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The Response of the German Agricultural Sector to the Envisaged Biofuel Targets in Germany and Abroad: A CGE Simulation

Die Reaktion des deutschen Agrarsektors auf die künftigen Biotreibstoffziele in Deutschland und im Ausland: eine CGE-Simulation

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Abstract

This article analyses the impact of national, European and global biofuel targets on German food production and land allocation until 2020. The LEITAP General Equilibrium Model simulates the interaction of agricultural and energy markets in response to the envisaged expansion of the biofuel industry. First generation biofuels are integrated in the production structure of the petroleum sector. Second generation biofuels are modelled indirectly via estimated bottom-up reductions in land available for agriculture. Biofuel targets are set exogenously according to the current policy goals. The model recursively responds to increments in the biofuel mandates over three time intervals. Each country or region is required the meet its respective target and is allowed to subsidize biofuel consumption through a budget-neutral mechanism. Thanks to a nested land specification, changes in land use take into account variable elasticities of substitution among different cultivations. The results indicate that German production of biofuel crops substantially increases. In particular, oilseed output experiences a remarkable growth. Land allocation and land prices also change significantly. However, higher production does not suffice to satisfy the demand for biofuels feedstock, and imports of oilseeds and sugar rise considerably. Moreover, the model suggests that the growth in biofuel crop production among the remaining EU-26 countries is driven by the new Member States of the EU, and that the supply of EU biofuel crops also has to be enhanced by imports from abroad. Biofuel policies outside Europe show only little additional impact on German agriculture. The projected changes in food commodity prices are in line with the results of other CGE analyses, although prices rise to a lesser extent than projected in studies based on Partial Equilibrium Models.

Key Words

biofuels; Germany; EU; CGE simulations

Zusammenfassung

In diesem Artikel werden die Auswirkungen der nationalen, europäischen und globalen Ziele für Biokraftstoffe auf die deutsche Nahrungsmittelproduktion und Landnutzung analysiert. In dem allgemeinen Gleichgewichtsmodell LEITAP werden die Interaktionen zwischen Agrar- und Energiemärkten abgebildet und die Wirkungen des geplanten Ausbaus der Biokraftstoffnutzung untersucht. Dabei sind Biokraftstoffe der ersten Generation in die Produktionsstruktur des Mineralölsektors integriert. Die Nutzung von Biokraftstoffen der zweiten Generation wird nur indirekt in die Modellanalyse einbezogen. In den Szenarien werden die Ziele der Beimischungsanteile von Biokraftstoffen für die einzelnen EU-Mitgliedstaaten durch Gewährung von Subventionen von landwirtschaftlichen Inputs in der Kraftstoffindustrie implementiert. Die erforderlichen Subventionen werden budgetneutral für öffentliche Haushalte durch eine endogene Verbrauchssteuer auf Mineralöl finanziert. Die direkten und indirekten Wirkungen der steigenden Nachfrage nach Biokraftstoffen auf die landwirtschaftliche Bodennutzung werden durch endogene Bodennachfrage und -angebotsfunktionen im Modell abgebildet. Die Ergebnisse deuten darauf hin, dass sich die Produktion von agrarischen Rohstoffen, die in der Erzeugung von Biokraftstoffen Verwendung finden, in Deutschland, in der EU und in Drittländern deutlich erhöht. Dies gilt besonders für die Ölsaaten- und Getreide-

produktion. Um die Beimischungsziele zu erreichen, werden neben inländisch erzeugter Rohware auch verstärkt Importe genutzt. Dabei wird deutlich, dass die Erzeugung in der EU-12 im Vergleich zur EU-15 besonders stark ansteigt. Die Auswirkungen der Biokraftstoffpolitiken in Nicht-EU-Ländern auf die deutsche Agrarproduktion sind als relativ gering einzuschätzen. Darüber hinaus gleichen die Veränderungen der Nahrungsmittelpreise denen der CGE-Modell-Prognosen, wenngleich die Preise in einem geringeren Maße ansteigen als in anderen Studien.

Schlüsselwörter

Biotreibstoffe; Deutschland; EU; CGE-Simulationen

1 Introduction

In the past decade biofuels have received increasing attention as an alternative to oil in the transport sector[1]. Investments in output capacities of biofuel production intensified especially during the surge in oil prices that spanned between 2003 and the beginning of the financial crisis in 2008. World fuel ethanol production rose from 24 to 66 billion liters over the 2003-2008 period, while biodiesel output grew from 2 to over 14 billion liters (BROWN, 2009)[2].

The expansion of the biofuel industry has been supported with consumption quotas, tax exemptions and other financial incentives by governments across the world (SORDA et al., 2010; RAJAGOPAL and ZILBERMAN, 2007). Biofuel subsidies in the OECD amounted to US$ 15 billion in 2007 (OECD/ITF, 2008), while in the US alone financial aid in 2006 surpassed the US$ 6 billion mark (KOPLOW and STEENBLIK, 2008).

Governmental support of the biofuel sector has been blamed for creating distortions in the food markets and damages to the environment. MITCHELL (2008) and SCHMIDHUBER (2007) accused biofuels of being major drivers of rising food prices between 2003 and 2008.[3] Soil erosion, deforestation, increased fertilizers and pesticide use, as well as the alteration of the natural landscape and biodiversity, have been associated with the support granted to the manufacture of ethanol and biodiesel. In addition, net contribution of biofuels to a reduction in GHG emissions has also been questioned (MACEDO et al., 2004; PIMENTEL and PATZEK, 2005; FARREL et al., 2006; CRUTZEN et al., 2008). While the net energy balance of production varies considerably depending on the feedstock and processing technique employed (OECD, 2008)[4], the indirect impact on land-use for biofuel crop production may lead to a substantial increase in greenhouse gases and remains a topic of debate (FARGIONE et al., 2008; SEARCHINGER et al., 2008).

Technological progress might help to mitigate the concerns related to the biofuel industry and great attention is given to “second generation” biofuels derived from non-food crops rich in lignocellulose, such as switchgrass and miscanthus.[5] Their production requires more complex and costly processing techniques meant to reduce direct competition for food crops, to increase production per land area and to contribute to net energy and environmental benefits as well as lower feedstock costs.[6] However, at the moment there are no commercially viable production facilities for second generation biofuels (SCHMER et al., 2008; LARSON, 2008). Ethanol is still derived from the fermentation of the sugars present in sugar cane, sugar beets or starch-rich grains such as corn, while biodiesel (in the form of fatty-acid-methyl-

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[1] Biofuel production consists primarily of ethanol and biodiesel. However, biofuels may also refer to biomethanol, biodymethyl-ether, syngas and bio-oil. See HAMELINCK and FAAIJ (2006) for a more extensive overview.

[2] Original values were given in US gallons. Data was taken from BROWN (2009), who quotes F.O. LICHT as the main source.

[3] The highly subsidized US ethanol production is almost exclusively based on corn (SCHNEPF, 2005), consuming almost 20% of total US corn production in 2006 (EIA, 2007). It should also be mentioned that the US is one of the largest corn exporters.

[4] The OECD (2008) provides a review of over 60 studies on the Life Cycle Assessment (LCA) of the net energy balance and the net GHG emissions across biofuel types subdivided by feedstock. Corn-based ethanol showed the most harmful LCA profile.

