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Costs of meeting a cellulosic biofuel mandate with perennial energy crops: Implications for policy☆

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ABSTRACT

We develop an analytical framework to examine the extent to which farmers' risk and time preferences, availability of credit to cover establishment cost, and subsidized crop insurance for conventional crops influence the decision to allocate land to a perennial energy crop and affect the costs of meeting a biofuel mandate using this crop as feedstock and its implications for the effectiveness of two alternative policies to supplement the mandate: an establishment cost subsidy and subsidized energy crop insurance. We examine the design of these policies to minimize the total (public and private) costs for meeting a one-billion-gallon biofuel mandate by using miscanthus as feedstock. We find that a high degree of risk aversion, high discount rate, credit constraint, and availability of crop insurance for conventional crops can increase the cost of producing enough biomass for a one-billion-gallon biofuel mandate by up to 43% and increase the land required by 16% as compared to otherwise; removal of subsidized crop insurance and credit constraints could lower these costs by 50%. We find that in most cases the cost-effective energy crop insurance subsidy rate is 0% whereas the cost-effective establishment cost subsidy rate is 100%. Relative to the case with no policy intervention for energy crops, energy crop insurance can reduce the total costs (net of government expenditures on subsidies) of meeting the 1 billion gallon mandate by 1.3% whereas establishment cost subsidy can reduce these costs by 34%.

1. Introduction

Concerns about energy security, dependence on fossil fuels, and climate change have led to policy support for biofuels in recent years. The Renewable Fuel Standard (RFS) established by the Energy Independence and Security Act (EISA) of 2007 in the US mandates 36 billion gallons of biofuels to be consumed annually by 2022, of which at least 16 billion gallons must be cellulosic biofuels.[1] Studies show that energy crops, such as miscanthus (*Miscanthus × giganteus*) and switchgrass (*Panicum virgatum*), are promising sources of feedstock for cellulosic biofuels due to their relatively high yields, potential to provide a range of environmental benefits, and ability to grow productively on low quality land and thereby mitigate the competition for land as compared to grain-based biofuels (Heaton et al., 2008; Chen et al., 2014; Dwivedi et al., 2014; Hudiburg et al., 2016).

However, these crops are costly to establish and are typically perennials with a lifespan of 10 to 15 years and a need for a long-term commitment of land to the crop. Without the access to subsidized crop insurance that is typically available for conventional crops, perennial crop production also involves risks that may differ from those of conventional annual crops (Miao and Khanna, 2014).[2] Perennial energy crops have a one- to three-year establishment period during which a farmer would incur fixed cost of establishing these crops and forgo returns that could have been earned under alternative use of that land (such as growing conventional crops). In the absence of credit, the establishment cost has to be borne upfront instead of being annualized over the lifespan of the crop. The decision to convert land from existing uses to a perennial energy crop will, therefore, depend on the risk and time preferences of farmers, the riskiness of alternative crops, correlation among those risks, as well as the presence of credit constraints and crop insurance.

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[1] Large scale production of cellulosic biofuels is at the take-off stage (Peplow, 2014). The first commercial-scale cellulosic biorefinery (Crescentino biorefinery) commenced operation in Italy in 2013. In the US, POET-DSM Advanced Biofuels opened a commercial-scale cellulosic ethanol plant in September 2014 (link: http://poetdsm.com/pr/first-commercial-scale-cellulosic-plant). One month later, Abengoa opened its 25-million gallon cellulosic biofuel plant in Hugoton, Kansas (http://energy.gov/lpo/articles/journey-commercializing-cellulosic-biofuels-united-states).

[2] Crop insurance coverage is currently available to more than 350 commodities in all 50 states and more than 80% of eligible acres are enrolled in various insurance programs with federally subsidized premiums. Crop insurance can provide coverage that replaces up to about 85% of the projected revenue of a crop. About 60% of insurance premiums are subsidized by the US federal government (Babcock, 2012).

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Studies suggest that farmers tend to be more risk averse than non-farm business owners (Roe, 2013; Menapace et al., 2013) and that their discount rates can be as high as 40% (Duquette et al., 2012). High degree of risk aversion and high discount rate, together with a constraint on credit, can raise the price at which farmers would be willing to supply a given amount of a perennial energy crop with high upfront establishment costs.[3] Since crop yields and riskiness differ spatially, risk and time preferences can also affect the spatial pattern of land allocated to energy crop production and have implications for the amount of land needed to meet a given level of biofuel production using an energy crop. Thus, the risk and time preferences of farmers with a credit constraint and subsidized crop insurance for conventional crops can result in inefficient outcomes in the form of higher cost of cellulosic biofuels and land requirements than otherwise.

While existing studies have examined the costs of supplying cellulosic feedstocks under certainty by risk neutral farmers with low discount rates (Khanna et al., 2011), there has been limited assessment of the impact of risk and uncertainty, liquidity constraints, and time preferences on incentives to produce energy crops. A few studies have examined the effects of a credit constraint and risk preferences (Bocquého and Jacquet, 2010), uncertainty about returns (Song et al., 2011) and crop insurance (Dolginow et al., 2014) on the incentives for a representative farmer to allocate land to a perennial energy crop. Yang et al. (2017) examine the effect of risk aversion on choice of marketing contracts for energy crops between biorefinery and landowners while Khanna et al. (2017) find empirical evidence that risk averse and present-biased farmers are less likely to grow an energy crop.

