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Efficiency of second-generation biofuel crop subsidy schemes: Spatial heterogeneity and policy design

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ABSTRACT

Policy schemes that aim to stimulate the cultivation of biofuel crops typically ignore the spatial heterogeneity in costs and benefits associated with their production. Because of spatial heterogeneity in biophysical, and current agricultural production factors, potential gains from stimulating biofuel crops are non-uniformly distributed across space. This paper explores implications of this type of heterogeneity for the net benefits associated with different subsidy schemes. We present a simple framework based on discounted cash flows, to assess potential gains from introducing the notion of heterogeneity into stimulation schemes. We show that agricultural subsidy spending can be reduced in a Pareto efficient way and simultaneously improve the total stimulation potential of biofuel policies, when schemes: 1) are production based instead of land based; 2) accommodate differences in opportunity costs, and 3) target sites where subsidies for conventional agricultural land-use types are high. These results are robust for a range of different bioenergy prices and the relative gains of addressing these key elements in policy compared to conventional stimulation schemes increase with lower bioenergy prices, and are largest when low prices coincide with high emission reduction ambitions.

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1. Introduction

The constraints of finite natural resources in combination with concerns about global warming have led researchers and policymakers to pay increased attention to the topic of sustainable energy policies and the reduction of greenhouse gas emissions. The switch to biofuels as a transportation fuel source has been put forward as a possible contribution to carbon emission reduction plans and overall sustainable energy strategies [25,49,38]. Second-generation ethanol production from lignocellulosic material is generally considered to avoid (partly) social and environmental impacts linked to biofuel production [52], and could become a key contributor to emission reductions. Although lignocellulosic ethanol production from biomass may become a suitable option in the future, large-scale production is not economically feasible at present and stimulation policies have to be implemented to achieve future bioenergy usage ambitions [67]. Many countries are struggling to achieve 2020 goals for fuel standards. In 2015, the average European blending share of crop based ethanol and biodiesel was estimated at respectively 3.3% and 4.3%, and at about 0.6% for non-food based biofuels [29]. Though the sector has achieved considerable growth worldwide in recent years [51], the strong decline in crude oil prices that started in the second half of 2014 has put the competitiveness of biofuels under severe pressure, and the current policy ambitions are not expected to lead to significant higher production in the next decade [44]. Because economic benefit is arguably the most important incentive for adoption, efficient subsidy strategies are of relevance for the future of biofuels and might not only be key in reaching 2020 fuel standards, but might determine when, or whether, we ever get a viable model for large scale production.

The focus of this paper is to explore possibilities to minimize subsidy spending and simultaneously increase the total stimulation potential of biofuel policies, while maintaining the income levels of farmers. Such possibilities allow for Pareto improvement with respect to the current situation as society can both save money on subsidies and gain from environmental benefits related to biofuel production, while profits of farmers would be unaffected by the subsidy reform. Reducing spending and increasing the stimulation potential of schemes can contribute to the overall cost effectiveness of policies and might strengthen the case of bioenergy production in the political arena. In past years, different studies proposed heterogeneous allocation of resources under different environmental policies, for example carbon sequestration contracts [2], air pollution emission trading programmes [31], vehicle emission abatement [42], and policies that promote investment in renewable electricity generators [26]. Current bioenergy stimulation policies typically do not recognize that there is substantial spatial variation in costs and benefits associated with biofuel crop production. This heterogeneity relates to interaction between policies stimulating the production of bioenergy, spatially heterogeneous production factors, agricultural land-use patterns, and other agricultural policies. The central thesis of this paper is that introducing the notion of spatial heterogeneity into subsidy schemes allows for more efficient allocation of subsidies, and potentially increases net social benefits by decreasing subsidy costs and increasing positive externalities. We build our analysis on the following three elements: first we assess spatial heterogeneity in Net Present Value (NPV) of current agricultural production systems; we then estimate site-specific net social costs and benefits of stimulation schemes; and finally, we compare the relative efficiency of alternative subsidy schemes in terms of associated potential net benefits. We repeat the analysis for a range of different bioenergy prices to show how the results change when the relative competitiveness of conventional land use and bioenergy production changes. We apply our analysis to explore production of a specific second-generation bioenergy crop - Miscanthus (*Miscanthus* × *Giganteus*) - in the Netherlands, a country with an advanced agricultural sector that has a high economic value per hectare. The Netherlands is currently far behind the European average for sustainable energy usage, and as we shall see in our application of the developed theory, could benefit from more effective bioenergy policy design.

The remaining part of this paper is organized as follows. In Section 2, we discuss inefficiencies that arise due to land heterogeneity. Section 3 details our methods. Section 4 describes our application to Miscanthus in the Netherlands. Section 5 presents the results, followed by a discussion and conclusion in Section 6.

2. The importance of spatial heterogeneity in agricultural policy

Agricultural systems are strongly determined by spatially heterogeneous agro-economic, socio-economic, and local biophysical conditions [15]. Spatial economic models that build upon this heterogeneity confirm that biomass is able to provide a substantial contribution to the overall energy supply. This future bioenergy potential has been assessed on the global scale [36,53], at the European level [61,12,27,28], and at national levels [5,57,62]. An overview of the different assessments and their respective strengths and weaknesses is given by [18], who point out that spatial variation in production characteristics is the most important aspect in assessing bioenergy potentials. Recent studies focusing on local opportunities for biofuel production were able to pinpoint specific areas of interest by using micro data on production characteristics [63,14]. Understanding the economic implications of spatial variability in local production factors might help researchers and policymakers in the field of environmental economics and resource management work towards more efficient forms of policy. However, existing agro-economic and bioenergy stimulation policies often do not explicitly address spatial heterogeneity and abstain from insights gained from bioenergy potential assessments.

Two examples illustrate this lack of attention to spatial aspects. The governments of Canada and the United States have proposed policies in which farmers are paid for the adoption of certain management practices to sequester carbon dioxide in agricultural soils [1,68]. In the European Union, farmers who grow bioenergy crops can apply for a standard land based subsidy [21]. Such a subsidy scheme is analogous to the proposed Canadian and United States government subsidy scheme as farmers are paid for adopting site-specific practices. Market-based incentives, however, are generally seen as more efficient than command-and-control or environmental design standard policies because there are cost-efficiency differences in abatement strategies among the entities within a sector, for example when both costs and environmental benefits differ among plots [59,55]. Efficient agricultural policies that aim to increase environmental benefits by influencing the management decisions of farmers, must therefore take into account the heterogeneity of the biophysical and economic factors that determine the agricultural system [37]. Paying farmers to adopt certain management practices in a land based system, disregarding the biophysical differences among their production sites, is generally seen as inefficient [35,3,30].

We particularize by distinguishing between two types of inefficiencies in bioenergy stimulation schemes: overfunding and misallocation of funds. When a farmer produces biofuel under a (government-funded) carbon contract, the contract value is part of the farmer's private profit function. In the economic environment of an emission trading market, contract values are conditional on a spatially varying factor, that is, the quantity of biomass produced