Modelling Interregional Trade of Energy Crops in Eastern Germany

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Abstract— **Renewable resources gain in importance in our modern society. The line of reasoning is based on their positive effects on agriculture, the environment and the economy. To support renewable energy from biomass the EU promotes the cultivation of energy crops. A spatial equilibrium model is applied based on the concept of maximizing net welfare, to provide information whether energy crop production competes with food production for land area.**

The Model of Interregional Trade of Energy Crops (ITEC) refers to Eastern Germany and adjacent areas of Poland. First results show that the regions have enough feedstocks to meet the required demand for food and biofuel production. In many cases both food crops and biofuels are either traded on interregional basis or exported to "Rest of Europe" indicating that there is no competition between food and energy crops. Only green maize for biogas production strongly competes in areas where the crop is required as feed for cattle.

Keywords— **Energy crops, spatial equilibrium analysis, interregional trade**

I. INTRODUCTION

Biomass energy has attracted increasing attention as energy source that can increase security of supply, reduce exhaust emissions and provide a new income source for farmers. Currently the dependency on energy imports in the EU is 50% and expected to rise over the next years if no action is taken. Furthermore, the EU has recognized the need to tackle the climate change issue to reduce greenhouse gas emissions. Energy crops are used to produce a broad spectrum of fuels including biodiesel, ethanol and power generation via biogas. To support renewable energy from biomass the EU promotes the cultivation of energy crops with area payments and reduced taxation of biofuels.

Commodity markets are strongly influenced by crude oil prices. A rise in oil prices increases production cost in agriculture but also creates economic incentives for biofuel production, thus representing a stimulating source of demand for agricultural commodities with effects on prices for agricultural products. With gradual liberalization of agricultural trade, market oriented production structures become more important and determine the profitability of farm enterprises in terms of comparative advantages.

Bioethanol, biodiesel and biogas can be produced from a wide range of crops. In Germany approximately 15% of UAA are used for energy crop production [1]. The most important energy feedstocks are rapeseed, wheat, rye and green maize. Increasing biofuel and biogas production require substantial amounts of feedstocks that can be hardly provided on a regional level. An example may illustrate the significant land requirements. In 2005 a large bioethanol processing plant with a production capacity of about 600,000 t of rye per year has been established in the federal state of Brandenburg. Assuming an average yield of 5 t per ha an acreage of 120,000 ha is needed.

The objective of this research is to determine if policy support for bioenergy sources is still justified and if energy crop production competes with food production for land area.

II. MODEL SPECIFICATION

Spatial equilibrium analyses are generally concerned with the establishment of equilibrium prices between regions, quantities of commodities supplied and demanded at each region. The Interregional Trade Model (ITM) approach applied for this research is a standard spatial equilibrium model, based on the concept of maximizing net welfare, in order to identify regions with comparative advantages for the production of specific agricultural products. The formulation of an ITM can be explained by using a "back to back" diagram. Figure 1 shows supply and demand functions[1] of two regions trading a homogenous product.

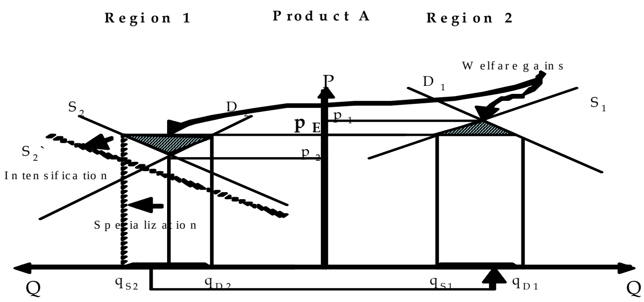

Figure 1 Equilibrium prices and trade illustrated by "back to back" diagram [2]

Region 2 illustrates a potential deficit region, while Region 1 shows a potential surplus region. In the absence of trade prices and quantities are determined by the domestic supply and demand curve for each region. When trade flows between the two regions, traders in Region 2 recognizing the lower price in Region 1 would arbitrage the products from Region 1 to Region 2. Under the new equilibrium condition prices in both regions are equal (p_E). Production and consumption in Region 1 are q_{S1}, q_{D1} and in Region 2, they are q_{S2}, q_{D2}. The trade between the two regions has an effect on net gain in welfare. Encouraged by the comparative advantage Region 1 will intensify and further specialize in the production causing a shift in the supply curve from S_2 to $S_{2'}$. This in turn will create new equilibrium conditions and generate further intensification and specialization effects. According to this concept, regional demands and supplies of the commodities can be represented by price dependent exponential functions with constant elasticities to deduce price and quantity conditions of spatial equilibrium. Hence, the interregional activity is formulated as non-linear programming problem. The analytical framework of the following welfare oriented non-linear programming model is described in detail by Takayama and Judge [3] and von Oppen and Scott [4].

