \mathrm{W})(\mathrm{Y}_b - \mathrm{Y}_{bt})]$$

Where $I = 1$ if $Y_{bt} > \mathrm{Y}_b$ i.e. when there is surplus and $I = 0$ otherwise and W represents a fixed average biomass per ton transportation cost to/from spot market. The per-acre profit is:

Without yield insurance for energy crops:

The per-acre profit for miscanthus π_{2t} is:

$$\begin{cases} -F_b & \text{if t=1} \\ P_y \mathrm{Y}_b + SM - \mathrm{V}_b - \mathrm{F}_p & \text{if t=2,3,...T} \end{cases} \tag{3}$$

The per-acre profit for switchgrass π_{2t} is:

$$\begin{cases} P_y \mathrm{Y}_b + SM - \mathrm{V}_b - F_b - \mathrm{F}_p & \text{if t=1} \\ P_y \mathrm{Y}_b + SM - \mathrm{V}_b - \mathrm{F}_p & \text{if t=2,3,...T} \end{cases}$$

With yield insurance for energy crops:

Yield-based crop insurance is coverage in which an insured yield (for example, tons/acre) is established as a percentage of the farmer's historical average yield. The insured yield is some percent of the average yield on the farm. If the realized yield is less than the insured yield, an indemnity is paid equal to the difference between the actual yield and the insured yield, multiplied by a pre-agreed value (P_a). Average biomass price (calculated as a function of ethanol price) is taken as pre-agreed value (P_a). For energy crops, insurance indemnity for the energy crop is:

$$\iota_t^{ej} = \mathrm{P}_a \max[\phi^c Y_b - \mathrm{Y}_{bt}, 0]$$

where ϕ^c is insurance coverage level for the energy crop, ρ is insurance premium subsidy rate, and Net Indemnity (NI) = $\iota_t^{ej} - (1-\rho)\mathrm{E}[\iota_t^{ej}]$, the profits from energy crop production can be written as:

The per-acre profit for miscanthus π_{2t} is:

$$\begin{cases} -F_b & \text{if t=1} \\ P_y \mathrm{Y}_b + SM - \mathrm{V}_b - \mathrm{F}_p + NI & \text{if t=2,3,...T} \end{cases} \quad (4)$$

The per-acre profit for switchgrass π_{2t} is:

$$\begin{cases} P_y \mathrm{Y}_b + SM - \mathrm{V}_b - F_b - \mathrm{F}_p + NI & \text{if t=1} \\ P_y \mathrm{Y}_b + SM - \mathrm{V}_b - \mathrm{F}_p + NI & \text{if t=2,3,...T} \end{cases}$$

Option 3 (Production of energy crops in Revenue Sharing Contract)

With a revenue sharing contract with revenue sharing rate α , Ethanol Price (\$/Gallon) P_{et} , biomass conversion rate (gallon/ton) G .

Without yield insurance for energy crops:

The per-acre profit for miscanthus π_{3t} is:

$$\begin{cases} -F_b & \text{if t=1} \\ \alpha \mathrm{P}_{et} \mathrm{G}\, \mathrm{Y}_b + SM - \mathrm{V}_b - \mathrm{F}_p & \text{if t=2,3,...T} \end{cases} \quad (5)$$

The per-acre profit for switchgrass π_{3t} is:

$$\begin{cases} \alpha \mathrm{P}_{et} \mathrm{G} \mathrm{Y}_b + SM - \mathrm{V}_b - F_b - \mathrm{F}_p & \text{if t=1} \\ \alpha \mathrm{P}_{et} \mathrm{G} \mathrm{Y}_b + SM - \mathrm{V}_b - \mathrm{F}_p & \text{if t=2,3,...T} \end{cases}$$

With yield insurance for energy crops:

The per-acre profit for miscanthus π_{3t} is:

$$\begin{cases} -F_b & \text{if t=1} \\ \alpha \mathrm{P}_{et} \mathrm{G\ Y}_b + SM - \mathrm{V}_b - \mathrm{F}_p + NI & \text{if t=2,3,...T} \end{cases}$$

(6)