[5] The composition of lignocellulosic biomass varies across plants, but on average it is made of 40% cellulose, 30% hemicellulose, 20% lignin and a remaining 10% of other compounds (LEE et al., 2007). The procedures employed to manufacture second generation biofuels can be grouped into two categories: biochemical and thermochemical biomass conversion. Biochemical processes are adopted to manufacture ethanol or butanol. Thermochemical processes give rise to fuel substitutes for both gasoline and diesel (HAMELINCK and FAIJ, 2006).

[6] Feedstock costs are the largest component in the price of biofuels (OECD/FAO, 2008). In case of ethanol produced from wheat and corn (the most “expensive” conversion combination), crops constitute more than 75% of the total manufacturing expenses (FAO, 2008).

ester) is predominantly obtained from vegetable oils[7] through transesterification[8].

Several issues related to biofuel production and governmental support have sparked an on-going debate that spreads across various disciplines. In economics, there is a growing body of literature that analyses the multi-sectoral effects of biofuel policies on agriculture, energy and the environment with Partial Equilibrium (PE) or Computable General Equilibrium (CGE) models. REILLY and PALTSEV (2007), DIXON et al. (2007) and MCDONALD et al. (2006) study the impact of bio-energy production on the US economy. ELOBEID and TOKGOZ (2008) focus on trade distortion in the American market, while FABIOSA et al. (2009) estimate the multiplier effects for land allocation and world prices associated with higher ethanol consumption in the US and a group of five ethanol producing countries. ARNDT (2008) assesses biofuels, poverty and growth in Mozambique. PERRY (2008) analyses the relationship between food production, biomass exports and land use in Argentina. Other studies estimate the impact of biomass polices on the aggregate world markets (i.e., BANSE et al., 2008; BIRUR et al., 2007; STILLMAN et al., 2008; HERTEL et al., 2008; HERTEL et al., 2010). TAHERIPOUR et al. (2009) and HAYES *et al.* (2009) pay particular attention to the livestock sector. BIRUR et al. (2008) integrate their analysis with a detailed land description by using the Agro-Ecological Zones (AEZ) framework developed by LEE (2005). TAHERIPOUR et al. (2008) emphasize the importance of including biofuel by-products such as Distillers Dried Grains with Solubles (DDGS) in the model. Several authors evaluate the implications of current EU policies on the agricultural sector. BANSE et al. (2008) and BANSE and GRETHE (2008) simulate the impact of European blending mandates on the global agricultural markets. GOHIN and MOSCHINI (2007) consider the implications for the EU farm sector and trade patterns. TOKGOZ (2009) studies the relationship between crude oil prices and the EU agricultural market. LINK et al. (2008) evaluate the potential for domestic biofuel production and the likely changes in the domestic farm sector.

The contribution of this paper is to evaluate the impact of current biofuel policies on the German and European agricultural sector. While most studies focus on aggregate regions, we take a closer look at the dynamics of the German market. As Germany is the European country with the highest share of biofuel consumption and production, it is of interest to consider in greater detail the effects of biofuel mandates on its agricultural production, land use and trade patterns. In addition, Germany play an important role in European agriculture, especially with respect to the crops employed as biofuel feedstock. In 2009 German production of oilseeds, cereals and sugar-beet amounted to 18%, 17% and 22%, respectively, of the EU-27 total.[9]

The analysis considers the envisaged biofuel targets in Germany, the rest of the EU and six other regions in the world, accounting for the main biofuel producers across the world. We adopt a general equilibrium framework (LEITAP) to simulate successive increments in biofuel targets over three time intervals between 2007 and 2020. Biofuel targets are set exogenously for the EU countries according to the current policy goals of the Renewable Energy Directive specified by the EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION (2009). In the LEITAP model the production structure of the petroleum sector allows for the use of agricultural commodities as feedstock, thus modelling first generation biofuels directly. The use of second generation biofuels is implemented via estimated bottom-up reductions in the available land supply, as the lack of data on energy grasses in the underlying database prevents direct inclusion of second generation biofuels in the production structure of transport fuels. In addition, changes in land use are associated with variable elasticities of substitution among different cultivations based on a nested land specification.

The next section describes the production technology in the petroleum sector in the LEITAP model. Section 3 presents the scenarios analysed. Section 4 illustrates and discusses the results of the simulations. Section 5 reports the sensitivity analysis conducted. We conclude by summarizing the most important insights and by drawing a comparison with the results of other publications.

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[7] Oily seeds such as a rapeseed, sunflower, coconut, palm and jatropha are the primary source of feedstock.

[8] Transesterification is the process of exchanging the alcohol group of an ester compound with another alcohol.

[9] The data are taken from the European Commision EUROSTAT, October 2010, and are available at http://epp.eurostat.ec.europa.eu. In 2009 the EU-27 produced 296 million tons of cereals (including rice, although rice accounted for only 1% of the total), 29 million tons of oilseeds and 114 million tons of sugar-beet.

2 The LEITAP Model

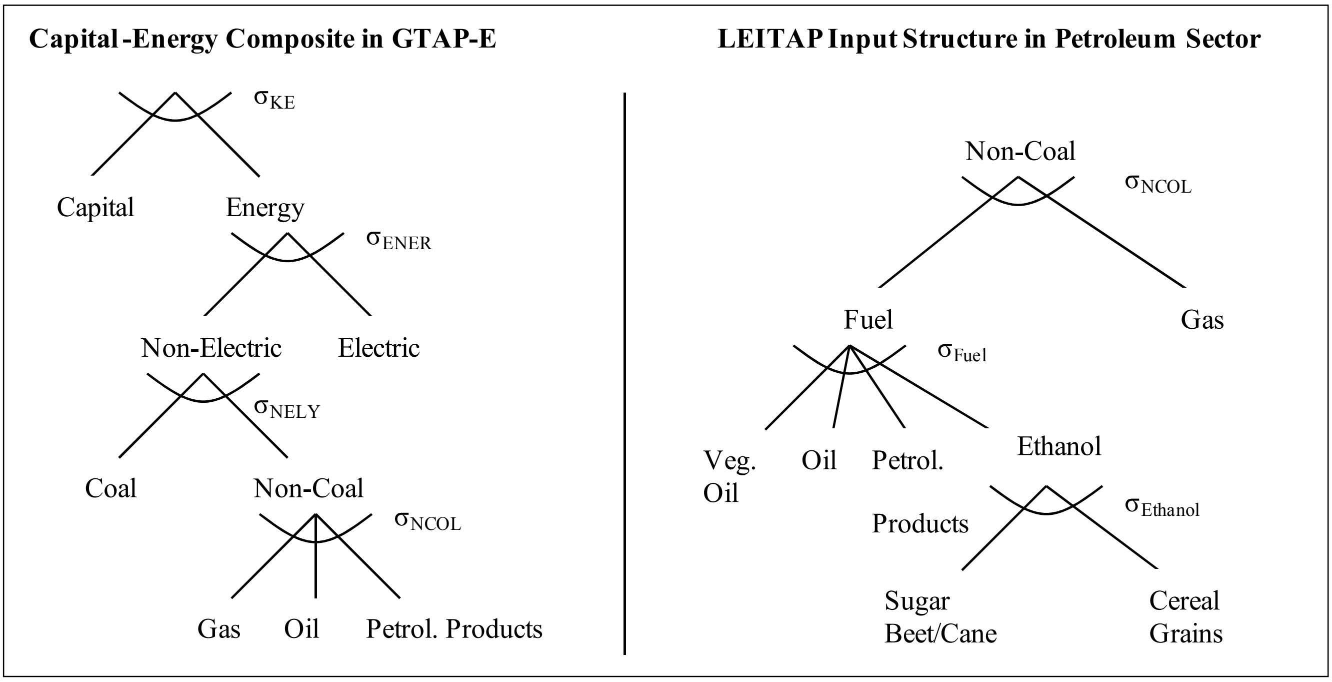
The simulations are carried out by an enhanced version of the LEITAP model introduced by BANSE et al. (2008). LEITAP is a multi-sector, multi-region, recursive dynamic CGE model derived from the GTAP framework (HERTEL, 1997). The energy sector is modelled building on the GTAP-E version by BURNIAUX and TRUONG (2002). In the latter, energy substitution is included into the production function by allowing energy and capital to be either substitutes or complements. Energy and capital inputs are modelled as an aggregate "capital-energy" composite. The energy related inputs are further subdivided in a tree-structure that differentiates between electricity, coal and the non-coal sector. The non-coal sector includes gas, oil and petroleum products (see figure 1).

