Effectiveness of Payments for Greenhouse Gas Mitigation to Induce Low Carbon Bioenergy Production

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Project Goals: This study provides a comprehensive analysis of the potential impact of incentivizing greenhouse gas (GHG) mitigation from cellulosic ethanol feedstocks in a risk-averse crop production context. We examine the impact of payments linked to GHG reduction on cropping decisions of risk-averse farmers in the rain-fed area of the United States at various biomass prices with a focus on aggregate GHG mitigation, aggregate cost to reduce emissions, and the spatial distribution of feedstock. Additionally, the project explores whether the manner of payment influences cropping decisions by comparing lump-sum upfront payments for total GHG mitigated to annual payments for GHG mitigated each year. Additionally, we explore the cost-effectiveness of a GHG reduction payment approach for achieving a given emission reduction target compared to a uniform establishment cost payment.

Abstract text:

Motivation: Cellulosic ethanol feedstocks such as corn stover and energy crops have the potential to provide substantial greenhouse-gas reduction benefits, first, through aboveground emission reduction as cellulosic ethanol can displace less carbon-intensive gasoline and, second, via carbon mitigation through soil carbon sequestration. These feedstocks vary greatly in terms of their GHG intensities, production costs, and risks due to differing and spatially varying input requirements, yields, and soil carbon sequestration effects. For instance, corn stover is a low cost but low yielding source of biomass readily available to farmers planting corn but harvesting stover also results in the removal of soil carbon that would have otherwise remained sequestered in the ground. In contrast, energy crops like miscanthus and switchgrass provide spatially varying GHG reduction benefits through relatively high annual yield over the mature period of the crop, substantial soil carbon sequestration through the life of the crop, and their ability to grow on marginal land. Long establishment periods with high upfront costs and uncertain yields due to weather variations, however, reduce incentives for risk-averse, impatient, and credit-constrained farmers to produce these GHG mitigating energy crops.

Previous research shows that upfront subsidies to reduce establishment costs can incentivize the adoption of energy crops by risk-averse decision-makers but have not yet considered directly incentivizing the spatially varying GHG mitigation that these feedstocks provide that make them appealing in the first place. Areas that have the lowest cost for energy crop cultivation, for instance, may not necessarily be the areas with the highest GHG mitigation potential due to spatial differences in high sequestration and high yield areas, spatial differences in high miscanthus and switchgrass yield areas, and payment for GHG mitigation benefits of corn stover. Earlier research finds heterogeneity in emission reduction potential from different sources and sites. Uniform payments schemes such as those under the Renewable Fuel Standard and the Biomass Crop Assistance Program that do not take variation in GHG reduction potential into account may not be incentivizing those crops that provide the most GHG mitigation. Providing payments based on emission reduction would take advantage of spatial variability in GHG reduction potential, yields, and costs by creating differing incentives for

feedstocks in different locations and increase the production of cellulosic ethanol where greenhouse gas intensity of biofuel produced and overall cost of production is lowest.

The purpose of this paper is, first, to examine the impact of payments linked to GHG reduction on the cropping decisions of risk-averse farmers in the rain-fed area of the United States at various biomass prices with a focus on aggregate GHG mitigation, aggregate cost to reduce emissions, and the spatial distribution of feedstock. Second, we explore whether the manner of payments influences cropping decisions by comparing lump-sum upfront payments for total GHG mitigated to annual payments for GHG mitigated each year. Third, we explore the cost-effectiveness of a GHG reduction payment approach for achieving a given emission reduction target compared to a uniform establishment cost payment. To the best of our knowledge, this study is the first one that provides a comprehensive analysis of the potential impact of incentivizing GHG mitigation from cellulosic ethanol feedstocks in a risk-averse crop production context.

