FARM-LEVEL MODELING OF SHORT-ROTATION COPPICE CULTIVATION WITH FLEXIBILITY IN PLANTING AND HARVESTING: A REAL OPTIONS APPROACH

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Overview

In the light of increasing demand on energy, bioenergy becomes of great significance worldwide. In particular perennial energy crops have substantial advantages[1] over the conventional land use. Among these, short rotation coppice (SRC)[2] is highly attractive as it is characterized by low-input production comparing with competing crops. In addition, there is a certain flexibility in SRC harvesting that is possible at intervals of 2-5 years[3]. The potential area for SRC is large. For instance, in Germany this is estimated as 5.7% (i.e. 0.68 Mio. hectares) of cropland and 33% (i.e. 1.5 Mio. hectares) of grassland, out of which only about 5'000 hectares are currently cultivated.

In order to explain the observed reluctance of farmers to convert to SRC, an economic analysis of SRC cultivation based on a simulation approach requires a model which reflects flexibility in management and investment, as well as relevant policy measures[4]. A number of simulation models have already been developed. However, they ignore either flexibility in harvesting, i.e. assume fixed harvesting period, or farm restrictions, i.e. analyse the investment decision as stand-alone, or both. The results of previous research are rather controversial with respect to economic (dis)advantages of perennial energy crops: about 20% of the studies demonstrate economic disadvantages, around 40% show economic viability, while the rest reports mixed results (Hauk, Knoke, and Wittkopf 2014). In this paper we address the limitations of existing models. In particular, we develop a farm-level model of SRC cultivation that allows for flexibility of planting and harvesting by using a multi-stage real options approach (ROA).

Methods

Our model is set-up as a stochastic mixed integer optimization problem to reflect both indivisibilities as well as the uncertainty of output prices as crucial determinants of farming decision. Specifically, we assume that the output price (per tonne of dry matter of SRC yield) follows an Ornstein-Uhlenbeck process – the simplest version of a mean-reverting process (MRP)[5]. The optimization problem aims to distribute a limited area of land between two investment projects such that the expected NPV[6] is maximized. ***Project "Short-rotation coppice"*** is a multi-stage American option, where exercising the first stage (planting) requires the initial investment[7] and exercising every following stage (harvesting) earns immediate stochastic cash flow which depends on the land area under SRC and the harvesting interval. The alternative ***Project "Traditional agriculture"*** is assumed to be a one-year risk-free investment project characterized by a net gross margin per hectare of land[8].

Planting of SRC can be postponed for a maximum period of 10 years. Harvesting can be exercised in 2 to 5 years after planting or previous harvesting. Starting from the second stage (i.e. having exercised "planting") holding an option, i.e. SRC plantation, binds the respective land area that might have been invested into the alternative project which thus incurs annual opportunity costs. In addition, at every stage, starting from the second one, SRC can be

1 Those include less operational efforts; soil protection against wind and water erosion; limited nutrient leaching; and reduced fertilization.

2 Common plants suitable for SRC include poplar (*populus spp*.) and willow (*salix ssp*.).

3 The flexibility in harvesting is even more substantial: 2-20 years depending on the end product. However, we restrict ourselves to the most common end product in Germany, namely wood chips, and therefore to the harvesting interval from 2 to 5 years. The rotation period, i.e. the time period between planting and the last harvesting, is restricted up to 20 years, because according to the Federal Forests Act , short rotation coppice or any perennial crop, rotated longer and intended for logging, is recognized as forest.

4 Currently there is no additional support for SRC cultivation in Germany beyond the Greening of Common Agricultural Policy (CAP) of the European Union that reduces the direct payments to farmers, unless certain environmental requirements are fulfilled (those can be fulfilled among others by cultivation of SRC).

5 The parameters of the MRP are the following: starting price 62.76 €/tDM, average price 50.40 €/tDM, variance 0.22, and speed of reversion 0.22. The model was solved by Monte-Carlo simulation with 1000 draws.

6 The annual discount rate is assumed to be equal 11.03%.

7 The initial investment is assumed to be equal 2875 €/Ha.

8 The net gross margin of the alternative project is assumed to be equal 324.83 €/Ha.

reconverted at some additional costs[9] and the freed land can be used for the alternative project. The SRC project has a maximal lifetime of 20 years after which the reconversion costs occur as well. The model simulation period is 30 years. The parameters of the model are taken from the literature and refer to the region Mecklenburg-Western Pomerania (northern Germany) which is characterized, compared to average German conditions, by low soil quality and percepitation, thus also low returns for the project "traditional agriculture".

The novelty of our approach is threefold. First, we consider flexible harvest intervals. That allows as a second extension to introduce yields[10] per hectare as a function of harvesting interval. The vast majority of existing models uses a fixed harvest interval and consequently also fixed biomass yields per hectare. Third, we introduce economies of scale by splitting up harvesting costs into three components[11]: costs at farm (fixed) and plot level (quasi-fixed) plus costs per ton of harvested biomass (variable) while previous models used costs per hectare.

Results

First, we find that under the current market conditions and available technology, SRC cannot compete with conventional crops which fits the empirical evidence of limited cultivation of SRC. In order to trigger SRC planting in a deterministic setting, its output price would need to increase by 63.26% over the one used in our benchmark[12]. Assuming stochasticity in the output price, Monte-Carlo simulations revealed that SRC cultivation is never optimal (100% of draws) under current input and output price conditions and no flexibility in harvesting. If we allow for flexibility in harvesting, SRC is optimal in solely 9.8% of draws.

Second, flexibility in harvesting decreases, as expected, the trigger value: ceteris paribus the incentive to plant is higher if harvesting intervals and consequently yields can be adjusted according to the (expected) market conditions.

Finally, economies of scale, introduced in the harvesting cost function, have no influence on the results: increasing the land endowment by 20% (by 10 Ha) has no significant effect on the investment triggers.

Conclusions

The paper contributes to the existing literature by developing a single farm simulation model of SRC cultivation that considers both farm-level constraint and alternative opportunities, as well as flexibility in planting and harvesting. We find that SRC cultivation has economic disadvantages over traditional agriculture under current market conditions. We also show that flexibility in harvesting, often ignored in the literature, substantially impacts results and thus should be considered in economic assessment of SRC. Our model can be used further in order to evaluate and compare alternative policies aiming to stimulate SRC cultivation. Further extensions could include differentiating land plots by soil quality, analysing different stochastic processes and switch to a stochastic programming approach.

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[9] Reconversion costs are assumed to be equal 1400 €/Ha.

[10] The yields depending on the harvesting period, which can be 2, 3, 4, or 5 years, are assumed to be 10.50, 21.30, 39.13, and 69.57 tonnes of dry matter per hectare respectively.

[11] The fixed, quasi-fixed, and variable components are assumed to be 66.75€, 272.13€ and 10.67€ respectively.

[12] By 176.04%, if we don't allow for flexibility in harvesting.