LEITAP builds on and alters the GTAP-E structure to model biofuel consumption. The non-coal inputs in the capital energy composite are subdivided into gas and fuel. Fuel is composed of vegetable oil, crude oil, petroleum products and ethanol. Vegetable oil is obtained from oily seeds and it is a proxy for biodiesel. Ethanol is derived from sugar cane, sugar beet and cereals. Demand for the agricultural crops used in first generation biofuel production (oilseeds, sugar beet/cane, corn) is therefore directly linked to the fuel sector, while biomass inputs play only a minor role in the non-energy sectors.

In energy-related industries the demand for intermediate inputs strongly depends on the cross-price relation of fossil- and biofuel-energy. The output prices of the petroleum industry are, among other variables, a function of the prices of fossil energy and biofuel feedstock crops. Due to the nested CES structure of the production function, the demand for biofuels is contingent on the price of crude oil relative to the price of agricultural commodities. Consequently, the values assigned to fuel and ethanol-crops substitution elasticities (σ_{Fuel} and $\sigma_{Ethanol}$) are important. These parameters determine the degree of substitutability between crude oil and biofuel crops. In our model the estimates of the elasticity of substitution are based on a historical simulation of the 2001-2006 period published by BIRUR et al. (2007).

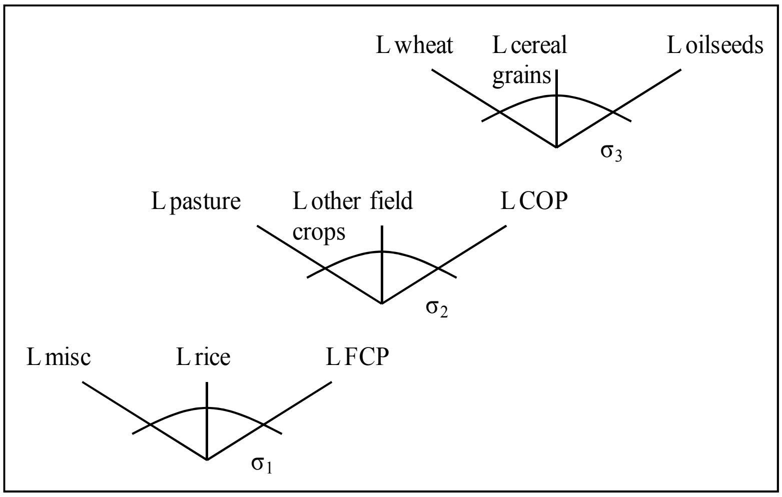
By linking the energy and agricultural sector, LEITAP is able to simulate the impact of biofuels on land use. In particular, land modelling within LEITAP takes into account the constraints associated with changing soil-use regimes. Following HUANG et al. (2004), different land types are matched to varying degrees of substitutability via a nested three-tier representation (see figure 2). At the upper level, wheat, cereal grains and oil seeds enjoy the same elasticity of substitution. Their aggregate, called "Cereal, Oilseed and Protein Cropland" (COP), has the same substitutability with land for pasture and other field crops in the middle tier. The middle group, called "Field Crops

Figure 1. Capital energy composite in GTAP-E and the extension of the input structure in the LEITAP model



Source: BANSE et al. (2008)

Figure 2. Land structure in LEITAP



Source: BANSE et al. (2008)

and Pastures" (FCP), has a constant degree of substitutability with land for rice and "miscellaneous agricultural land" (misc) at the bottom level (see figure 2). It is generally assumed that $\sigma_3 > \sigma_2 > \sigma_1$. The nested structure implies that it is easier to transform land cultivated with wheat into land destined to cereal grains (i.e., corn) than to convert wheat acreage into pasture areas. In addition, land supply is linked to rental prices and land use conversion rates. The approach adopted here is different compared with the Agro-Ecological Zones (AEZ) framework introduced by LEE (2005) and adopted also by BIRUR et al. (2008) and HERTEL et al. (2010), which focuses on the soil characterization associated with temperature and specific moisture regimes.

In this paper biofuel policies are modelled as blending obligations fixing the share of biofuels in the transport sector. The implementation of mandatory blending is budget neutral from the government point of view. Whenever necessary, the model calculates and applies a subsidy on biofuel inputs used in the petrol industry in order to achieve the exogenously set biofuel target. The subsidy is needed to change the relative price ratio between biofuel inputs and crude oil in case the biofuel share obtained by the model is lower than the blending requirement. Budget-neutrality is achieved by financing the subsidy with an end-user tax on fuel consumption. The end-user tax on fuel endogenously generates a budget sufficient to fund the subsidy destined to the biofuel inputs. End-consumers ultimately pay for the mandatory blending as prices of fuel increase. The higher prices result from the mandatory adoption of biofuel inputs, which are often more expensive than crude oil.

The simulations are based on version 6 of the GTAP database. The latter contains detailed bilateral trade, transport and protection data characterizing economic linkages among regions. All monetary values of the data are in US$ millions and 2001 is used as the base year. The social accounting data originally comprising 57 industries and 88 regions is aggregated into 23 sectors and 37 regions. The commodity aggregation specifies agricultural crops that can be used for producing biofuels (e.g., cereal grains, oilseeds, sugar cane and sugar beet), sectors and goods important from a land use perspective (paddy rice, wheat, vegetable and fruits, other crops, cattle, etc.) and energy industries related to the demand for biofuels (e.g., crude oil, petroleum, gas, coal and electricity). The regional aggregation separates Germany from the remaining EU-26 countries.[10] The most important biofuel producing regions outside the EU are also accounted for and include Brazil, NAFTA, South Africa, Japan-South Korea, East Asia, the Rest of Asia and a composite Rest of the World area. The model is updated to 2007 values and the time frame of the scenarios covers the period from 2001 to 2020. All relevant macro-economic changes (e.g., GDP, population and factor productivity growth) between 2001 and 2007 are implemented in the model. The results presented always refer to 2007 as the starting point of the projection period.