This study extends this literature by developing a framework that analyzes the continuous choice of land allocation to an energy crop while incorporating a range of determinants including the returns from energy crop production relative to alternative use of the land, the riskiness and temporal profile of those returns, and the potential to use energy crops to diversify the crop portfolio. Unlike the representative farmer assumption and option value framework to examine the decision of whether and when to produce an energy crop under uncertainty as in Song et al. (2011), we characterize the spatial and temporal variability in crop yields using a biophysical crop growth model and estimate the heterogeneity in riskiness and returns to energy crop production across the rainfed region of the US. We use this to endogenously determine the biomass price that achieves a mandated level of production under various assumptions about the risk and time preferences of farmers, the presence of credit constraints, and crop insurance for conventional crops. With a binding biofuel mandate, the key question being addressed here is not whether or when to produce an energy crop (as under a real option framework) but rather the cost of meeting the mandate with a perennial energy crop whose production is risky and farmers are risk-averse and impatient.

Various policy incentives, such as tax credits and establishment cost share subsidies are currently being provided to supplement the RFS in order to facilitate the development of cellulosic biofuels.[4] Crop insurance programs have been proposed for energy crops to offset the disincentives for switching from conventional crops that are usually covered by subsidized crop insurance (Farm Service Agency, 2013).[5] We apply the framework developed here to analyze the design of two supplemental policy interventions to a mandate (an establishment cost subsidy and subsidized crop insurance for energy crops) that would minimize the total cost of achieving the mandate which includes both the public cost of supporting a policy instrument incurred by the government and the aggregate private costs of biofuel production incurred by growers and biorefineries. By sharing the risks of energy crop production and providing access to low-cost funds to cover establishment costs, government intervention could lower the net costs of meeting a binding biofuel mandate. Our analysis provides insights about the conditions likely to influence the effectiveness of such policies as supplements to a binding mandate for cellulosic biofuels from perennial energy crops.[6]

We use this framework to numerically simulate the cost of meeting a binding one-billion-gallon cellulosic biofuel mandate using a perennial energy crop, miscanthus, in the rainfed region of the US.[7] We endogenously determine the price of biomass and county specific allocation of land to meet the mandate under a range of assumptions about the risk and time preferences of farmers, credit constraints, and the presence of crop insurance for conventional crops. We use county-specific simulated yields of miscanthus on high and low quality land and observed yields of corn and soybeans under 27 years of weather conditions to incorporate both the temporal and spatial variability in yields. We examine the effect of risk and time preferences and credit constraint on the county-specific allocation of land to energy crops to meet the one-billion-gallon mandate. We compare the implications of an establishment cost subsidy and subsidized energy crop insurance for the total cost of meeting the mandate, net of the cost of additional government expenditures on these policy instruments. The subsidy rates for each policy are selected to minimize the total cost. We also examine the effects of these policies on the spatial pattern of energy crop production in the rainfed US and its implications for land requirements to meet the mandate.

The article proceeds as follows. Sections 2 and 3 outline the conceptual framework and simulation framework, respectively. Data used in the simulation are described in Section 4. Section 5 discusses simulation results and Section 6 concludes.

2. Conceptual framework

We present a conceptual model of a farmer's decision problem of allocating a tract of land between a conventional crop and an energy crop to maximize expected utility while taking crop prices and policy incentives as given.[8] We examine how the optimal land allocation between the two crops is affected by the farmer's risk and time preferences, the presence of insurance for conventional and energy crops, an establishment cost subsidy, and credit availability to finance the establishment of the energy crop. We then use this framework to numerically simulate the biomass price needed to induce the mandated level of biomass

[3] Studies find that about 10% of U.S. farmers were either denied or had difficulty obtaining credit (Briggeman et al., 2009) and that younger farmers are more likely to be credit constrained (Bierlen and Featherstone, 1998). Since younger farmers are more likely to adopt energy crops (Jensen et al., 2007; Altman et al., 2015) a credit constraint could limit widespread adoption of energy crops.

[4] The Cellulosic Biofuel Production Tax Credit provides a $1.01 per gallon tax credit for blending cellulosic biofuels with fossil fuels while the Biomass Crop Assistance Program, established in Food, Conservation, and Energy Act of 2008 and re-authorized in the Agricultural Act of 2014, provides an establishment cost subsidy for energy crops.

[5] A survey of farmers by Fewell et al. (2011) suggests that availability of insurance programs for energy crop production will be a key factor in incentivizing farmers to grow energy crops.

[6] Other justifications for government intervention to support energy crop production include the environmental benefits (such as greenhouse gas mitigation) they provide that are not priced. The policy to address those could be a Pigouvian tax (such as a carbon tax) targeted at the externality. Chen et al. (2014) show that an unrealistically high carbon tax would be needed to induce production of cellulosic biofuels given their current costs, even if the effects of risk and time preferences of farmers are ignored.

[7] Miscanthus is a particularly productive energy crop whose yields can be twice as high as those of other energy crops such as switchgrass. Studies show that it is likely to be more profitable to produce than switchgrass under a wide range of growing conditions in the rainfed US (Jain et al., 2010; Chen et al., 2014; Beach et al., 2012; Miao and Khanna, 2014).

[8] The diversion of land from a conventional crop to an energy crop may increase the price of land and the costs of producing the two crops. However, given the fact that perennial energy crop production at commercial scale does not exist yet and we only consider a relatively small energy crop production (biomass for one billion gallons of cellulosic biofuels which requires about one million acres of land) in our simulation, we assume prices of the conventional crop are not affected by adopting the energy crop. Relaxing this assumption would obscure, but not obviate, the insights we seek to provide in this study because our focus is on how farmers' risk and time preferences, availability of credit to cover establishment cost, and crop insurance for conventional crops may influence farmers' decision to allocate land to a perennial energy crop.