Modelling the Consequences of Increasing Bioenergy Demand on Land and Feed Use

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1 Introduction

Rapid development of bioenergy production is expected to have profound impact on agricultural production and land use at global level. Already in the 2007/2008 crop year, harvested rapeseed area and production in the EU increased by 21% and 14% respectively, and it is expected that rapeseed area and production increases further by 20% and 32% respectively until 2018. Similar production effects are triggered by bioenergy initiatives in other parts of the world, e.g. the US, Japan, Indonesia. Several papers indicate severe impact of bioenergy policies on agricultural markets with increasing food and land prices. Increasing feed costs is projected to affect livestock production negatively and intensified land use is projected to have a negative impact on the environment. Besides of biofuel, the processing of first-generation biofuel crops yields feed co-products such as Dried Distillers Grains with Solubles (DDGS) and oilseed meals (BDBP). The use of biofuel co-products in the feed sector could reduce the negative effects of increasing feed prices and could also lower the demand of agricultural land used for feed grain production. This paper aims to evaluate these impacts of mandatory bioenergy policies around the globe such as the Renewable Energy Directive of the EU on the production, land use and trade in the EU and its major trade partners.

In order to project the impact of an enhanced bioenergy production, we will run the simulation experiments based on an extended version of the Global Trade Analysis Project model GTAP. This extension includes improved land market modelling and substitution possibilities between capital and energy as well as between different energy sources including biofuels. To analyze feed by-products of biofuels production impact on the agricultural sector development, we implemented the feed by-products into LEITAP model. This extended version of the model shows the use of processed oilseed (vegetable oil and BDBP) and grains (ethanol and DDGS) for different end users.

This paper is organized as follows. Section 2 introduces the model's database. Next section gives a short outline of the LEITAP model. In section 3, feed byproducts of biofuels production process are introduced. Section 4, describes scenarios set-up. The following section presents simulation results. We close with a summary in the final section.

2 Database

The analysis is based on version 6 of the GTAP data (Dimaranan, 2006). The GTAP database contains detailed bilateral trade, transport and protection data characterizing economic linkages among regions, linked together with individual country input-output databases which account for intersectoral linkages. All monetary values of the data are in $US millions and the base year for version 6 is 2001. This version of the database divides the world into 88 regions. The database distinguishes 57 sectors in each of the regions. That is, for each of the 65 regions there are input-output tables with 57 sectors that depict the backward and forward linkages amongst activities. The database provides quite a great detail on agriculture, with 14 primary agricultural sectors and seven agricultural processing sectors (such as dairy, meat products and further processing sectors).

The social accounting data were aggregated to 37 regions and 13 sectors. The sectoral aggregation distinguishes agricultural sectors that use land (e.g. rice, grains, wheat, oilseed, sugar, horticulture, other crops, cattle, pork and poultry, and milk) and the petrol sectors that demands fossil (crude oil, gas and coal) and bioenergy inputs. The regional aggregation includes all EU-15 countries (with Belgium and Luxembourg as one region) and all EU-12 countries (with Baltic regions aggregated to one region, with Malta and Cyprus included in one region and Bulgaria and Romania aggregated to one region) and the most important countries and regions outside EU from an agricultural production and demand point of view.

For modelling biofuel policy options and implementing first generation of biofuels, the GTAP data base has been adjusted for the intermediate input of grain, sugar and oilseeds in the petroleum industry to reproduce 2004 biofuels shares in the fuel demand for transportation.

3 Quantitative Approach

3. 1 The LEITAP model

The LEITAP model is a multi-regional, multi-sectoral, static, applied general equilibrium model based on neo-classical microeconomic theory (Hertel, 1997). It is an extended version of the standard GTAP model (Nowicki at al., 2007 and van Meijl et al., 2006), using, a multilevel nested CES production function. In the primary value added nest, the multilevel CES production function describes the substitution of different primary production factors (land, labor, capital and natural resources) and intermediate production factors (e.g. energy and animal feed components). The CES nest is also introduced to allow for substitution between different energy sources including biofuels (Banse et al., 2008). The model uses fixed input-output coefficients for the remaining intermediate inputs.