In addition, the GTAP database has been updated to include recent developments in the biofuel sector. The calibration of the use of biofuel crops in the model is based mainly on sources published in F.O. LICHT (2007). The input demand for grain, sugar, and oilseeds in the petroleum industry has been adapted in order to account for the observed production of first generation biofuels.

3 Scenarios Description

We implement mandatory blending schemes in five different scenarios. First, we impose biofuel shares only in Germany and subsequently extend the scope of our analysis to include biofuel targets in Europe

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[10] Apart from the Baltic states, Bulgaria and Romania, all EU Member States are modelled as individual nations in LEITAP.

Table 1. Scenarios implemented

Scenario	Country/Region	by 2010	by 2013	by 2020
NoBFD	All Countries/Regions	No mandatory biofuel blending		
GerAlone	Germany	5.25%	6.25%	10%
EU27	Germany	5.25%	6.25%	10%
	EU26	3.50%	5.75%	10%
Ger2ndHigh	Germany	5.25%	6.25%	7%
	Land Displacement	0	0	648 kHa
	EU26	3.50%	5.75%	10%
Ger2ndLow	Germany	5.25%	6.25%	7%
	Land Displacement	0	0	972 kHa
	EU26	3.50%	5.75%	10%
Global	Germany	5.25%	6.25%	10%
	EU26	3.50%	5.75%	10%
	Brazil	25%	25%	25%
	NAFTA	3.14%	3.86%	4.69%
	Land Displacement	94 kHa	937 kHA	9836 kHA
	East Asia	0.75%	1%	2.5%
	Rest of Asia	1%	3%	5%
	Japan-South Korea	0%	1%	2%
	South Africa	0%	2%	2%

Source: own calculation

and in other regions of the world. This sequential approach allows us to determine whether the main drivers behind the change in agricultural production and land allocation in Germany are due to domestic or international policies. We also account for the possibility that part of the German biofuel target in 2020 will be met by ethanol obtained from second generation production technologies (see table 1).

All the simulations are compared to a reference scenario with no mandatory biofuel targets (NoBFD). The reference scenario includes policy changes that are relevant for the international agricultural markets. These include the EU CAP Health Check (phasing out of milk quotas, decoupling of remaining coupled payments, modulation of direct payments and transfers to 2nd Pillar) and – between 2013 and 2020 – the multi-lateral implementation of a WTO agreement according to the Falconer Proposal of December 2008. In addition, even though in the base scenario we do not exogenously impose a biofuel share in any country, the model projects a level of biofuel consumption of 22% in Brazil due to the relatively low cost of local sugar cane production[11]. Besides Brazil, no other country has a significant consumption of biofuels between 2007 and 2020, as biofuel feedstock is projected to be too expensive in relation to oil.

The first simulation (*GerAlone*) applies mandatory biofuel blending only in Germany. A biofuel quota of 5.25% is set to be binding in 2010, while the share of renewable fuel rises to 6.25% by 2013. Finally, Germany is expected to reach a biofuel share of 10% by 2020.[12] Note that although the EU Directive 2009/28/EC specifies that the 10% share of energy consumed in the transport sector by 2020 can be derived from *any* kind of renewable sources, we assume that biofuel will play a predominant role if the 10% target is to be met by 2020.

In the second scenario (*EU-27*), the biofuel goals of both Germany and the remaining EU Member States (EU-26) are modelled. The EU-26 countries are expected to meet a 3.5% blending share by 2010 and progressively increase their quota to 5.75% by 2013 and 10% by 2020.[13] Germany maintains the blending requirements set in the *GerAlone* scenario.

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[11] A biofuel integration level of 22% is consistent with Brazil's current biofuel consumption trends.

[12] The Biokraftstoff-Nachhaltigkeitsverordnung, BUNDESGESETZBLATT (2009), and the "Verordnung zur Änderung der Biokraftstoff-Nachhaltigkeitsverordnung (Biokraft-NachV)", BUNDESGESETZBLATT (2010), outline sustainable criteria for the implementation of EU Renewable Energy Directive in Germany. However, it is still unclear how these criteria will affect biofuel blending in Germany. Therefore, this analysis assumes mandatory blending targets for Germany as outlined in the EU Renewable Energy Directive, EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION (2009).

[13] The EU Renewable Energy Directive set a 5.75% target for biofuel market penetration by 2010. However, in 2005 biofuels accounted for only 1% of transport fuels in the EU. The 2010 goal is likely to have been missed, with an expected share of 4.2% (EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2009). With the exclusion of Germany, it is reasonable to expect a biofuel share of 3.5% in the remaining EU-26 countries in 2010. We further assume that in the EU-26 the 5.75% target (initially envisaged for 2010) will instead be achieved by 2013.

In *Ger2ndLow* and *Ger2ndHigh* we again evaluate the impact of the EU biofuel targets, but we assume that 3% of total fuel consumption in Germany in 2020 will be supplied by domestically produced second generation ethanol derived from switchgrass[14], while the EU biofuel goals remain unaltered. However, switchgrass is not included as a commodity in the GTAP database and LEITAP cannot directly use it as feedstock for the production of ethanol[15]. We tackle this problem in two steps: first, the exogenous blending share of biofuel in Germany is set at 7% in 2020. Second, we reduce the available land supply. The reduction in land supply in Germany corresponds to the cultivated area that would be required to manufacture enough ethanol to meet the remaining 3% of the biofuel target. Due to the fact that the production of cellulosic ethanol is under great technological change and future estimates of ethanol output per hectare of land may vary considerably, we account for the potential deviation in output per hectare under alternative assumptions of technical improvements and specify two scenarios based on low- (*Ger2ndLow*) and high-conversion efficiencies (*Ger2ndHigh*).

Low conversion efficiency implies that a larger portion of cultivated land has to be dedicated to ethanol production in order to meet the required 3% target from second generation bio-crops. It follows that in the low conversion scenario German land supply experiences a greater reduction in comparison to the high conversion case. We also assume that part of the area destined for switchgrass cultivations comes from wasteland and low quality soils with a low yield level, so that only 80% of the total surface required for cellulosic ethanol production is actually removed from the original land supply.

The last scenario (*Global*) includes the main biofuel policies in other parts of the world outside the EU. In addition to the envisaged biofuel targets in Germany and the EU, we consider the following group of countries: Brazil, NAFTA (US, Canada, Mexico), South Africa, Japan and South Korea (as one region), East Asia (China, Hong Kong, Macau, Mongolia, North Korea), and Rest of Asia (India, Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, Rest of South East Asia, Bangladesh, Sri Lanka, Rest of South Asia). For each region we estimated the energy content of projected biodiesel and bioethanol production as a share of the energy required in the transport sector. Table 1 shows the renewable fuels ratios assigned to each region.

In the *Global* simulation Germany does not produce second generation biofuels. However, in the US the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 specifically target quotas of biofuel output to be derived from second generation technologies. This in turn affects blending mandates in the US and requires estimates of second generation biofuel crop inputs. We repeat the procedure adopted in the *Ger2ndLow* and *Ger2ndHigh* scenarios and calculate the amount of land necessary to include cellulosic-ethanol from switchgrass in the model. However, for the US we estimate an average level of conversion efficiency that lies between the high and low boundary values implemented in the *Ger2ndLow* and *Ger2ndHigh* scenarios.