[1] These are shown in linear forms for ease of illustration only.

The general form of the net-welfare function (the objective function to be maximized) for a commodity or group of commodities is determined by the sum of the line integrals of the regional demand functions $D_j(y_j)$ and the negative line integral of the regional supply functions $S_i(x_i)$ over the appropriate quantity domains and the negative sum of the unit transport costs T_{ij} multiplied by the transported quantities of the commodity X_{ij} [3]. The subscripts i and j indicate supply and demand regions respectively. The net welfare function NW is generally stated as follows:

$$NW(y,x,X) = \int_0^y D_j(y_j)dy_j - \int_0^x S_i(x_i)dx_i - T_{ij}X_{ij} \quad (1)$$

Processing costs are treated in the same way as transportation costs and are determined exogenously. In forming the quasi net welfare function, the exogenous costs incurred in making spatial allocations from region i to j are subtracted from the total quasi welfare function (W). Thus the quasi net-welfare function can be expressed as:

$$NW \equiv W - \sum T_{ij} X_{ij} \quad (2)$$

where T is a matrix of exogenous costs associated with the spatial allocation of each unit of X from i to j.

The model of Interregional Trade of Energy Crops (ITEC) refers to Eastern Germany with the Federal States of Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt and Thuringia and adjacent areas of Poland including the Voivodships Western Pomerania, Lubusz, Greater Poland, Lower Silesia, Pomerania and Opole. As an additional trading region a hypothetical residual "Rest of Europe" is implied.

For each region the crops; wheat, rye, rapeseed and green maize are taken into account which can be used either as food (incl. foreage) or as energy crop. Area payments for energy crops are not taken into account. On the basis of given processing costs and transformation rates the model considers the analysis of the following bioenergy sources:

- production of biogas from green maize
- production of bio-diesel from rapeseed

- production of bio-ethanol from rye and wheat

Selected data of input data from Eastern Germany is presented in Table 1.

Table 1 Crop activities, yields and market prices in the base run [5]

	Rye	Rape-seed	Wheat	Green Maize
Brandenburg				
Area [`000 ha]	164	147	151	105
Yield [t]	4.0	3.3	5.4	23.7
Supply Price [€/t]	125	212	125,0	25
Mecklenburg-W. Pomerania				
Area [`000 ha]	50	243	328	88
Yield [t]	4.5	3.8	7.3	30.7
Supply Price [€/t]	127	245	126	25
Saxony				
Area [`000 ha]	28	130	179	34
Yield [t]	4.7	3.5	6.1	34.7
Supply Price [€/t]	127	244	123	25
Saxony-Anhalt				
Area [`000 ha]	63	159	331	63
Yield [t]	4.7	3.8	6.9	28.7
Supply Price [€/t]	127	244	122	25
Thuringia				
Area [`000 ha]	9	114	218	38
Yield [t]	6.2	3.7	6.7	40.0
Supply Price [€/t]	127	243	120	25

The data on biogas and biofuels are obtained from specialized reports [6]. Consumption quantities have been estimated on the basis of total national consumption and projected at regional level [7;8]. Consumer prices, reflecting actual market prices are compiled from market reports [5]. The supply and demand elasticities have been consulted with experts and verified by technical literature [9]. No regional differences in elasticities were allowed for as these were not available. Processing costs are generated from different sources [1;10]. To account for transfer costs a transportation cost matrix between regions, taking distance and cost into consideration was formulated. The transportation costs were generated based on current fright data from a german transport company [11]. The reference year is 2006.

The formulated non-linear programming model was solved using GAMS/MINOS.

III. RESULTS OF ESTIMATION

First results for Eastern Germany show that green maize and rapeseed are predominantly used for bioenergy purposes. Table 2 illustrates that over 80% of green maize is used as biogas substratum and in the case of rapeseed around 70% of the crop is converted to biofuels. Sole exception are Saxony and Saxony-Anhalt were more than 50% of the produce is used as food crop. To satisfy the demand of biodiesel Saxony imports 63,000 t of biodiesel from Thuringia and Saxony-Anhalt. Another large amount of 199,000 t of the produce is exported from Mecklenburg-Western Pomerania to "Rest of Europe" indicating a comparative advantage for biodiesel (Table 3). Until now biogas is used on a regional basis and is not traded. The same applies for green maize due to the high transportation costs of the bulky produce over long distances. The equilibrium prices from green maize and rapeseed differ from the reference prices and rise around 11% up to 14% which are the basis for further calculations. Area increases for both crops average out at 4%.