The per-acre profit for switchgrass π_{3t} is:

$$\begin{cases} \alpha \mathrm{P}_{et} \mathrm{GY}_b + SM - \mathrm{V}_b - F_b - \mathrm{F}_p + NI & \text{if t=1} \\ \alpha \mathrm{P}_{et} \mathrm{GY}_b + SM - \mathrm{V}_b - \mathrm{F}_p + NI & \text{if t=2,3,..T} \end{cases}$$

Option 4 (Grow only conventional crops):

The per-acre profit by growing conventional crops (corn and soybean in this study) is π_{ct} *for* $t = 1, 2, ...T$. Corn stover, as a by-product of corn, may be harvested for biomass. We have also included profits from corn stover in calculation of profits by growing conventional crops, as even at low prices of biomass, refinery will get biomass from corn stover. The fixed and variable costs of producing conventional crop *i* in year *t* are represented by f_t^i per unit of land and v_t^i per unit of yield, respectively. Because more than 80% of major crops' acreage is covered under federal crop insurance in the United States (Shields, 2015), we include indemnity payments provided by crop insurance in farmer's profits from conventional crops. We consider the case of revenue insurance for corn (and for soybean if under corn-soybean rotation) which is widely adopted for conventional crops by U.S. farmers (Shields 2015). The indemnity payment per unit land in year *t* and on land type $j \in \{h, l\}$ for a conventional crop is specified as

$$\iota_t^{cj} = \max\{\theta^c \mathrm{E}(y_t^{cj}) \max[p_t^{\text{proj}}, p_t^{\text{harv}}] - p_t^{\text{harv}} y_t^{cj}, 0\}, \qquad (7)$$

where θ^c is insurance coverage level for the conventional crop; E(·) is the expectation operator; p_t^{proj} and p_t^{harv} are respectively projected price and harvest price established by Risk Management Agency (RMA) (2011) of U.S. Department of Agriculture (USDA). The profit per unit of land for the conventional crop in year *t* on land type *j* can then be written as

$$\pi_{ct} = \pi_t^{cj} = (p_t^c - v_t^{cj})y_t^{cj} - f_t^{cj} + \iota_t^{cj} - (1-\rho)\mathrm{E}[\iota_t^{cj}], \qquad (8)$$

where ρ is insurance premium subsidy rate for the conventional crop.

As mentioned earlier, out of these four options, farmer will choose the option having maximum net present value (NPV) of expected utilities of above mentioned profits over the lifespan of energy crops *T* years. We do the above optimization for each of the county included in our analysis. Thus, as a result we have one selected optimal option for each of the county. From these results, we calculate aggregate acres enrolled in the land leasing contract (denoted by vector $A_1 = A_{12}, A_{13}, A_{14}...)$, aggregate acres enrolled in the fixed price contract (denoted by vector $A_2 = A_{21}, A_{22}, A_{23},...)$, and aggregate acres enrolled in the revenue sharing contract (denoted by vector $A_3 = A_{31}, A_{32}, A_{33},...)$. With these aggregate acres, we also calculate total acreage for energy crops (L_e) and total biomass production level (B_T) for all counties taken together. In other words, we can say that we calculate one combined regional figure for total acreage for energy crops and total biomass production. On basis of this information, we calculate the profits of refinery for that particular menu of contract terms.

This whole process mentioned above (first calculate NPV of expected utility for all four options for farmer, choose the maximum one, calculate total acreage for energy crops for whole region, and then based on these land acreages calculate profits of refinery) will be undertaken for all possible menus of contract terms. Thus, we will have the refinery profits for all possible menus of contract terms. Refinery will also undertake its optimization problem by choosing the menu with highest profits.

5. Refinery's optimization

We assume a risk-neutral biorefinery that sets the terms for each of the three contract types to maximize the net present value of its expected profits. For optimization, we have taken some assumptions based on analysis conducted by Yang et al. 2016. We consider the case of a production capacity of 500 million gallon (K gallons of ethanol (*e*) per Year) a year cellulosic biorefinery. The decision-making unit is a 1-acre land parcel. We assume that 80 gallons of cellulosic ethanol can be produced per ton of feedstock. (*G* gallons of ethanol can be produced per ton of biomass). The capital cost is calculated on the assumption that capital cost for a 35 million gallons per year biorefinery is $303 million, and that the operating cost of refinery is $1.44 per gallon. (The fixed cost of the refinery is F_e and its variable cost per gallon of ethanol is V_e).