4 Results

Production, price levels, trade and land use of the relevant agricultural commodities are examined individually. Despite the global dimension of LEITAP, we focus our analysis on Germany and the EU. We present the outcome of the simulations as percentage changes occurring between 2007 and 2020, the period during which increasing shares of blending mandates are gradually implemented in the model scenarios. In order to evaluate the implications of biofuels policies, all changes occurring between 2007 and 2020 are relative to the simulation results obtained in the reference scenario *NoBFD*, which excludes mandatory biofuel blending.

4.1 Production

The introduction of blending requirements leads to a 13.8% increase in the production of arable crops in Germany (see table 2, *Global* scenario). The same trends emerge for biofuel crops (the crops employed in the production of ethanol or biodiesel), though the magnitude of change is larger. In particular, biofuel policies significantly push for higher production levels of cereal grains and oilseeds, whose domestic supply increases by 13.0% and 55.6%, respectively.

On the other hand, the output of agricultural commodities directly competing with biofuel crops for

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[14] We are aware that 3% is an *ad-hoc* value unrelated to legislative or economic considerations. However, in order to consider the potential impact of second generation biofuels, 3% represents a small but significant change to the fuel market.

[15] Ethanol can be produced from sugar beet, sugar cane and corn. A combination of these commodities at given proportions and costs can represent a reasonable approximation of first generation ethanol.

Table 2. Change in agricultural production in Germany and the EU-26, in percent relative to the NoBFD scenario, 2007-2020

		Total Agric.	Arable Crops	Biofuel Crops	Cereals	Oilseeds
Germany	GerAlone	0.9	7.9	14.7	2.3	47.9
	EU-27	2.0	12.8	21.1	11.7	52.7
	Ger2ndHigh	1.6	9.0	16.3	9.3	33.5
	Ger2ndLow	1.4	8.0	15.3	8.2	29.7
	Global	2.3	13.8	22.2	13.0	55.6
EU-26	GerAlone	0.1	0.2	0.7	0.1	3.1
	EU-27	0.3	7.2	24.8	8.4	61.2
	Ger2ndHigh	0.3	7.2	24.6	8.4	60.6
	Ger2ndLow	0.3	7.2	24.6	8.4	60.6
	Global	0.5	7.7	25.8	9.1	64.9

Source: own results from LEITAP

land is not strongly affected by blending obligations and relatively small production variations are projected in the simulations between 2007 and 2020. The most significant change due to biofuel policies occurs to the supply of wheat, which is projected to decrease in volume by 5% once global biofuel policies are taken into account.

The ability to produce 3% of the mandated quotas from cellulosic ethanol (*Ger2ndHigh* and *Ger2ndLow*) decreases the impact of the EU biofuel mandate on German crops production and indicates that second generation technologies, as modelled here, would to some extent curb the impact of biofuels on food products.

The remaining countries in the EU also alter their production patterns in response to the introduction of mandatory blending. Aggregate arable crops production increases by 7.7% under the *Global* scenario mainly due to a significant expansion in cereals (25.2%) and oilseed output (64.9%). Interestingly, the growing supply of biofuel crops is driven by the new Member States and Poland in particular, where the volume of cereal grains relative to the no biofuels scenario increases by 38.7%.

Comparing the results across the different scenarios, two trends emerge. First, the growth in domestic oilseed output is mainly due to the German biofuel target, while the increase in cereal grain production is driven by the implementation of biofuel quotas in the rest of the EU. These results are consistent with current biofuel production patterns, where Germany is the leading biodiesel producer (with oilseeds as its main feedstock), whereas France is the main European manufacturer of ethanol.

Second, the inclusion of blending mandates in other parts of the world contributes only to a marginal additional increment in the production of biofuel crops in Germany and the EU. Three reasons can be named for the minor additional impact of biofuel policies outside of the EU on the German and European agricultural sector. To begin with, the EU biofuel targets are comparably larger than their counterparts in other countries (with the exception of Brazil, which achieves a 22% biofuel share in transportation fuel consumption in the reference scenario without the need of binding mandates). In addition, the production volume of crops used as biofuel feedstock already increases significantly in order to reach the EU target and a further capacity expansion is limited, among other things, by structural conditions in the EU agricultural sector (land changes, land availability, demand for other agricultural commodities). This is also reflected in the surge of biofuel feedstock imports despite the increase in domestic production (see section 4.3). Finally, the responsiveness of domestic production to changes in international prices is driven by the level of Armington elasticities, which are the same across the various scenarios. Alterations to trade patterns (and indirectly production) in response to price variations are smaller and in our view more realistic than those projected in models that assume homogeneity of commodities irrespective of the country of production.

4.2 Prices

World prices are calculated as a trade-weighted average of export prices. In general, world prices are most responsive to changes in production when domestic markets are integrated in international trade. Consequently, biofuels cause the largest impact on both domestic and international prices in the *Global* scenario where biofuel policies across the world are modelled simultaneously.

Mandatory biofuel consumption increases the demand for energy crops, which stimulates both production and trade of biofuel feedstock. In addition, production of other agricultural commodities is also affected as agricultural land is allocated towards biofuel cropping. The result is an upward shift in agricultural prices in comparison to the reference scenario (see table 3).

Table 3. Change in world prices, in percent relative to the NoBFD scenario, 2007-2020

	Total Agric.	Arable Crops	Biofuel Crops	Cereals	Oilseeds
GerAlone	0.2	0.3	0.3	0.2	0.5
EU-27	1.8	2.7	2.8	3.5	3.7
Ger2ndHigh	1.7	2.5	2.6	3.4	3.4
Ger2ndLow	1.7	2.5	2.7	3.5	3.5
Global	2.8	4.3	5.1	5.8	8.2

Source: own results from LEITAP

Once domestic and international mandates are taken into account, the world price of cereal grains is expected to increase by around 5.8% relative to the *NoBFD* scenario, while oilseed prices rise by more than 8%. The model also projects a 5.1% increase in the average price for biofuel crops. Other agricultural commodities indirectly competing for land with biofuel crops experience more modest price increments. Overall, the weighted price of primary agricultural products rises by 2.8% and thus signals a rather moderate upward trend on agricultural commodities. In addition, despite the fact that world ethanol production is much larger than biodiesel, the impact of biofuel policies on oilseed prices (and production) is stronger than on cereals because the oilseeds market is substantially smaller in comparison to the cereals market.

It is important to mention that even though food prices are affected by biofuels policies, the model does not reproduce the price surge that occurred in recent years. In January 2011 the world price indexes for cereal grains, oils, and sugar were respectively 245%, 278% and 420% higher than their 2002-2004 average values.[16] The causes of this inflationary rise remain hotly debated. JOHNSON (2007), SCHMIDHUBER (2007) and MITCHELL (2008) argue that biofuels have been a main driving element in the recent price trends (especially with respect to corn and oily seeds). On the other hand, the UNCTAD's position on biofuel policies and the global food crisis asserts that "increased biofuels production has been, for certain crops and certain countries, a driver of food price inflation, but not the dominant one.[17]"

As shown in table 3, the scenario results indicate a relatively small impact of biofuel policies on average food prices, although it suggests that oilseeds and (to a lesser extent) cereal grains (i.e. corn) will be significantly affected. Our results are consistent with the outcome other studies. It should be clear, however, that differences in model specification and structure are bound to generate different responses, even if similar policy shocks are simulated. In order to consider the result of studies with a comparable methodology, we limited our attention to research papers based on partial or general equilibrium models.