In the western voivodships of Poland the food-energy crop-ratio for green maize is higher and ranges between 20% and 50%. The increase in area amounts to 10%. Rapeseed is used as food crop. In some areas (Lubusz, Opole) the utilization as food crop amounts to 90%.

Table 2 Food-Energy Crop-Ratio for different crops in Eastern Germany

	Rape-seed	Rye	Wheat	Green Maize
Brandenburg [%]	31.4	54.6	100.0	17.9
Mecklenburg- W. Pomerania [%]	19.4	66.1	70.8	1.2
Saxony [%]	58.3	75.8	100.0	7.0
Saxony-Anhalt [%]	55.1	56.2	98.1	4.6
Thuringia [%]	26.3	75.8	98.4	2.6

Source: computed from model

The regions do not trade with Eastern Germany but with "Rest of Europe".

Biofuels are produced from rye and wheat respectively. The model suggests an increase in wheat production of about 5% up to 7% for Eastern Germany. Generally the use of wheat to produce bioethanol is of minor importance except

Mecklenburg-Western Pomerania where almost 30% of the wheat production is used for bioethanol production. The excess supply of both the crop and ethanol is mainly exported to "Rest of Europe". This indicates that there is no competition between energy and food crop. Rye is the preferred crop for bioethanol production since it has a better conversion ratio and is produced at lower cost than wheat. The model suggests an area increase of about 10%. In Brandenburg almost 46% of rye is used for bioethanol production. Ethanol from rye is exported in large part from Brandenburg to "Rest of Europe" (Table 3). Lower quantities are traded from Brandenburg to Saxonia and From Saxony-Anhalt to Thuringia. The equilibrium prices do not significantly differ from the reference prices which show the competitiveness of the regional markets for these crops.

Table 3 Exported biofuel quantities from Eastern Germany to "Rest of Europe"

Biofuel	Federal State	Exported quantity to "Rest of Europe"
Biodiesel	Brandenburg	
	Mecklenburg- W. Pomerania	199,501
	Saxony	
	Saxony-Anhalt	
	Thuringia	
Ethanol $_{Rye}$	Brandenburg	89,829
	Mecklenburg- W. Pomerania	19,381
	Saxony	
	Saxony-Anhalt	30,815
	Thuringia	
Ethanol $_{Wheat}$	Brandenburg	
	Mecklenburg- W. Pomerania	224,466
	Saxony	
	Saxony-Anhalt	
	Thuringia	46,925

Source: computed from model

In Poland the results for rye as energy crop are inconsistent. For example, in Western-Pomerania and Greater Poland 75% of rye is used for bioethanol production, while the crop is only used as food crop in Lower-Silesia and Opole. The crop is not traded as food crop but exported as bioethanol to "Rest of Europe".

IV. CONCLUSIONS

Concerning the present issue "food versus energy" a spatial equilibrium model is developed to assess the potential impacts of energy crop on food production. The results of the model clearly indicate that most regions have enough feedstocks to meet the required demand for food and biofuel production. Typical food crops like wheat and rye are predominantly used as food crops. In many cases both food crops and biofuels are either traded on interregional basis or exported to "Rest of Europe" which indicates that there is no competition between food and energy crops. Moreover the export quantities of biodiesel and bioethanol imply the competitive advantage of producing energy crops and processing it into biofuels. Sole exception is green maize which is mainly used as biogas substratum and strongly competes in areas, where maize is required as feed for cattle.

The possibility to utilize crops as energy source has lead to a bioenergy boom where market prices are in constant flux. In order to test whether policy support is still justified, the energy crop premium was not considered in the model. The results show that there is no need to promote energy crops. Further promotion of energy crops would even distort market oriented production structures.

The regarded crops in the model require on average 65% of UAA, which means that there is still growth potential. However, the numbers approach a limit in terms of crop rotational aspects and the share of grassland.

Further steps are planned to extent the model. These imply the inclusion of short rotation coppices, "Biomass to Liquid" fuels (BtL) and the expansion to other regions.

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