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Research paper

Policy analysis of perennial energy crop cultivation at the farm level: Short rotation coppice (SRC) in Germany

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ABSTRACT

Perennial energy crop production methods such as short rotation coppice (SRC) have gained interest among farmers and policy makers. SRC is characterised by rapid biomass production, low inputs, and high managerial flexibility. SRC plantations also provide environmental advantages relative to annual crop production and contribute to the transition towards renewable energy. Yet, the combination of high sunk costs and high uncertainty hampers SRC adoption among farmers. Policy instruments currently implemented to foster SRC adoption exhibit limited success. In this paper we assess the performance of different policy measures intended to stimulate SRC adoption in terms of efficiency and farm-level effects, taking into account related uncertainty. We use a combination of stochastic programming and the real options approach in our model featuring SRC poplar cultivation in Germany. We analyse four policy measures intended to foster SRC adoption: an establishment subsidy, a price floor, a guaranteed price, and increasing the "Ecological Focus Area" (EFA) value for SRC systems within the European Union Common Agricultural Policy. Our results indicate that a guaranteed price can stimulate immediate SRC adoption; however, it is inferior to the other instruments in other dimensions. An establishment subsidy as recently implemented in the study area might incentivise farmers to adopt SRC by contributing substantially to farm income, but should be modified because it may encourage postponement of SRC adoption. Increasing the EFA coefficient and a price floor are more efficient measures in terms of governmental expenditures, while having limited positive effects on bioenergy produced.

1. Introduction

In light of increasing global energy demand and concerns about greenhouse gas contributions to climate change, renewable energy sources are becoming increasingly important, including bioenergy sources [1]. In the European Union (EU) the demand for biomass energy is expected to increase by 19.8% by 2020 [2] in order to meet renewable energy targets. The largest share of this increase is expected to be satisfied with solid biomass, including woody biomass [3]. A major advantage of biomass energy over solar and wind is its dispatchability (i.e. the ability to produce energy resources when and where they are necessary) [4]. Biomass is hence considered to be a major contributor to balancing renewable energy supply and demand in emerging energy systems that rely heavily on solar and wind power [5]. In the EU the transition process towards increased production and use of renewable energy sources is strongly supported by policy. Existing biomass energy programmes focused on traditional annual crops such as maize or rapeseed, however, have considerable environmental and financial costs [6,7]. In contrast, short rotation coppice (SRC) offers a more environmentally friendly and economic means to source woody biomass. Ebers et al. [8] distinguish between socio-economic, ecological, and environmental advantages of woody biomass production. Perennial crop production via SRC is characterised by reduced soil erosion and increased biodiversity and overall landscape diversity relative to annual energy crops [9,10]. Due to its positive effects on soil fertility, Tolbert et al. [11] suggest that SRC could be applied to increase yields of subsequently cultivated crops. In addition, SRC is considered carbon neutral because the amount of atmospheric carbon assimilated during growth is converted to energy [12,13]; with poplar (*Populus* spp.) and willow (*Salix* spp.) being the most efficient carbon sinks among SRC tree species [14]. Moreover, SRC is suitable for a spectrum of soils in terms of productivity, including marginal soils [15], which can reduce competition with the production of annual crops and related food and feed production trade-offs [16]. Once established with fast growing trees, SRC systems can be coppiced several times at intervals between two and five years (for wood chip production) before

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clear cutting at approximately 20 years when they can be replaced with annual crops [17]. Farmers can adjust the timing of SRC harvests to market and farm conditions, such as harvesting during winter when on-farm labour resources are more available and thus avoid competition for farm labour resources with other activities [18].

Studies in Scotland [19], Germany [20]– [22], Sweden [23], and Latvia [24] have shown that farmers are often reluctant to adopt SRC despite its many advantages. In Germany SRC is practiced on only about 50 [25]–70 km^2 [26,27] out of over 20,000 km^2 of potential production area [28]. In the UK approximately 100 km^2 are currently dedicated to energy crop production out of an estimated range of 9300–36,300 km^2 of suitable land [29]. Considerable profit uncertainties due to volatile energy (i.e. woody biomass output) prices combined with high establishment and subsequent reconversion (i.e. sunk) costs have been identified as the major obstacles to SRC adoption [30,31].