In general, our results are in line with the projections published in other studies applying a CGE framework. For instance, TAHERIPOUR et al. (2009) use an enhanced version of the general equilibrium GTAP-E model, which includes Agro-Ecological Zones (AEZ) for land use and biofuel byproducts for animal feed. They simulate the impact of biofuel mandates in the US and the EU from 2006 to 2015 and find significant changes in the prices of cereal grains in the US (a 15% increase), oilseeds in the EU (a 42.8% rise) and sugarcane in Brazil (a 25.2% increment). However, world prices experience significantly smaller changes as oilseeds go up by 11.4% while sugarcane and cereal grains increase by only 4.3% and 1.0%, respectively.

KRETSCHMER et al. (2009) use the DART[18] model to consider the impact of the EU 10% biofuel target on agricultural markets, CO_2 emissions and overall welfare implications for 12 world regions. The base scenario accounts for the EU 2020 CO_2 emission target. In addition, biofuel policies are assessed on top of the EU strategy on renewable energy, which expects 20% of energy consumption to be derived from renewable sources by 2020. According to the their simulation results, European prices of biofuel feedstock are expected to rise between 4% and 7.4 % over the 2001-2020 period, while world agricultural prices will increase by up to 3.5%.

By contrast, partial equilibrium models simulate steeper inflationary responses to the introduction of biofuel mandates. BRITZ and HERTEL (2009) assume that biodiesel will meet a 6.25% blending share in the EU by 2015. They link a CGE model with the partial equilibrium CAPRI model in order to investigate in greater detail land use and production changes in the EU. Their results show a 48% increase in oilseeds

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[16] See the FAO Food Price Indices, retrieved on August, 1 2011 and available at http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/.

[17] See UNCTAD's position on biofuels policies and the global food crisis, retrieved on the 1st June 2011, available on http://www.unctad.org/Templates/Page.asp?intItemID=4526&lang=1.

[18] Dynamic Applied Regional Trade (DART) model, a multi-sector CGE model calibrated with reference to the GTAP6 database with 2001 as base year.

prices and a 33% rise in oilseed output in the European Union.

FABIOSA et al. (2009) evaluate the impact of increased ethanol consumption based on the partial equilibrium model developed at the Food and Agricultural Policy Research Institute (FAPRI). Separate exogenous shocks in ethanol demand are applied between 2007 and 2017 for the US and a group of world regions (Brazil, China, the EU and India). Based on the estimation of specific multipliers, they argue that the U.S. policy aim of a 15 billion gallons ethanol production by 2017 would cause world corn and wheat prices to rise by nearly 25.9% and 17.1%, respectively.

ROSEGRANT et al. (2008) use the IMPACT partial equilibrium model developed by IFPRI. Specific quantities of feedstock commodities are allocated to satisfy the demand derived from biofuel production in 2020. Compared to the baseline scenario, world commodity prices in 2020 are 26% higher for corn, 18% higher for oilseeds, 12% higher for sugar and 8% higher for wheat. If a drastic biofuel expansion is assumed, world prices would increase by 72% for corn, 44% for oilseeds, 27% for sugar and 20% for wheat.

As pointed out by GERBER et al. (2008), WIGGINS et al. (2008) and GALLAGHER (2008), there is a general consensus that current biofuel policies will have an impact on agricultural commodity prices (especially oilseeds, corn and sugar), but the scale of the effects varies significantly across different studies. In particular, partial equilibrium models simulate stronger price responses in comparison to general equilibrium models. The reason is that, following the simulated shocks, general equilibrium models usually allow for stronger quantity adjustments to production, trade and consumption across all sectors, thus dampening the impact on prices more than partial equilibrium models do.

4.3 Trade

With the introduction of mandatory blending targets, European trade in biofuel crops faces a remarkable change as imports surge by around 150% in the EU-26 and exports drop by almost 20%, see tables 4 and 5.

German oilseed consumption, despite the increase in production, relies predominantly on foreign imports. Following the implementation of biofuel mandates at the global level, the ratio of imports to domestic consumption rises from 54% in 2007 to 62% in 2020. The volume of oilseed imports expands by 101% relative to the reference scenario (table 4, *Global* scenario). Similarly, the volume of exports in relation to domestic production drops from 13% to 9.6% in 2020 once the biofuel targets are accounted for. Perhaps counterintuitively, the volume of German oilseeds exports actually rises by 13% (table 5, *Global* scenario). However, this is a result of the low export volumes in the reference scenario, the high international oilseed prices and the increase in domestic production. Only 3% of the incremental oilseeds produc-

Table 4. Change in the volume of imports in Germany and the EU-26, in percent relative to the NoBFD scenario, 2007-2020

		Total Agric.	Arable Crops	Biofuel Crops	Cereals	Oilseeds
Germany	GerAlone	6.2	13.3	68.5	3.3	95.7
	EU-27	6.0	14.6	75.6	1.2	105.5
	Ger2ndHigh	3.5	9.3	45.7	0.9	65.8
	Ger2ndLow	3.6	9.6	47.3	1.5	67.6
	Global	5.6	14.0	74.4	0.7	101.4
EU-26	GerAlone	-0.2	-0.3	-0.7	-1.3	-0.5
	EU-27	25.1	50.8	155.0	61.1	159.6
	Ger2ndHigh	25.1	50.6	154.4	60.9	159.2
	Ger2ndLow	25.1	50.5	154.3	60.5	159.3
	Global	23.6	48.8	153.0	59.4	151.6

Source: own results from LEITAP

Table 5. Change in the volume of exports in Germany and the EU-26, in percent relative to the NoBFD scenario, 2007-2020

		Total Agric.	Arable Crops	Biofuel Crops	Cereals	Oilseeds
Germany	GerAlone	-4.8	-10.6	-20.0	-9.9	-64.3
	EU-27	3.2	12.3	34.6	17.4	4.2
	Ger2ndHigh	4.4	14.0	42.3	18.0	28.9
	Ger2ndLow	3.6	11.2	38.3	15.1	19.3
	Global	4.2	14.2	37.3	19.3	13.1
EU-26	GerAlone	0.9	2.6	13.2	-0.1	45.2
	EU-27	-8.4	-10.9	-22.3	-22.2	-59.0
	Ger2ndHigh	-8.5	-11.2	-25.3	-22.0	-67.6
	Ger2ndLow	-8.5	-11.1	-25.1	-21.9	-67.4
	Global	-7.9	-10.0	-19.3	-20.1	-51.3

Source: own results from LEITAP

tion that has followed the introduction of the biofuel mandates is reallocated to the export market. It is also indicative that the ratio of oilseeds exports to total consumption actually decreases from 7.6% in 2007 to 5% in 2020.

By contrast, German production of cereal grains is sufficient to satisfy its internal consumption and little is used to produce biofuels. As such, imports of cereal grains remain unvaried, while production and exports rise due to increased demand from EU Member States (as we already mentioned in section 4.1). At the same time, the introduction of second generation biofuels (*Ger2ndHigh* and *Gen2ndLow*) would curb the demand for imports of crops for biofuel production.