On the consumption side, the regional household is assumed to distribute income across savings and (government and private) consumption expenditures according to fixed budget shares. Consumption expenditures are allocated across commodities according to a non-homothetic dynamic CDE expenditure function which allows for changes in income elasticities when purchasing power parity (PPP)-corrected real GDP per capita changes. Government expenditures are allocated across commodities according to fixed shares. The commodities consumed by firms, government and households are CES composites of domestic and imported commodities. In addition, imported commodities are differentiated by region of origin using Armington elasticities.

Regional endowments of labor, capital and natural resources are fixed and fully employed and land supply is modeled by land supply curves (Eickhout et al., 2008), which specify the relationship between land supply and a land rental rate. Labor is divided into two categories: skilled and unskilled. These categories are considered imperfect substitutes in the production process.

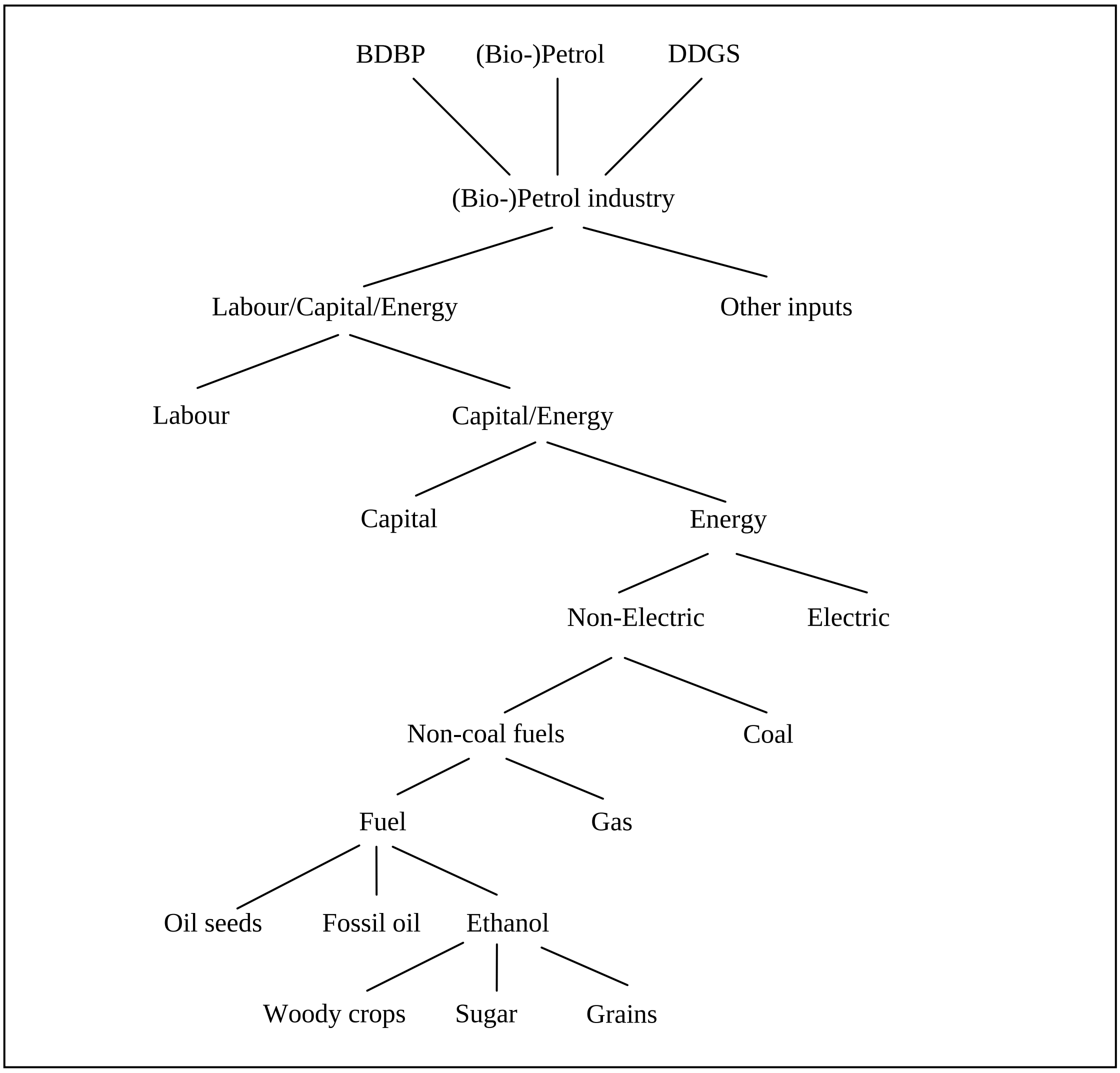
Land and natural resources are heterogeneous production factors, and this heterogeneity is introduced by using a CET transformation function which allocates these factors among the agricultural sectors. Capital and labor markets are segmented between agriculture and non-agriculture. Labor and capital are assumed to be fully mobile within each of these two groups of sectors, but imperfectly mobile across them. This leads to differences in prices of capital and labor between agriculture and non-agriculture. This is implemented by using a dynamic CET function where changes in capital and labor supply in agricultural and non-agricultural sectors depend on relative agricultural to non-agricultural remuneration of these factors and total factor supply.