In order to increase the adoption of perennial bioenergy crop production using practices such as SRC, a large set of policy instruments have been proposed and discussed [18,32–34]. Existing policy instruments supporting SRC and the production of other perennial bioenergy crops (e.g. switchgrass [*Panicum virgatum*] and *Miscanthus* spp.), as well as more general policy measures intended to reduce uncertainty that inhibits farmer investment in perennial biomass energy production can be classified into: (i) cross-sector instruments such as taxation or quotas for fossil energy use [35], (ii) investment in research and development [34], and (iii) farm-level policy measures. It is argued that policies intended to increase the competitiveness of SRC over alternative land uses, and reducing risk burden could facilitate SRC adoption [9,10,24]. To the best of our knowledge, however, a structured comparison of different policy instruments with regard to their performance (e.g. related governmental expenditures), outcome (e.g. energy output), and farm-level effects (e.g. income) considering uncertainty does not exist. We attempt to fill this research gap by using a farm-level analysis that assesses different policy approaches intended to increase SRC adoption. Our normative analysis focuses on farm-level policy instruments and provides policy makers with the necessary basis for subsequent analysis at greater scales and across sectors. We simulate and assess policy interventions on a typical farm in northern Germany, a highly suitable region for SRC cultivation and an area where there is considerable interest in fostering SRC adoption among policy makers. We analyse four relevant policy measures: (i) environmental requirements within the Common Agricultural Policy (CAP) of the EU [36] (which favours SRC over conventional annual crops), (ii) SRC establishment subsidies (which were recently introduced in our study area) [37], and (iii) guaranteed prices [38,39] and (iv) price floors [40] for SRC biomass. We incorporate the importance of risks for farmer investment decisions relevant to SRC adoption using a combination of the real option approach and stochastic programming. Our framework allows analysis and comparison of policies effects across various dimensions, including additional bioenergy production, governmental expenditures, and farmer income [41].

2. Methodology and data

2.1. Characteristics of SRC and the model

SRC is a long-term management option for the production and harvest of woody biomass from fast growing tree species. Due to its long-term nature SRC binds land resources for a much longer time period than most alternative land uses; although SRC plantations can be clear-cut at any time, triggering sunk costs and thus partial irreversibility of investments made. Unlike annual crops, the establishment and harvest schedule for SRC systems is not predefined and can be adjusted to suit market and farm conditions. Similar to other crop production systems, there is spatial flexibility: a farmer can decide how much land to convert to SRC and later either expand or revert to previous land uses. Hence, SRC production is characterised by: (i) sunk costs related to establishment and harvest; (ii) temporal and spatial flexibility related to establishment, harvest and reconversion; and (iii) risk throughout SRC production cycles. These three aspects imply the existence of an option value (i.e. potential incentives for a farmer to wait and make investment decisions in response to future states-of-nature [42]), which is captured by real options theory. The conceptual advantages of the real options theory over the classical net present value (NPV) approach for analysis of SRC adoption is also supported in the literature [30,43]. To date, the real options approach has been employed to analyse policy interventions supporting renewable energy on the national level [44,45]. In contrast, we simulate SRC management decisions under different policy instruments at the farm level.

Our analysis features a farm composed of plots with predefined sizes and a total area of 100 ha. The farmer makes decisions about the management of each plot; essentially whether or not to convert it to SRC. We assume that the area under SRC is not fractional, but rather based on 5-ha increments (i.e. 0, 5, 10, …, 100 ha). Establishment of SRC systems on each plot is considered an option that can either be postponed for a maximum of three years or else never exercised. Harvests can be conducted every two to five years after establishment or the previous harvest. The maximum age of a SRC plantation is 20 years, although reconversion back to annual crops is an option at any time interval after establishment. The total time horizon considered is 24 years (Fig. 1). Our model takes into account the full flexibility of SRC management: (i) the ability to postpone a decision to establish SRC plantation on each plot, (ii) the potential to invest in variable sized plantations, (iii) the ability to convert plantations to other land uses before the end of a plantation's production cycle, and (iv) flexibility with respect to harvest intervals.

Resources not used for SRC management can be devoted to other farm activities (as fractional shares). Constraints capture competition for land and labour endowments between SRC and alternative land uses: two annual crops, one of which is more labour intensive and profitable than the other, as well as the options to set-aside land or cultivate short cycle catch crops. The latter two options are introduced to fulfil “Ecological Focus Area” (EFA) requirements according to the latest CAP reform [46]. According to this requirement, arable farms must devote 5% of farmland to land uses that qualify towards EFA [47]. In order to meet this requirement set-aside land is fully valued (e.g. 1.0) based on area, whereas the area of SRC land or combined catch and annual crop cultivation is valued at a factor of 0.3 [48]. Catch crops are planted in the winter [33], therefore it is assumed that they do not compete with annual crop production for land and labour resources. Likewise, it is assumed that SRC harvests do not to compete with annual crop production for labour because they take place in winter and are usually outsourced [20]. Fig. 1 provides a visual representation of competition among different farm activities in our model over the considered time horizon. A farmer maximises expected NPV over 24 years subject to three types of constraints: (i) resource endowments, (ii) EFA requirements, and (iii) managerial constraints related to SRC management.

We assume that SRC output prices and annual crop gross margins are stochastic and follow a mean-reverting process (MRP) in logarithmic form. Note that risks related to annual crop production are not specified in detail, but summarised using a general proxy for stochastic gross margins, which represents the opportunity costs of SRC management. Since a farmer has no flexibility with respect to the harvest of annual crops, further specification of annual crop gross margins or set-aside land would have no influence on farmer behaviour. For simplicity and clarity, we only model one stochastic process for the annual crop gross margin based on a single MRP. The simulated level for each node in the scenario tree is then modified with a multiplicative fixed factor for each of the two annual crop options. A correlation coefficient between SRC biomass price and alternative crop gross margins enters the stochastic processes as presented in equation (1) [49]. We consider a