FARMING IN EASTERN GERMANY: FROM FOOD TO ENERGY CROP PRODUCTION?

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Abstract

Renewable resources are of importance in our modern society due to their positive effects on agriculture, the environment and the economy. To support renewable energy from biomass the EU promotes the cultivation of energy crops. This creates alternative income sources for farmers as primary or energy producers and strengthens added value and employment. For the analysis a model is developed to assess the potential impacts of energy crop production on cropping activities. A basic quadratic version of PMP is used to maximize total gross margin in two regions, which allows one to simulate farmers` behavior under different conditions. Different scenarios show, that the bio-energy boom partially contributes to crop substitution effects. Potential energy crops like rye, rape seed or silage maize are more profitable. This has an impact on crop rotations because less profitable crops are substituted. However, these tendencies approach a limit in terms of limited area and crop rotational aspects.

Keywords: energy crops, land-use change, positive mathematical programming (PMP)

Introduction

The development of renewable energy has for some time been a central aim of energy policy within the European Union. There are two reasons. Firstly, the dependency on energy imports is already 50% and is expected to rise over the next years if no action is taken. Secondly, the EU has recognized the need to tackle the climate change issue to reduce greenhouse gas emissions. Consequently, the expansion of energy production from biomass becomes more important. Biomass is a key source because of its potential to limit CO_2 emissions. Energy crops will be used to produce a broad spectrum of fuels including bio-diesel, ethanol and the new Biomass-To-Liquid (BTL) fuels. To support renewable energy from biomass in the EU promotes the cultivation of energy crops with area payments and allows the cultivation on set-aside land.
As a result energy crop production has come to offer an alternative for agricultural enterprises as it opens new income sources for farmers besides food production and simultaneously strengthens added value and employment particularly in rural areas. In the scope of multifunctional agriculture farmers may act as primary food or energy producers in the future. Across Germany almost 1.4 million ha, that is 8% of land under cultivation, were being used for energy crop production in 2006.

Rising demand for food and the increasing area for energy utilisation as biogas or transport fuel have positive effects on prices for agricultural commodities. Food versus energy production is at present a commonly used "slogan". In light of the decoupling of area payments and the gradual liberalization of agricultural trades, market oriented production structures gain in importance and determine the economic success of farm enterprises. Concerning the cost-value ratio this has an impact on crop rotations which are mainly influenced by monetary and phytosanitary concerns. The study assesses the possible impacts of these aspects on cropping portfolios and provides information about future trends of biomass production.

Methodology

For policy analyses in the agricultural sector Linear Programming (LP) is one of the main instruments used to analyse the effects on production output, land use and farm income. By assuming optimum production combinations and profit maximising behaviour the approach is based on simulation models that reflect farmers reactions and allows an analysis of policy changes. However, most of these studies refer to a more or less tangible and empirical application because this kind of approach requires comprehensive data and field-work (Varela et al. 1998). Another drawback is the phenomenon of over-specialization; the number of constraint functions is smaller than the number of activities observed in the base period. For that reason the modeller is obliged to extent the set of constraints to avoid overspecialization with the intention to calibrate results to the observed situation. Both characteristics limit the information value of usual farm models. Models should reproduce base-run results according to observed production activities and should react reasonably.

In response to this problem and to analyze different spatial units in a regional agricultural production model alternative approaches were developed, to overcome the lack of accuracy and to ensure greater analytical capacity for agricultural policy problems.

The Positive Mathematical Programming method (PMP), originally developed by Howitt and Mean (1983), is designed to tackle the above mentioned problems of traditional linear programming and has become widely used to calibrate agricultural production models at various levels e.g. farm, region or sector. In revisions the methodology was improved by Paris (1988) and Howitt (1995). A recent development is to combine PMP with the method of maximum entropy (Paris and Howitt 1998; Heckelei and Britz 1999). The basic concept of PMP is that it is easier to get information on farm output data compared with data on production costs. Output levels are the result of complex decision making processes by farmers. These are based on total cost functions, which are difficult to measure externally and only known to the farmer. In the end it is possible with this information to develop models that can accurately represent farmers behaviour (Arfini 2001). Further advantages of the approach are exact representation of the reference situation as well as a smooth response of model results to changes in exogenous parameters.

PMP methodology is a three step procedure. In the first phase a conventional LP model is defined and solved to provide activity based dual values. These are used in the second stage to derive calibration coefficients with the aim of specifying a nonlinear objective function of the calibrated model in stage three. The new calibrated programming model reproduces almost exactly observed crop allocations compared to the base-run.