The refinery can lease land to produce the energy crop itself (i.e. land leasing contract) or it can induce farmers in the vicinity of the refinery to produce energy crops under one of two other types of contracts (i.e. fixed price contract and revenue sharing contract). Another alternative is to purchase biomass from a spot market. We assume a risk-neutral biorefinery that sets the terms for each of the three contract types to maximize the net present value of its expected profits. Thus in this refinery's optimization problem, the choice variables will be the contract terms for the three contracts i.e. ($\omega, \overline{P_y}, \alpha$)

The bio-refinery's optimization problem is expressed as follows:

$$Max_{(\omega,\, P_y,\alpha)} : \mathrm{E}\left\{\sum_t (\frac{1}{1+r})^{t-1}\ (P_{et}K) - F_e - \sum_t (\frac{1}{1+r})^{t-1}\ (V_e K)\right.$$

$$- (F_b + \sum_t (\frac{1}{1+r})^{t-1}\ V_b + \sum_t (\frac{1}{1+r})^{t-1}\ \omega)\ A_1 - (\sum_t (\frac{1}{1+r})^{t-1}$$

$$P_y \mathrm{A}_2 Y_b) - (\sum_t (\frac{1}{1+r})^{t-1} \alpha \mathrm{P}_{et} \mathrm{G} \mathrm{A}_3 Y_b)$$

$$+ \mathrm{I}[\sum_t (\frac{1}{1+r})^{t-1} (\mathrm{P}_{bt} - \mathrm{W})\ (\mathrm{Y}_{bt} - \mathrm{Y}_b)\mathrm{A}_1] + (\mathrm{I} - 1)[\sum_t (\frac{1}{1+r})^{t-1} (\mathrm{P}_{bt} + \mathrm{W})\ (\mathrm{Y}_b - \mathrm{Y}_{bt})\mathrm{A}_1]\}$$

subject to $[A_1 Y_{bt} + (\mathrm{A}_2 + A_3) Y_b + (\mathrm{Y}_b - Y_{bt})]G = K$ (9)

Where $I = 1$ if $Y_{bt} > \mathrm{Y}_b$ and $I = 0$ otherwise and W represents a fixed average biomass per ton transportation cost to/from spot market.

Thus, we calculate the NPV of refinery's profits for each possible menu of contract terms and choose the menu with highest NPV of expected profits. In this way, refinery optimizes its profits, and for that optimized menu of contract terms, farmers have already optimized their utility from expected profits.

Due to fixed limited capacity of the refinery, there may arise one issue of selecting few counties among all counties for the biomass production. For example, in case of land leasing contract, at a specific rent, let's say at rent of $100 per acre per year, a lot of counties may be willing to give their land on lease, all of them may not be required by refinery, as refinery has a specific limited demand of biomass due to its' fixed production capacity. So, here problem is that how refinery will choose the counties for land leasing contract, when there is no transportation cost from the farm-gate to the refinery (in absence of transportation cost, refinery has no incentive to choose counties near its vicinity). We let the refinery sign contracts with farmers who produce the cheapest biomass. That is, farmers with least $/ton biomass will win the contracts. For this, we arrange counties in ascending order of total cost to get one ton of biomass. Refinery first collects the biomass from that county where total cost to get one ton of biomass is minimum, and then so on, until refinery gets all required biomass in order to achieve its maximum capacity (we have assumed a 500 million gallons a year cellulosic biorefinery in every region). We have taken this approach for all three contracts.

We have done above joint optimization in two scenarios: 'With insurance' and 'Without insurance' for energy crops to see how presence of crop insurance for energy crops will affect the optimal contract design and will affect land allocation under a certain contract type. We assume conventional crops are covered by "Revenue Insurance" and energy crops are covered by "Yield Insurance". We also assume that there is no credit constraint and farmers could finance their establishment stage investment using credit market. We will do our analysis for Miscanthus and we assume that the lifespan of miscanthus is 15 years.

