Does Biofuel Demand Increase Food Prices? Impacts of Energy Crops on Food Production and Commodity Prices in Eastern Germany

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***Abstract*—**

Renewable resources are gaining importance in modern society due to their expected 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 and to show the effects of increased biofuel demand on food prices. The Model of Interregional Trade of Energy Crops (ITEC) refers to Eastern Germany and adjacent areas of Poland. Results show that the regions produce enough feedstocks to meet the 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. The assumed demand shift for biofuels has almost no effect on prices for wheat and rye.

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

1. 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 stimulating 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 (FNR 2007). 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, to supply this processing plant.

The objective of this research is to determine if energy crop production competes with food production for land area and if a raise of compulsory biofuel blending to a level of 10% is causing fundamental changes in prices for agricultural commodities.

2. Model Specification

Spatial equilibrium analyses are generally concerned with the establishment of equilibrium prices between regions, quantities of commodities supplied and demanded in 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 of two regions trading a homogenous product.

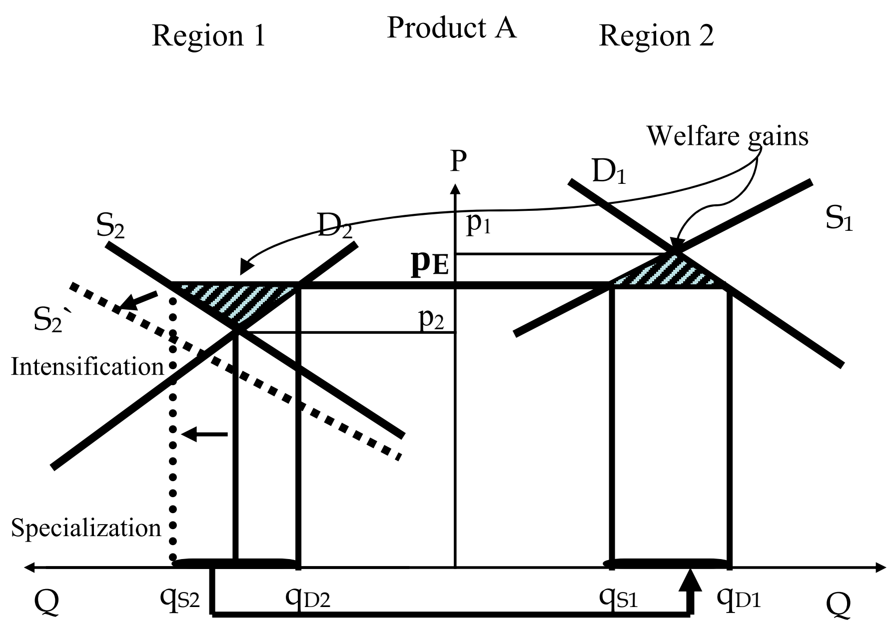

Figure 1: Equilibrium prices and trade illustrated by "back to back" diagram

Region 2 illustrates a potential deficit region, while Region 1 shows a potential surplus region. In the absence of trade prices 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 (1971) and von Oppen and Scott (1976).

The general form of the net-welfare function 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} (Takayama and Judge 1971). The subscripts i and j indicate supply and demand regions respectively. The net welfare function NW is generally stated as follows:

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

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:

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

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 (FNR 2007; KTBL 2006) the model considers the analysis of the following bioenergy sources:

- production of biogas from green maize
- production of biodiesel from rapeseed
- production of bioethanol from rye and wheat

Selected data of input data from Eastern Germany is presented in Table 1. Specific data on biogas and biofuel production volumes are obtained from specialized reports (F.O. Licht 2007). Consumption quantities have been estimated on the basis of total national consumption and projected at regional level (EUROSTAT 2008; FAO 2008). Consumer prices, reflecting actual market prices are compiled from market reports (ZMP 2007). The supply and demand elasticities were consulted with experts and verified by technical literature (Gardinger et al. 1989). No regional differences in elasticities were allowed for as these were not available. 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 fright data from a German transport company (RWZ 2007).

Table 1: Input data for the base run scenario

	Crops			
	Rye	Rapeseed	Wheat	Green Maize
Brandenburg				
Area [`000 ha]	164	147	151	105
Yield [t/ha]	4.0	3.3	5.4	23.7
Supply price [€/t]	135	249	135	25
Mecklenburg-Western Pomerania				
Area [`000 ha]	50	243	328	88
Yield [t/ha]	4.5	3.8	7.3	30.7
Supply price [€/t]	137	255	136	25
Saxony				
Area [`000 ha]	28	130	179	34
Yield [t/ha]	4.7	3.5	6.1	34.7
Supply price [€/t]	137	254	133	25
Saxony-Anhalt				
Area [`000 ha]	63	159	331	63
Yield [t/ha]	4.7	3.8	6.9	28.7
Supply price [€/t]	137	254	132	25
Thuringia				
Area [`000 ha]	9	114	218	38
Yield [t/ha]	6.2	3.7	6.7	40.0
Supply price [€/t]	137	253	130	25

Source: ZMP (2007)

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

Specifically, the study uses the following scenarios:

(1) Baseline run: *(Δ base)* in order to achieve equilibrium conditions. The reference year is 2006.

(2) Raising use of biofuels: *(Δ biofuels)* in this scenario a 10 % blending of biofuels with mineral fuels is assumed to show how changes in quantity may affect the prices and the use of agricultural products on the basis of the baseline results.

3. Results of Estimation

The presented results refer to Eastern Germany with a focus on "Food-Energy Crop-Ratios", prices and quantities supplied[1].