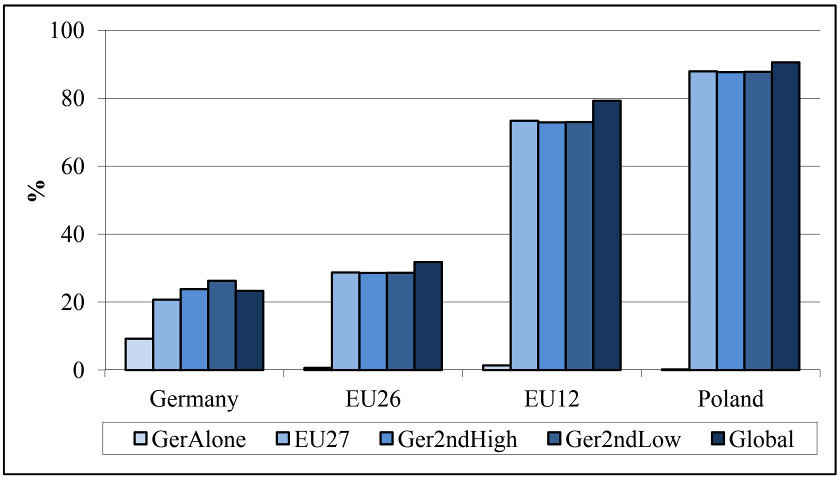
Within the remaining EU countries, biofuel policies clearly lead to a significant deterioration in the trade balance of agricultural commodities. In the EU-26 exports decline and imports of biofuel crops increase strongly relative to the *NoBFD* scenario. The results indicate that European production of biofuels feedstock is not sufficient to meet the mandatory blending quotas, and cereal grains, oilseeds and sugar imports grow significantly. At the same time, exports of all energy crops are cut back. Whereas the export volume of cereal grains, oilseeds and sugar amount to less than 5% of their respective production level in 2020, imports correspond to a significant share of the total consumption of biofuel crops in the EU-26 region. Despite the increase in production, especially in the new EU Member States, the ratio of biofuel feedstock imports to consumption increases from 16% in 2007 to 33% in 2020.

4.4 Land Use

Biofuel policies have a direct impact on land allocation and prices. Figure 3 shows the change in land prices relative to the *NoBFD* reference scenario. The price of agricultural land in Germany rises by 20% between 2007 and 2020. In the remaining EU countries the response is even stronger with an increase of more than 28%. The price increase in the EU-26 region is driven by a strong supply response in the new EU Member States, where average land prices are 70%-80% higher compared with the *NoBFD* scenario. In particular, in Poland land prices increase by almost 90% relative to the reference scenario.

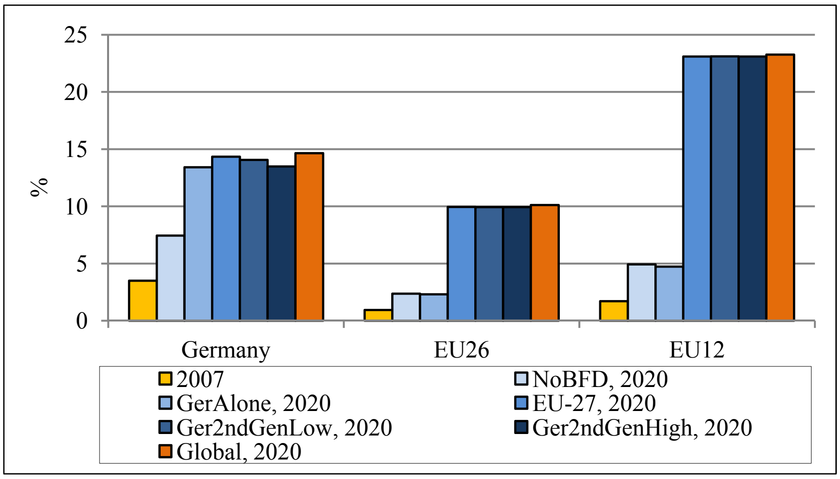
Mandatory blending targets also have an impact on land allocation. In the EU-26 region farm products employed for biofuel production move from occupying less than 1% to almost 10% of the total land supply between 2007 and 2020 (figure 4). The new EU Member States are characterized by an even higher ratio and allocate more than 23% of their land for bio-crops in 2020, while in 2007 the corresponding share was close to 2%. These results coincide with a growth in the production of energy crops induced by the mandatory blending set by the EU Renewable Energy Directive. A change in crop patterns and a relatively

Figure 3. **Change in land price under different scenarios, in percent relative to the NoBFD scenario, 2007-2020**



Source: own calculations

Figure 4. **Share of land used for biofuel crops in total agricultural land under different scenarios in 2007 and 2020**



Source: own calculations

low spare capacity of agricultural land contribute to a redistribution of land resources at higher land prices.

Analogously, in Germany the share of total agricultural land devoted to the production of biofuel crops moves from 3% in 2007 to above 14% in 2020. With the inclusion of second generation biofuels, the share of land devoted to biofuel crops is slightly lower[19] (13.5% and 14.1% with high and low conversion efficiency, respectively, in comparison to 14.3% in the *EU*-27 scenario). However, land rental prices in the *Ger2ndLow* and *Ger2ndHigh* scenarios are slightly higher. This outcome is a result of our modelling approach and requires some further explanation.

The increase in German land prices is, among other elements, a consequence of how land supply and rental rates are modelled, see van Meijl et al. (2006). When more land resources are exploited and aggregate land-use moves closer to its potential total supply, farmers start to cultivate less fertile land at higher production costs and land rental rates increase. However, given an equal increment in land demand, land rental rates increase to different degrees depending on land availability as a share of total potential land supply. In the *Ger2ndLow* and *Ger2ndHigh* scenarios we reduce total potential land supply in Germany (and exogenously allocate it to switchgrass cultivations). As a result, land price increases are slightly steeper than in the previous scenarios, and we find that that the remaining demand for biofuel feedstock, even though smaller, is sufficient to drive land prices upwards. The magnitude of the price change conforms to the trend outlined in the other scenarios and leads to the conclusion that second generation techniques may reduce demand for food crops, but will maintain a high demand for land and thus contribute to a rise in prices.

5 Sensitivity Analyses

Sensitivity analyses were conducted by assuming higher crude oil prices, different biofuel shares and alternative levels of Armington elasticities implemented in the model. Each variable was altered independently by ±25%. We adopted the *EU-27* scenario as a reference for comparisons and present the results of the analysis in tables 6 to 8.