3.2 Implementation feed by-products of biofuel production in LEITAP model

We implement two feed byproducts of biofuel production in LEITAP model: Dried Distillers Grains with Solubles (DDGS) and oilseed meals (BDBP). DDGS is a byproduct of grains used in the petrol sector to produce grains based ethanol and BDBP is a by-product of oilseeds used in petrol sector to produce biodiesel (Figure 1). This means that the petrol sector is treated in the model as the multi-output sector producing (bio-)petrol, DDGS and BDBP. The feed byproducts are only used as intermediate goods in the livestock sectors and not in private or government consumption.

We assume that the production of the byproducts is technically related with the biofuels production, i.e. the use of associated biofuel inputs use in the petrol sector. We use the fixed fraction - conversion coefficient - to determine a quantity of DDGS produced from grains and a quantity of BDBP produced form oils used in this sector.

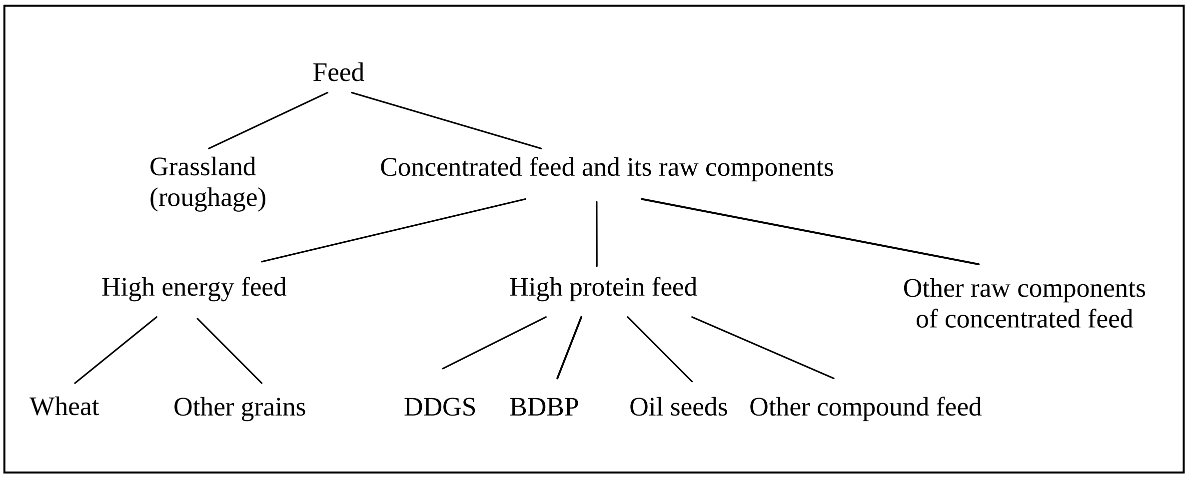
Figure 1: The (bio-) petrol industry nested production structure