6. Simulation Results

We conduct our simulation under eight scenarios, which are the combinations of two discount rates (2% and 10%), two energy crop insurance status (with insurance and without insurance), and two risk aversion parameter values ($\alpha = 0.0001$ for high risk averse and $\alpha = 0.00005$ for low risk averse). Under each of these eight scenarios, we study the representative farmer's optimal choice out of four available choices and how the energy crop insurance status affects the optimal contract design and land allocation under a certain contract type. We use biomass production and land devoted to bio-energy crops as measures of bioenergy crop adoption.

6.1 *Effect of energy crop insurance on bioenergy crop adoption and optimal contract design*

For energy crop insurance, we assume that the premium subsidy rate is 55% and coverage level is 75% of average energy crop yields. This study preferred to take these values as one of the most popular coverage levels chosen by farmers for conventional crops is 75% and its' corresponding subsidy rate is 55% specified by RMA (Shields 2015). From Table 2 and Table 3 we can see that in all cases the presence of energy crop insurance increases the land acreage and biomass production under fixed price contract. The presence of energy crop insurance incentivizes farmers to grow miscanthus under fixed price contract as crop insurance a major risk management tool in agricultural production is complementing the other risk management tool i.e. contract.

We can also see that without energy crop insurance, bioenergy crop adoption is more under land lease contract as compare to bioenergy crop adoption under land lease contract with energy crop insurance. As, under land leasing contract, farmers are offered a fixed rental rate per acre per year for the contract period to lease their land to the refinery to produce bioenergy crops, and the farmer receives a risk-free return each year during the lease, therefore in absence of other risk management tool i.e. energy crop insurance, more farmers prefer to choose land leasing contract over fixed price contract. The total impact of energy crop insurance on bioenergy crop adoption under all three contracts taken together is small for miscanthus. A possible explanation is that yield risk of miscathus is smaller (table 1), which causes insurance premium and hence premium subsidy directed to miscanthus is not large. From Table 4, we can also see that in all cases optimal contract design changes with presence of energy crop insurance.

7. Conclusions

In this paper, we investigate the interaction of two major risk management tools i.e. crop insurance and contracts in improving the risk management ability of farmers who want to adopt production of bioenergy crops. We set up a joint optimization framework for farmers and biorefinery, where a representative farmer optimally makes a choice of whether to use their land to grow conventional crops or to use their land for production of bioenergy crops under one of three different contract choices offered by the biorefinery. We do this joint optimization in two scenarios: 'With insurance' and 'Without insurance' for bioenergy crops to see how presence of crop insurance for bioenergy crops will affect the optimal contract design and will affect land allocation under a certain contract type. We find that presence of energy crop insurance increases the land acreage and biomass production under fixed price contract, and also affects the optimal contract terms for land leasing contract. We have seen that insurance and contracts as two major risk management tools complements each other.

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Table 1. Summary Statistics of Data Utilized in the Simulation[a]

			Mean	S.D.	Min.	Max.
Yields[b]	miscanthus on high quality land (MT/ha)		27.2	2.9	3.5	48.3
	miscanthus on low quality land (MT/ha)		26.8	2.8	2.8	47.4
	switchgrass on high quality land (MT/ha)		14.1	2.8	0.4	32.1
	switchgrass on low quality land (MT/ha)		12.7	3.3	0.4	31.1
	corn stover on high quality land (MT/ha)		2.6	0.6	0.01	6.9
	corn stover on low quality land (MT/ha)		2.4	0.54	0.02	6.5
	corn grain on high quality land (bu./acre)		139.1	39.2	0.7	304.5
	corn grain on low quality land (bu./acre)		127.2	34	0.5	297.3
	soybeans on high quality land (bu./acre)		42.9	20	1	112.3
	Soybeans on low quality land (bu./acre)		41.5	19.5	0.1	109.2
Costs	miscanthus (Yr 1)	establishment cost ($/ha)	3,108	46.2	3,033.6	3,247.9
	(Yrs 2-15)	variable cost ($/MT)	17.2	2	14.2	19.6
		fixed cost ($/ha)	166	29	113.1	258.7
	switchgrass	variable cost ($/MT)	17.2	2	14.2	19.6
	(Year 1)	fixed cost ($/ha)	332.7	22.8	294	392.9
		establishment cost ($/ha)	249.4	20	223	319
	(Year 2)	fixed cost ($/ha)	254.9	53.9	143.5	368.3
	(Yrs 3-10)	fixed cost ($/ha)	251.6	40.6	169.1	354.1
	corn stover	variable cost ($/MT)	17.5	2.1	12.6	21.7
		fixed cost ($/ha)	48.5	10.9	20.3	75
	corn	variable cost ($/bushel)	1.3	0.4	0.8	2.7
		fixed cost ($/acre)	136.5	28.6	91.4	221.8
	soybeans	variable cost ($/bushel)	1.5	0.3	0.8	1.8
		fixed cost ($/acre)	107.4	45.4	59.4	195.9
Prices[c] **($/bushel)**	corn	projected price	4.1	1.2	2.6	7.8
		harvest price	3.8	1.3	2.2	8.1
		received price	4	1.3	1.9	9.1
	soybeans	projected price	9.5	2.9	5.4	17.2
		harvest price	9.3	3	5.4	19.3
		received price	9.2	2.6	5.3	17.3
Acreage (hectare per county)		High quality land	28,841	38,228	202	252,448
		Low quality land	4,507	4,680	0	42,154