Rapeseed

The results of the base run for Eastern Germany show that rapeseed is predominantly used for bioenergy purposes. Table 2 illustrates that over 60% of rapeseed is converted to biofuels. Sole exception are Saxony and Mecklenburg-Western Pomerania were more than 40% of the produce is used as food-crop. To satisfy the demand of biodiesel Saxony imports 43,588 t of biodiesel from Brandenburg and Thuringia. Further quantities of the produce are exported from Mecklenburg-Western Pomerania, Thuringia and Saxony-Anhalt to "Rest of Europe" indicating a comparative advantage for biodiesel.

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

	Rapeseed		Rye		Wheat	
	Δ *base*	Δ *biofuels*	Δ *base*	Δ *biofuels*	Δ *base*	Δ *biofuels*
Brandenburg [%]	34.3	24.1	56.7	52.1	96.6	100.0
Mecklenburg- W. P. [%]	41.8	9.4	64.4	54.9	83.0	75.9
Saxony [%]	58.9	44.6	71.2	61.3	98.0	100.0
Saxony-Anhalt [%]	26.0	19.7	53.5	46.5	100.0	70.6
Thuringia [%]	26.9	20.2	74.4	62.4	99.5	98.7

Source: Own calculations

Concerning the Δ *biofuels* scenario the Food-Energy Crop-ratio would decrease in all states, especially in Mecklenburg-Western Pomerania with a value of 9.4%. Due to the increased demand it is more profitable to produce and export biodiesel instead of the crop. In the Δ *base* scenario Mecklenburg-Western Pomerania exports around 257,723 t of rapeseed and 162,427 t of biodiesel to "Rest of

[1] The amount of liquefied petroleum gas is negligible. 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. To complete the results; the equilibrium prices from green maize and rapeseed differ from the reference prices and rise around 14%.

Europe". Regarding the raise of biofuel blending the region specializes on the production of biodiesel and increases the export quantity up to 245,609 t while rapeseed exports are stopped. The equilibrium prices for rapeseed differ from the reference prices and rise around 13%. To meet the market induced shift in supply in the Δ *biofuels* scenario the model suggests an area increase of about 14%. The rapeseed price would again increase around 10% (cp Table 3).

Table 3: Equilibrium prices and price changes of crops among regions from the different scenarios

	Rapeseed Δ base		Rapseed Δ biofuels	
	[€/t]	% change	[€/t]	% change
Brandenburg	289.33	15.78	318.72	10.16
Mecklenburg- W. P.	289.33	13.29	318.60	10.12
Saxony	293.05	15.37	322.48	10.04
Saxony-Anhalt	289.33	13.91	318.60	10.12
Thuringia	289.33	14.36	318.69	10.15
	Wheat Δ base		Wheat Δ biofuels	
	[€/t]	% change	[€/t]	% change
Brandenburg	155.36	15.08	155.84	0.31
Mecklenburg- W. P.	146.46	7.45	146.94	0.33
Saxony	157.76	19.06	158.24	0.30
Saxony-Anhalt	146.46	10.95	146.94	0.33
Thuringia	146.71	12.85	147.19	0.33
	Rye Δ base		Rye Δ biofuels	
	[€/t]	% change	[€/t]	% change
Brandenburg	160.00	18.52	163.08	1.93
Mecklenburg- W. P.	160.00	16.79	163.08	1.93
Saxony	162.00	18.25	166.81	2.97
Saxony-Anhalt	160.00	16.79	163.08	1.93
Thuringia	163.90	19.64	166.98	1.88

Source: Own calculations

Rye and Wheat

Biofuels are produced from rye and wheat respectively. The model suggests an increase in wheat production of about 4% in the Δ *base* - and up to 11% in the Δ *biofuels* scenario. Generally the use of wheat to produce bioethanol is of minor importance except Mecklenburg-Western Pomerania where almost 17% 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. Wheat gains in importance in the Δ *biofuels* scenario. The reduced Food-Energy Crop-Ratio of 70.6% (cp. Table 2) indicates, that Saxony-Anhalt starts with ethanol production, while Brandenburg and Saxony stop production. The increased demand of biofuels has no impact on wheat prices (cp. Table 3).

Rye is the preferred crop for bioethanol production since it has a better conversion ratio and is produced at lower cost than wheat.

In Brandenburg and Saxony-Anhalt almost 45% of rye is used for bioethanol production. However with 658,000 t Brandenburg is by far the largest rye producer among model regions. In the baseline scenario the state increases its supplies by 42,000 t at an additional amount of 91,000 t in the case of increased biofuel demand. Ethanol from rye is exported in large part from Brandenburg to "Rest of Europe". A lower quantity is traded from Brandenburg to Saxony. The equilibrium prices significantly differ from the starting values. The percentage rates range between 16 and 20%. The effect of increased biofuel demand on rye prices is moderate.

4. Conclusions

Concerning the present issue "food versus energy" a spatial equilibrium model is developed to assess the potential impacts of energy crops 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.

The possibility to utilize crops as energy source has lead to a bioenergy boom where market prices are in constant flux. The model results do not support the hypothesis that biofuel demand increases food prices of the considered crops rye and wheat. The assumed demand shift leads to decreasing Food-Energy Crop-

Ratios which have almost no effect on market prices. In case energy supply will increasingly be provided locally exports are reduced to meet the domestic demand.

As the regarded crops in the model require on average 65% of UAA, it could be argued that there is still growth potential with respect to cropland substitution. However, crop rotational aspects and the share of grassland are likely to limit this growth.

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