Although the calculation of PMP coefficients requires lower data requirements a minimum amount of a priori information such as supply elasticity or expected yield variation is needed to identify the cost or yield function of the marginal crop. This is a disadvantage as these data are sometimes not easily available with regard to time and financial restrictions.

A PMP approach developed by Paris (1988) is a suitable option to specify all crops, while the above mentioned a priori information is not needed. The corresponding dual formulation of the initial LP version is used to derive equations for calculating the PMP coefficients.

The calibration model can be compactly written as follows:

max *TGM* with

$$TGM = \sum_i \left[(y_i p_i + PR_i - vc_i X_i \gamma_i X_i^2\right]^1 \qquad (1)$$

[1] The dual formulation of the model appears as :

$$TC = \sum_i (X_i)\lambda_{land} + \sum_i (X_i \lambda_i) \qquad \lambda_{land} + \lambda_i \geq GM_i \qquad \lambda_{land}\lambda_i \geq 0$$

with TC =Total Cost
λ_{land} = shadow price of land
λ_i = dual value of calibration constraint
GM = Gross Margin

subject to

$\sum_i (X_i) \le \sum_i (\hat{X}_i)$ resource constraint to calculate (λ_{land}) (2)

$X_i \le \hat{X}_i (1+\varepsilon)$ calibration constraint to calculate (λ_i) (3)

$\sum_i X_i \ge 0$ non-negativity condition (4)

where *TGM* denotes the objective function value of Total Gross Margin; *y* is a vector of crop yield; *vc* is a (n x 1) vector of variable cost per production activity; *X* is a (n x 1) vector of production activity levels; *PR* is a vector of area payments for energy crops; *i* denotes the crop type and ε is a perturbation coefficient with a small positive number.

By assuming the optimum production combination the coefficients for λ_i can be calculated due to the major condition that marginal gross margins of each activity are identical in the base run. The marginal gross margin results from the shadow price of the resource constraint which is identical with the difference of the gross margin and shadow price of the calibration constraint for each crop (compare note 1).

subject to

$$\frac{\partial GM_i}{\partial X_i} = y_i p_i + PR_i - 2vc_i \gamma_i \hat{X}_i = \lambda_{land} = GM_{i(LP)} - \lambda_i \quad (5)$$

Now γ_i can be isolated by extending the equation with the variable cost term on both sides and rewritten in the following way:

$$\gamma_i = \frac{vc_i + \lambda_i}{2vc_i \hat{X}_i} \quad (6)$$

It this expression the right hand side represents the slope coefficient of the cost function. The term includes variable costs for the considered cropping activities and the shadow price of the calibration constraint (λ_i). The composition of the term demonstrates why there is no need for a special operation to calculate the PMP coefficients for the marginal crop. Even if there is no value of the calibration constraint the numerator is in either case greater than zero since vc_i is typically positive. Hence, a further step to calibrate the marginal crop is not necessary.

The approach developed by Paris (1988) has its limitations as well. Especially noteworthy is the assumption that marginal costs are equal to zero at an activity level of zero, which means that the marginal cost curves intersect the origin. This leads to an overestimation of the gross margins at least for the marginal crop.

In our case a basic quadratic version was applied instead of a more recent development of PMP because of the bioenergy boom and its implications on prices and yields. For the period under consideration market prices have changed significantly and did not allow to calculate reliable supply elasticities. The problem with yield functions has its origin in the alternative ways of biomass utilization. For bioenergy purposes either the whole plant or the seeds are used as substratum. Depending on utilization different quality parameters are important such as starch for bioethanol production. For that reason it is difficult to get data about yield variations.

For the study variable cost data were available for both ways of utilization from the Ministry for Rural Development, Environment and Consumer Protection of the Federal State of Brandenburg (LVLF 2005) and the KTBL (2006).

Empirical application

Using this methodological framework an initial model with a comparative-static approach was defined which allowed easy application. The model operates on regional level and provides information on land use changes resulting from different scenarios. On the basis of regional statistics, typical farms and their crop rotations are defined.

For each region six different cropping activities are differentiated. The crops include wheat, rye, barley, triticale, rape seed and maize silage. On the basis of different land categories information about crop prices, yields, input use per crop, variable costs per activity and area payments were available. [2] In addition it is assumed that 40% of rape seed, rye and corn silo are calculated with area payments for energy crops.

Specifically, the study uses the following scenarios:

(1) Market price changes for different crops *(Δ price)*; the price comparison refers to prices from November 2005 and 2006. The price increases for the differing crops were different ranging from 5% for triticale to almost 25% for wheat (see Table 2).