Methodology: We first present a theoretical framework under which a representative farmer optimally chooses her land allocation between conventional and energy crops. We examine how GHG mitigation payments will affect the farmer's optimal land allocations under various risk and time preferences and credit constraint specifications. We show that crop allocations will depend in part on yield riskiness, the temporal profile of returns, and diversification of the farmer's crop portfolio.We then use a stylized integrated model simulation framework that links an economic model with a biogeochemical model, DayCent, to analyze farmers' cropping allocation under GHG reduction payments while accounting for spatial and temporal heterogeneity in crop yields and GHG intensities. We use a Copula method to generate joint distributions in all crop yields and conventional crop prices to measure the risks of feedstock yields and conventional crop prices for each county. Each county is considered a representative farmer maximizing expected utility under various exogenously determined GHG reduction payment scenarios and carbon and biomass prices for an exogenous degree of risk aversion, time preferences, and credit constraints. The model is simulated for a fifteen-year cropping cycle for energy crops, where farmers can choose to allocate crops on cropland and marginal land and choose whether to harvest a portion of the corn stover from areas under corn production.

Data: Our numerical simulation focuses on the 1,919 rainfed counties in the eastern United States. In order to reflect the stochastic nature of prices and yields, county-level yields for thirty years for corn grain, corn stover, soybean, miscanthus, and switchgrass from DayCent and thirty-year harvest and futures corn and soybean Chicago Board of Trade prices are used to estimate a joint distribution for all yields and conventional crop prices. Belowground sequestration rates for conventional and energy crops are calculated from DayCent. Aboveground displacement is calculated as the sum of electricity co-product credits, material input use, emissions generated through electricity, diesel, transportation, and ethanol production, each of which are calculated using input intensities taken from the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model, model, nitrogen application rates from DayCent, and simulated yields. Additionally, land acreage by county for both cropland and marginal land is taken from National Agricultural Statistics Service (NASS). Input quantities for energy crops are compiled from Ohio State Extension documents, with input costs from NASS. Input quantities and costs for conventional crops are compiled from state extension documents and NASS. Parameters for the landowner's risk and time preferences are obtained from the literature. The model is solved for cropping shares under exogenous payment scenarios with exogenously varying biomass payment and an exogenous cost of carbon.

Results: Results show that without GHG reduction payments farmers require high biomass prices (at least $50 per ton in a not risk-averse, not credit constrained, and low discount scenario, and $70 per ton in the risk-averse, credit constrained, and high discounting scenario) to induce them to plant energy crops. GHG reduction payments cause farmers to adopt energy crops at low carbon prices when biomass price is between $30 and $60 per ton, with the potential to incentivize up to 200 million tons of biomass and displace or mitigate 350 million metric tons of carbon.

The manner in which GHG reduction is paid for influences feedstock adoption. Yearly payments are more cost-effective in driving farmer adoption when farmers are not risk-averse, not credit constrained, and have a low discount rate. For example, at a biomass price of $40 per ton, an $80 dollar price per ton of carbon drives farmers to produce 100 million metric tons of energy crops per year compared to 50 million metric tons when payment is upfront. Upfront payments being better are driving adoption when farmers are risk-averse, credit constrained, and have a high discount rate, with farmers producing 80 million metric tons from upfront payments but only 25 million metric tons from yearly payments.

GHG reduction payments are able to induce farmers to mitigate GHG more cost-effectively than uniform payments. For example, a uniform establishment cost share subsidy at a biomass price of $40 per ton in a less constrained scenario would cost 350 million dollars and result in 30 million metric tons of carbon displaced or mitigated. An upfront GHG reduction payment can achieve the same GHG mitigation goal for a cost of 250 million dollars by incentivizing just 46 counties that are able to mitigate GHG the most with the emissions reduction goal being met through a mix of energy crops and corn stover use.

Potential for generating discussion: Current bioenergy programs such as BCAP and RFS incentivize the production of energy crops but do not directly incentivize GHG mitigation and the impact of incentivizing GHG mitigation on biomass feedstock production by risk-averse farmers has not yet been studied. This study provides comprehensive economic analysis of the impact of GHG reduction payments on aggregate GHG mitigation, energy crop production, cropping choices, and geographical configuration of land allocation. Therefore, it should be of interest to economists and policy analysts who are interested in programs that support GHG mitigation or bioenergy production.

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