The feed by-products of biofuel production are demanded by livestock sectors in LEITAP. This demand is generated through the substitution process in the feed nest in the livestock sector. In order to model substitution between different feed components and feed byproducts of biofuel production, we use three-level CES nest describing the substitution between different inputs in the animal feed mixture production (Figure 2). The top level describes the substitution possibility between concentrated feed and its components and grassland (i.e., roughage). On the intermediate level substitution between high energy feed, high protein feed and other raw feed components is modeled. The lowest level describes the composition of high energy feed (grain and wheat), and high protein feed (DDGS, BDBP and other compound feed). We assume (almost) perfect substitution within the lowest level nests, while the values of substitution elasticity between the different categories at the intermediate and top levels of the feed nest are defined at lower levels. The elasticity at the top of the feed tree vary between 3.2 for EU and 0.1 for Brazil (Tsigas, 2004) and on the intermediate level is set to 0.9 (Keeney and Hertel, 2005)

Intermediate demand for feed byproducts products has to adjust to these products supply. The market price for the feed byproducts serves as the variable equilibrating intermediate input demand for byproducts with its supply.

Figure 2: The animal feed nested structure



The implementation of feed byproducts requires adjustment of the GTAP database for intermediate inputs of feed by-products for livestock sectors production. To achieve the data base consistency, this extra inputs was compensated by a reduction in the other food use (which includes the animal feed in GTAP database) in the animal sectors. Simultaneously, the extra production of feed byproducts in the petrol was compensated by lowering petrol production. To restore supply and utilization balance of other food and petrol, consumption levels of these commodities were adjusted. The disadvantage of this procedure is that it distorts the original database. However, since in the benchmark database the biofuel production and consequently feed byproducts of biofuel production is very small, this distortion seems not too important for the final results.

One disadvantage of the nesting structure is that there is no guarantee that the animals will have enough energy and proteins. This could be solved by adding a linear equation that determines the amount of feed and protein that should be directly related with the production of the livestock sector. Differences between the energy and protein generated with the diet according to the CES nest and the amount required by the animals could be accommodated by adjusting one of the productivity parameters, for example the feed productivity parameter. Discussion with specialists in this field is required for this, while the lack of precision in the data limits the opportunity for really fine-tuning the model.

4 Description of Scenarios

The paper analyses the impact of by-products in biofuel production in the European Union by running two different model versions; one version which explicitly takes by-products into account (BP) as described in figure 2 and another version (NOBP) where the biomass input in the bio-petrol industry is processed into biofuels (biodiesel and bio-ethanol) without the supply of a co-product, such as DDGS or BDBP.

For both model versions we run two scenarios:

- Reference scenario (REF) where biofuel blending in the petrol sector is not enforced by mandatory blending;
- Biofuel scenario (BIOF) with a final mandatory blending rate of 10% by 2020 across all EU member states.

In this paper we do not take biofuel policy measures in other countries into account. With this combination of two similar scenarios and two different models we will show results for the reference scenario as REF_BP and REF_NOBP and for the scenario with mandatory blending targets as BIOF_BP and BIOF_NOBP.

The reference scenario depicts the economic development in the EU and at global level without mandatory biofuel targets. Biomass utilisation depends on the relative prices of biomass and fossil energy. Therefore the macroeconomic development affects the bioenergy demand also under the Reference scenario. The REF scenario includes a set of assumptions concerning the most important macroeconomic drivers influencing the world economy in general and the agri-food sector in particular. These assumptions are related to the rates of technical progress, changes in labour and capital availability and the associated GDP growth as well as the population growth. These factors mainly determine consumer demand and factor supply.

For our simulation experiment, we have taken the GDP and population growth projections provided by the USDA Economic Research Service (ERS). We assume that the capital stock will grow with the same rate as the GDP and employment with the same rate as the population. For the projection of productivity growth in agriculture, additional information on yields is derived from FAO forecasts (Bruinsma, 2003).

5 Scenario Results

The implementation of blending obligations affects the production of those agricultural commodities relevant for biofuel production. Table 1 reports percentage changes in the output volume of arable crops, biofuel crops[1], oilseeds and grains between 2007 and 2020.