(2) Technical progress *(Δ yield)*; in this scenario a 10 % increase in yields is assumed for all crops to show how changes in quantity may affect the cropland allocation on the basis of current prices.

(3) Elimination of area payments for energy crops *(Δ premium)*; it is assumed that this area payment is abolished as the bioenergy boom has stimulated the market prices.

The different scenarios refer to the selected regions Barnim and Uckermark in the Federal State of Brandenburg. The study determines the effects on crop production without accounting for animal husbandry response. The crop activities for the base-run are illustrated in Table 1.

Table 1. Crop activities in the base-run

Region	Crop activities						Total area
	Rape seed	Wheat	Rye	Barley	Triticale	Maize silage	
Barnim [ha]	3.700	4.000	6.500	2.900	5.300	3.200	25.600
Uckermark [ha]	25.300	46.000	16.100	11.500	6.900	8.000	113.800

Source: ATKIS (2005)

Table 2. Market prices for crops within the observation period

	Rape seed	Wheat	Rye	Barley	Triticale	Maize silage
Market price 2005 [€/t]	205	92	75	82	79	21
Market price 2006 [€/t]	256	115	94	90	83	25

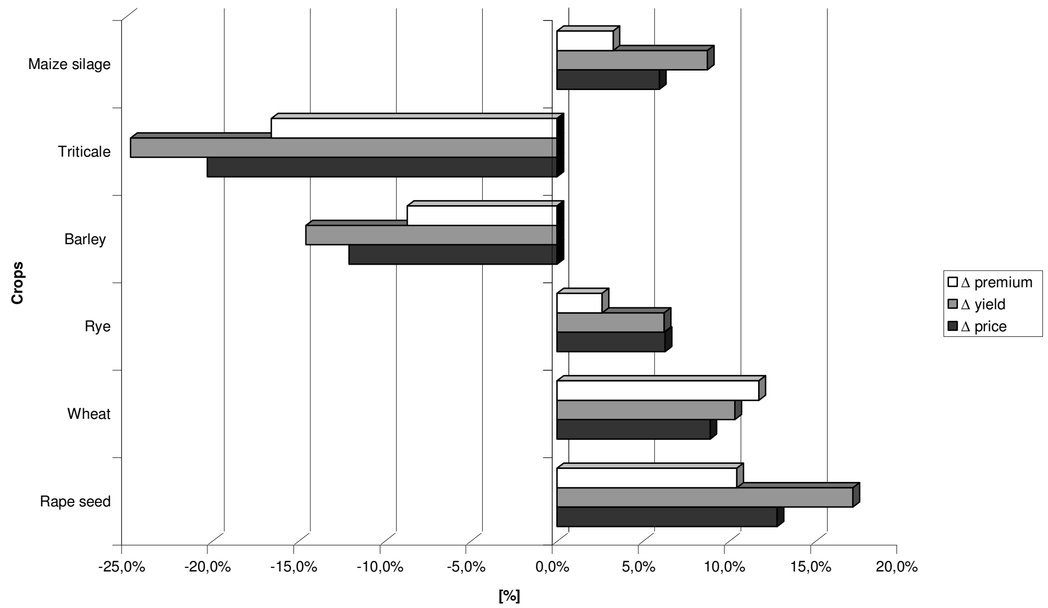
[2] *Organic farming areas, pasture lands and other crops with a minimum percentage rate are not included. The documented share of acreage amounts to 70%.*

Source: ZMP (2006)

Figures 1 and 2 show percentage changes of cropping portfolios for the described scenarios. Results show that rising market prices induce farmers to change cropping patterns. In the Barnim region area increases for rape seed, wheat and rye are most pronounced. The growth of rape seed arises from the increasing demand for biodiesel resulting in rising prices of about 25% within a year. The changes for wheat profitability can not only be attributed to the bio-energy discussion but rather increasing world market prices. Interestingly enough, maize silage did not react in the same way although prices increased by 20%. However maize silage competes with other crops for limited area even though it is one of the main substratum for biogas plants. Rye is an important crop in this region due to the poor land quality. Recently, the crop has gained importance as not far away from this region a large bioethanol factory with a production capacity of about 600,000 tons/year has been established. Prices for barley and triticale did not react in the same way as neither crop is used for bioenergy purposes nor plays a major role in the food sector. The area of these crops may be substituted by rye and where the land is suitable by wheat. The considered technical progress for the second scenario *(Δ yield)* would enhance the effects of the price scenario with the exception of rye.

An elimination of the area payments may induce a 3% reduction for the considered energy crops compared to the price scenario. However, significant effects on cropland allocation are still observed (see Figure 1). Thus the elimination of the energy crop premium has a minor effect on crop activities on the basis of current prices.