Note: [a] Costs and prices are in 2010 dollars; MT refers to metric tons of biomass with 15% moisture content. [b] Corn grain and stover yields are under corn-soybean (CS) rotation. Under corn-corn rotation, yields are assumed to be 12% lower than that under CS rotation. [c] The received price is state-level annual average price while the projected price and harvest price are futures prices calculated following RMA (2011).

Table 2: Bioenergy Crop Adoption without Crop Insurance for Bioenergy crops

	High Risk Averse Low Discount Rate	High Risk Averse High Discount Rate	Low Risk Averse Low Discount Rate	Low Risk Averse High Discount Rate
Contract_Lease				
Acreage (Acres in Millions)	1.98	0.20	2.20	0.16
Biomass (millions MT)	15.66	2.22	16.17	1.87
Contract_Fixed Price				
Acreage (Acres in Millions)	2.69	1.36	3.24	1.77
Biomass (millions MT)	24.57	15.97	30.97	18.07
Contract_Revenue Sharing				
Acreage (Acres in Millions)	0.00	0.00	0.00	0.00
Biomass (millions MT)	0.00	0.00	0.00	0.00
Total				
Acreage (Acres in Millions)	4.67	1.56	5.44	1.93
Biomass (millions MT)	40.23	18.19	47.14	19.94

Table 3: Bioenergy Crop Adoption with insurance for Bioenergy crops

	High Risk Averse Low Discount Rate	High Risk Averse High Discount Rate	Low Risk Averse Low Discount Rate	Low Risk Averse High Discount Rate
Contract_Lease				
Acreage (Acres in Millions)	0.63	0.20	2.39	0.17
Biomass (millions MT)	4.51	2.22	15.92	2.01
Contract_Fixed Price				
Acreage (Acres in Millions)	3.45	1.44	3.42	1.94
Biomass (millions MT)	34.87	16.63	35.32	20.29
Contract_Revenue Sharing				
Acreage (Acres in Millions)	0.00	0.00	0.00	0.00
Biomass (millions MT)	0.00	0.00	0.00	0.00
Total				
Acreage (Acres in Millions)	4.08	1.64	5.80	2.11
Biomass (millions MT)	39.38	18.85	51.25	22.30

Table 4: Optimal Menu Values under Different Scenarios - Miscanthus

	Fixed price ($) (per ton of biomass)	Fixed % of revenue generated (per ton of biomass)	Rent ($) (per acre per year)
	Without Insurance		
High Risk Averse, Low Discount Rate	50	20	135
High Risk Averse, High Discount Rate	50	20	40
Low Risk Averse, Low Discount Rate	50	20	145
Low Risk Averse, High Discount Rate	50	20	40
	With Insurance		
High Risk Averse, Low Discount Rate	50	20	100
High Risk Averse, High Discount Rate	50	20	45
Low Risk Averse, Low Discount Rate	50	20	150
Low Risk Averse, High Discount Rate	50	20	45