Table 1: Change in Agricultural production under the Ref scenario, 2007-2020, with both types of models, in %

	EU27	HighInc	NAFTA	LowInc /2	Brazil	World
Model: NoBP						
Primary Agric.	-1.0	9.1	13.5	18.4	14.5	12.2
Biofuel crops /1	-2.8	13.7	15.4	25.4	22.1	17.4
Grains	-2.3	5.5	5.5	17.2	7.7	10.8
Oilseeds	7.5	42.7	42.8	14.0	23.4	21.3
Sugar	-6.2	4.4	6.0	43.0	26.3	20.1
Model: BP						
Primary Agric.	-1.0	9.1	13.4	18.4	14.4	12.2
Biofuel crops /1	-2.9	13.4	15.0	25.3	22.0	17.3
Grains	-2.3	5.5	5.5	17.2	7.5	10.7
Oilseeds	7.4	41.4	41.4	13.8	23.4	20.9
Sugar	-6.3	4.4	6.0	42.9	26.0	20.0

Remarks: /1: Biofuel Crops describes the aggregate of the agricultural commodities used as inputs in the manufacture of biofuels. /2: HighInc covers non-EU OECD countries. LowInc: Latin America, Africa, Middle East, FSU, Asia excl. Japan and Korea.

Source: Own calculations based on the LEITAP model.

Due to changes in the EU CAP under the reference scenario, arable crops production (especially cereal grains) in the EU-27 decline after 2013. The results show that both models – with and without by-products – show similar results under the Ref scenario. The model BP – covering by-products of

[1] The term ‘Biofuel Crops’ refers to the aggregation of the agricultural commodities employed as inputs in the manufacture of biofuels; i.e. the quantity of sugar beet/cane employed to produce biofuels is counted in, not the whole production of sugar.

biofuel production – shows slightly lower growth rates of biofuel crops production compared to the NOBP model, due use of by-products in the livestock sector and the substitution effects in the composition in feed demand for livestock.

Mandatory blending requirements raise the production of 1st generation biofuel crops. The volume of oilseed output is projected to increase in the EU under the BIOF scenario by more than 50% between 2007 and 2020. Mandatory blending in the EU will also stimulate oilseeds production outside the EU, although the increase is smaller compared to the EU and global production in biofuel crops is around 5 percentage points higher compared to the reference scenario. Due to the high relevance of biofuel crops in total primary agricultural production in Brazil, Brazilian agricultural production is 3.2 percentage points higher under the BIOF scenario. Aggregated European agricultural production is only 0.6 % higher under the BIOF scenario compared to the reference.

Both models show a similar effect of the implementation of the Renewable Energy Directive of the EU. Production of crops used for biofuel production strongly increases. Growth rates in sugar and grain production are moderate compared to oilseeds, which can be explained by the high market share of biofuel in total oilseed demand.

Table 2: Change in Agricultural production under the BioF scenario, 2007-2020, with both types of models, in %

	EU27	HighInc	NAFTA	LowInc	Brazil	World
Model: NOBP						
Primary Agric.	-0.3	9.6	14.1	19.0	17.7	12.8
Biofuel crops	17.7	16.4	18.3	29.0	37.2	23.4
Grains	10.5	6.1	6.1	18.5	19.3	13.7
Oilseeds	50.5	52.0	52.7	21.6	51.9	32.6
Sugar	12.5	5.1	6.4	45.2	24.7	24.9
Model: BP						
Primary Agric.	-0.4	9.6	14.1	18.9	17.6	12.8
Biofuel crops	17.6	16.1	18.0	28.9	37.0	23.2
Grains	10.3	6.1	6.1	18.5	19.1	13.7
Oilseeds	50.2	50.8	51.3	21.4	51.9	32.1
Sugar	12.5	5.1	6.4	45.2	24.4	24.8

Source: Own calculations based on the LEITAP model.