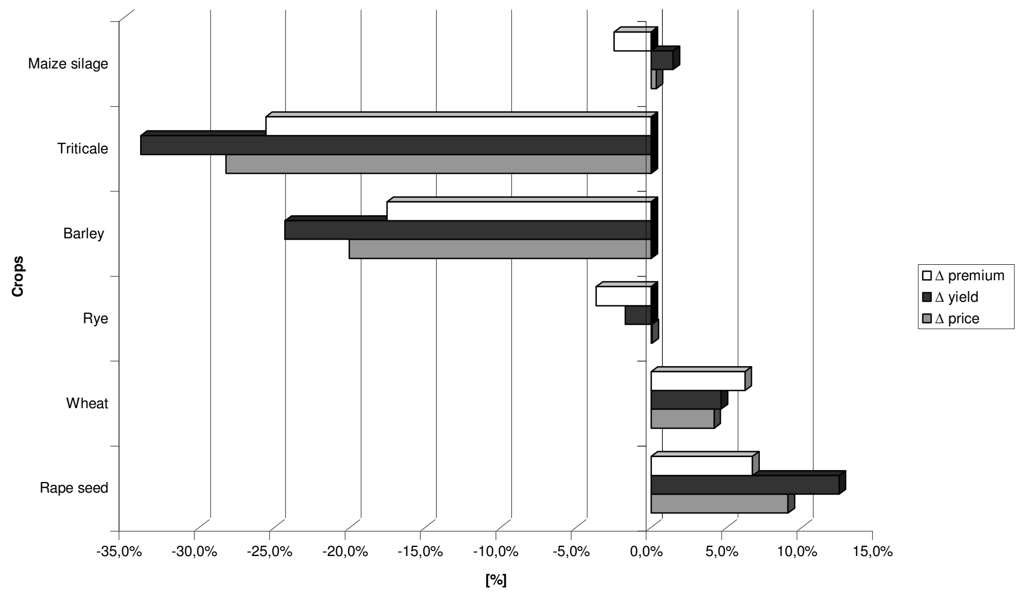
Figure 1: Area changes in Barnim compared to the base-run in %



Wheat and rape seed are the main crops in the Uckermark indicating a better land quality. The dominating crop rotation in this area is rape seed, wheat and barley or rye depending on market prices (see Table 1 and 2). The results of the scenario runs are presented in Figure 2. Areas of rape seed and wheat increase but are different from the results of Barnim. Area changes in the first scenario *(Δ price)* are lower demonstrating that there is little scope left to extent the current crop rotation. The area increases for rye and corn silo are negligible and show that these crops are not competitive at current prices. The elimination of the area payment *(Δ premium)* leads to cropland substitution.

Technical progress has a significant impact on rape seed production. Considering crop rotational aspects rape seed production will approach a limit in the near future. Areas for triticale and barley decline most compared to other crops due to the very small activity levels of these crops (see Figure 2).

Figure 2: Area changes in Uckermark compared to the base-run in %



Conclusions

Renewable resources are of importance in our modern society due to their positive effects on agriculture, the environment and the economy. The EU promotes the cultivation of energy crops. Germany has introduced further incentives like the Renewable-Energy-Law which guarantees fixed energy prices for electricity produced from biomass. This kind of promotion creates alternative income sources for farmers as primary or energy producers and strengthens added value and employment. The question is whether it starts to change the landscape of agriculture ?

Concerning this issue a model is developed to assess the potential impacts of energy crop production on cropping activities. A basic quadratic version of PMP is used to maximize total gross margin in two regions which allows to simulate farmers` behavior under different scenarios. Although the approach is simple and has its limitations, it is used because there is a lack of adequate data because the potential to utilize crops as sustainable energy source has lead to a bioenergy boom where cropped areas and market prices are in constant flux.

Results show increasing cropping areas of rape seed and wheat for all scenarios. Rye and maize silage increase or decrease depending on the scenario and region. Barley and triticale are substituted by more profitable crops. The area expansion of rape seed production can be attributed to the increased demand for biodiesel, whereas high yield prices are the result of rising world market prices.

Consequently, the bioenergy boom has partially contributed to crop substitution effects. Potential energy crops like rye, rape seed or silage maize are more profitable. This has an impact on crop rotations because less profitable crops are substituted. However, these tendencies approach a limit in terms of phytosanitary and crop rotational aspects. For instance, area changes in the Uckermark scenario are lower demonstrating that there is little scope left to extent the current crop rotation. Thus energy crops provide an opportunity as alternative income source besides food production in the scope of multifunctional agriculture.

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