Table 6. Effects of the EU biofuel policy on production, in percent relative to the NoBFD scenario, 2007-2020

		Arable crops	Biofuel crops	Cereal grains	Oilseeds
Germany	original	12.8	21.1	25.3	52.7
	higher Armington elast.	12.2	20.9	24.9	47.8
	lower Arminton elast.	13.7	21.9	26.4	58.6
	higher oil price	1.9	2.7	8.5	-0.9
	lower oil price	20.0	32.8	34.3	99.5
	higher blending shares	16.3	26.2	33.3	66.7
	lower blending shares	9.1	15.6	17.7	36.5
EU-26	original	7.2	24.8	24.2	61.2
	higher Armington elast.	7.0	24.5	23.6	58.4
	lower Arminton elast.	7.6	25.1	25.2	65.1
	higher oil price	3.1	11.7	12.6	21.1
	lower oil price	9.6	31.6	30.5	86.3
	higher blending shares	8.7	29.2	29.1	74.3
	lower blending shares	5.7	19.9	19.1	47.2

Source: own results from LEITAP

Table 7. Effects of the EU biofuel policy on exports, in percent relative to the NoBFD scenario, 2007-2020

		Arable crops	Biofuel crops	Cereal grains	Oilseeds
Germany	original	12.3	34.6	57.7	4.2
	higher Armington elast.	12.2	35.2	59.7	-3.4
	lower Arminton elast.	12.7	34.7	56.4	12.7
	higher oil price	11.1	29.0	36.7	27.6
	lower oil price	15.2	42.9	72.2	4.8
	higher blending shares	14.1	39.6	71.5	-8.3
	lower blending shares	11.2	31.2	45.1	18.2
EU-26	original	-10.9	-22.3	-18.6	-59.0
	higher Armington elast.	-11.3	-22.0	-18.0	-65.6
	lower Arminton elast.	-10.1	-22.0	-18.9	-51.0
	higher oil price	-7.3	-19.7	-11.9	-52.6
	lower oil price	-11.3	-21.6	-20.4	-54.2
	higher blending shares	-12.3	-25.0	-21.5	-64.1
	lower blending shares	-9.0	-19.1	-15.1	-52.4

Source: own results from LEITAP

Deviations from the assumed course of oil prices produce significant changes in the projected results. If oil prices were 25% higher, then agricultural commodities would be considerably less affected by the introduction of biofuel mandates. This outcome occurs because of the underlying production structure of

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[19] We account for the total land used for biofuel crops as well as for switchgrass coltivations destined to ethanol production.

Table 8. Effects of the EU biofuel policy on imports, in percent relative to the NoBFD scenario, 2007-2020

		Arable crops	Biofuel crops	Cereal grains	Oilseeds
Germany	original	14.6	75.6	2.8	105.5
	higher Armington elast.	14.1	70.9	2.9	101.8
	lower Arminton elast.	15.1	79.6	2.9	109.2
	higher oil price	0.4	1.9	-0.9	2.6
	lower oil price	21.9	118.6	4.6	175.0
	higher blending shares	21.6	112.8	4.9	154.7
	lower blending shares	8.3	41.5	1.1	60.2
EU-26	original	50.7	155.0	172.5	159.6
	higher Armington elast.	50.8	154.4	180.9	158.0
	lower Arminton elast.	51.3	157.7	165.6	163.3
	higher oil price	26.8	86.5	85.2	83.7
	lower oil price	63.5	193.8	221.2	205.7
	higher blending shares	65.3	202.1	226.2	204.4
	lower blending shares	36.9	110.6	123.7	116.7

Source: own results from LEITAP

the LEITAP framework. Higher oil prices increase the competitiveness of biofuel crops relative to fossil energy. Hence, biofuel consumption increases due to market forces and not due to imposed biofuel mandates. Low oil prices, on the other hand, show the opposite effects.

The results of the model are also sensitive to the blending targets imposed on the transport sector. In particular, the production of oilseeds fluctuates considerably in response to changes in the biofuel quotas. Exports and imports compensate for the variations in production and therefore follow a correlated pattern.

By contrast, altering the level of Armington elasticities, which determine the responsiveness of domestic production and consumption on world price changes, has only a minor impact on the results. It may be the case that GTAP-based models allow European production of agricultural commodities to respond swiftly to external demand shocks, while international trade plays a secondary role. BRITZ and HERTEL (2009), for instance, suggest that the CAPRI model simulates smaller changes in the EU oilseeds supply in comparison to the GTAP-BIO framework by HERTEL et al. (2010). As a consequence, the impact of the EU biofuel mandate on foreign countries may be underestimated.

6 Conclusions

Our analysis shows that current biofuel policies may have a significant impact on German agriculture. Mandatory biofuel consumption leads to an increase in the production of the agricultural commodities employed as biofuel feedstock. In particular, the supply of cereals and oilseeds grows by more than 20% and 50%, respectively.

The increase in domestic output of energy crops is followed by a reallocation of land resources. The share of land devoted to biofuel feedstock expands from around 3% in 2007 to about 14% in 2020. At the same time, land prices rise by more than 20% relative to the *NoBFD* scenario. The model also indicates that competition for agricultural products between the food and energy sectors may be eased if part of the biofuel blending target is met with cellulosic ethanol. Nevertheless, land allocation and prices will be similarly affected by first and second generation manufacturing technologies.

The other EU-26 countries also increase their output of biofuel crops in response to the introduction of blending mandates. The EU new Member States reallocate a significant share of their land resources to the cultivation of biofuel feedstock and experience a significant increase in land prices.

Our simulations further suggest that mandatory biofuel consumption would influence international trade in both Germany and the rest of the EU. Despite increasing production, domestic supply of biofuel feedstock is not sufficient to satisfy the internal demand and imports are necessary to meet the blending obligations.

In addition, the implementation of international biofuel policies has a small but evident impact on world prices of agricultural commodities. In relation to the reference scenario, agricultural products become more expensive, and world prices rise between 4.3% for arable crops to 8.2% for oilseeds. The results are in line with the projections published in other studies based on CGE models. Publications that use partial equilibrium frameworks, on the other hand, simulate stronger price responses under mandatory biofuel blending.

Key insights of our analysis correspond to the findings of other studies. First, the agricultural sector in the EU is mostly affected by its own biofuel policies, while the biofuel targets of other countries lead to only minor additional changes (HERTEL et al., 2008). Second, EU agricultural production and world price of arable crops increase significantly. Cereal grains and especially oilseeds show a considerable expansion (BANSE and GRETHE, 2008). Third, the rise in biofuel crop production coincides with a strong drop in exports and a surge in imports (GOHIN and MOSCHINI, 2007).

By looking at Germany separately, our study allows us to identify specific dynamics that characterize German agriculture. According to our analysis, Germany responds to the blending mandates by increasing the production of oilseeds and by importing more oilseeds and sugar. On the other hand, the increase in the domestic supply of cereal grains is destined to satisfy the EU demand for biofuel feedstock. In addition, Germany maintains its role as an important agricultural market for biofuel crops in the European Union. Our model simulates that German production of biofuel feedstock corresponds to a 16% share of the EU-27 in 2020. In particular, German production of oilseeds and cereal grains account for 18% and 15% of the European output in 2020.

The results presented here are based on the most recent available data. As it may be expected, the outcome of the simulations is sensible to the evolution of oil prices and the level of biofuel blending implemented. Moreover, the impact on world food prices and international trade is influenced by the underlying structure of the model (esp. the use of Armington elasticities and CGE vs Partial Equilibrium). Our analysis could be improved in the future with the inclusion in the model of by-products of biofuel manufacture in order to adequately assess the implications of blending mandates on the livestock industry, e.g. TOKGOZ et al. (2007), TAHERIPOUR et al. (2008) and TAHERIPOUR et al. (2009).

Nonetheless, our study sheds some light on the impact of biofuel mandates in Germany. Most importantly, the change in land allocation, the evolution of production and the impact on prices confirm that biofuel policies will affect the European farm sectors and that imports from other countries will be necessary to meet the ambitious EU targets.

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