What is the impact of taking co-products into account in the modeling exercise? Table 2 shows similar trends in production growth for both types of models. However, with by-products, growth rates are smaller! The increase in biofuel production raises the supply of co-products and feed grains are substituted for DDGS and BDBP in the fodder rations. Under the model without by-products (NOBP) grain production increases by 10.5 % while the model with by-products shows an increase of only 10.3% which is equivalent to 750,000 t of grain.

Apart from changes in production, current discussion on the impact of increasing biofuel demand is often focused on the land use changes. Here, direct and indirect land use changes of biofuel production are in the center of the debate. The results show that increasing availability of by-products of politically induced biofuel production lowers the demand of feed grain. Therefore, one can expect that the indirect land use changes of biofuel production will be also smaller under a model presenting biofuel production together with the production of by-products.

Table 3 shows the changes in land use induced by EU biofuel mandates for both models applied for this paper, i.e. land use change under scenario BIOF_NOBP minus land use changes under REF_NOBP as well as land use change under BIOF_BP minus land use change under REF_BP.

Applying the model NOBP expansion of land use for agriculture is projected to be 41.04 million ha higher than under the reference scenario. The model version which covers biofuel by-products shows a slightly smaller expansion of land use for agricultural purposes. Under the model BP global land expansion due to EU biofuel mandates is projected to be 40.16 million ha, i.e. by-products compensate for around 0.9 million ha at global level.

However, under the application of the BP model, biofuel production is stimulated also outside of EU, even without a mandatory blending policy in these regions. In 2020 the world share of biofuels in total fuel transportation is projected to be 3.1% in a case of BP model and 2% in case of NOBP model. If we constrain biofuel production to the 2% level obtained from the NOBP model and apply this share in the BP model, global agricultural land use for grains, oilseeds and sugar is projected to be 2.9% (or approx. 22.5 million ha) lower due to the additional supply of fodder in terms of DDGS and BDBP.

Table 3 also indicates that the major part of this reduced land expansion is projected for the aggregate of low income countries. Here land expansion is 750,000 ha lower under the model BP compared with the projection of model NOBP. For Brazil land expansion under the model BP is projected to be 130,000 ha lower compared to the projection based on the model NOBP. For most of the OECD countries the effect of taking by-products into account is rather moderate.

Table 3: Change in agricultural land use, 2007-2020, with both types of models, BioF miuns Ref, in million ha

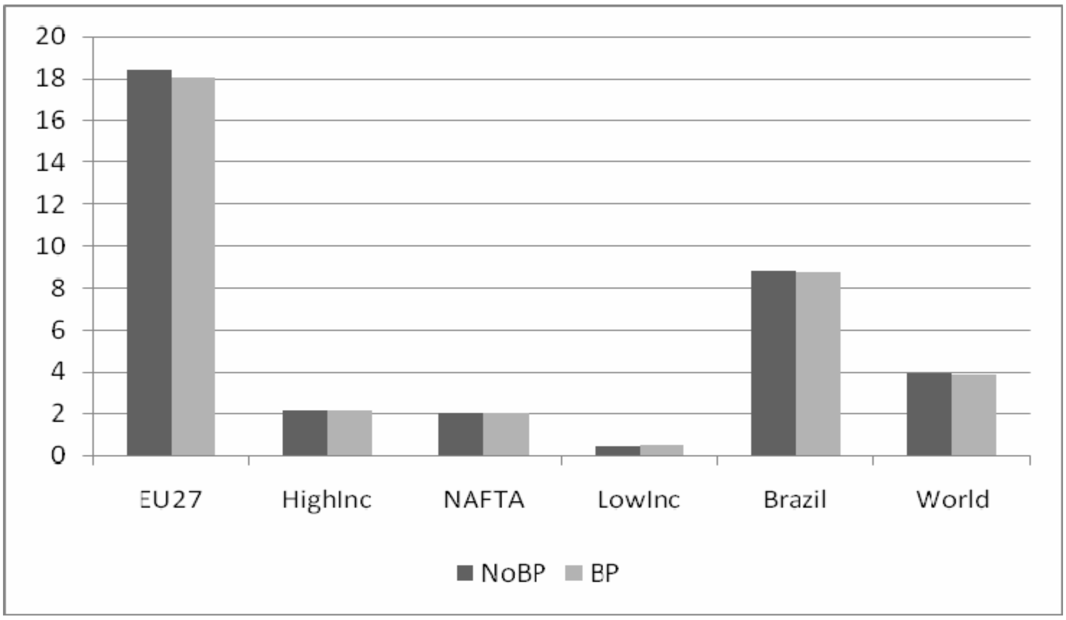
	EU27	HighInc	NAFTA	LowInc	Brazil	World
Model: NOBP						
Primary Agric.	4.52	13.35	12.09	23.17	6.75	41.04
Biofuel crops	6.76	7.39	6.93	14.10	6.32	28.24
Grains	3.92	0.60	0.50	2.87	1.54	7.39
Oilseeds	2.84	6.78	6.43	11.23	4.78	20.85
Model: BP						
Primary Agric.	4.46	13.27	12.03	22.43	6.62	40.16
Biofuel crops	6.70	7.40	6.95	13.83	6.25	27.93
Grains	3.88	0.60	0.50	2.76	1.52	7.24
Oilseeds	2.82	6.80	6.45	11.07	4.73	20.69

Source: Own calculations based on the LEITAP model.

The main reason of this 'uneven' distribution of different land expansion is mainly due to the characteristics in the land market of these countries/regions. Land markets in most OECD countries are quite tight, i.e. land reserves are almost not existent and total land expansion for agricultural purposes is very small. However, in the group of LowInc countries land expansion is possible but only for marginal land or land with low yield potential. Therefore, the difference in production and land use changes (projected by both models) in LowInc countries shows a small number in production and a relatively large effect in land use change.

Figure 3 show the difference in land prices projected under the reference and the biofuel scenario. The presentation of biofuel by-products shows only a marginal effect in countries/regions outside Europe. In the EU the model BP shows a smaller increase in land prices if by-products are covered in the model.

Figure 3: Change in agricultural land price, 2007-2020, with both types of models, BioF miuns Ref, in percent



Source: Own calculations based on the LEITAP model.

6 Conclusions

The aim of this paper is to show the consequences of a model extension towards the presentation of by-product in the production of biofuels. By-products such as BDPB and DDGS can be used as a substitute for feed grain use in livestock production. Therefore, a boost in biofuel production due to the implementation of the Renewable Energy Directive of the European Commission will also show a strong increase in the availability of by-products. To identify the impact of modelling biofuel production with and without presentation of by-products two different model versions have been applied; one with explicit presentation of by-products in biofuel production and another which does not consider the production of co-products. The simulation results of both model versions show that the EU mandatory blending mandate has a pronounced impact on the markets for grains, oilseeds and sugar but a rather limited impact on production level of aggregated primary agricultural output.

The harvested area of biofuel crops (grains and oilseeds) is projected to increase by 17%, while production increases by around 20% indicating a more intensive production of EU biofuel crops. Sugar production is expected to increase by 18% as a result the EU Biofuels Directive. Even with this strong increase in European production total demand exceeds domestic supply and the imports of these biofuel crops are projected to increase significantly.

Due to the EU BFD, the use of biofuel crops in the EU petrol sector increases by almost 10 times. As a consequence fewer biofuel crops are available to feed animals but with higher biofuel production additional feed byproducts are produced. Therefore, the composition of compound feed shift towards a higher share of by-products and less feed grain is used in compound feed. The EU Biofuels Directive leads to an increase of prices for land and for agri-food products at global level. Land prices increase by 18% in the EU and 4% globally.

This analysis shows that presenting by-products in biofuel production does not alter the general result of the analysis but land use changes induced by an increase in biofuel demand are projected to be smaller, if by-products are covered in the quantitative analysis.

The analysis shows that apart from direct effects of an enhanced demand for bioenergy on production and land use, the indirect effects of the EU BFD dominates. Additional production of biofuel crops within and outside the EU leads to strong indirect land use changes which are partly compensated for a higher availability of feed byproducts of biofuel production. Increasing supply of byproducts such as DDGS and BDBP with a high content of protein enables to substitute for feed cereals in compound feed which are now used as inputs in the biofuel production.

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