Impact of EU Biofuel Policies on World Agricultural and Food Markets

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Abstract:

This paper assesses the global and sectoral implications of the EU biofuels directive in a multi-region computable general equilibrium framework. Our results show that without mandatory blending or subsidies to stimulate the use of biofuel crops in the petroleum sector the targets of the EU Biofuel directive will not the reached in 2010. With mandatory blending the enhanced demand for biofuel crops has a strong impact on agriculture at the global and European level. The additional demand from the energy sector might slow down or reverse the long term process of declining agricultural prices.

Key words: Biofuels, EU biofuel directive, agricultural markets, Computable General Equilibrium modeling

1 Introduction

World-wide production of biofuels is rapidly growing. World wide production of ethanol tripled from 20 billion liters to 50 billion litres (see, Figure 1) and world biodiesel production has grown from 200 million gallons to almost 1000 million gallons in the period 2001-2005. In the European Union in 2004, about 0.4% of the EU cereal and 0.8% of the EU sugar beet production was used for bioethanol, and more than 20% of oilseed production was processed into biodiesel. The growth rate over the previous two years (2002-2004) was 27% and 70% for bioethanol and biodiesel, respectively.

The production of biofuels started after the high oil prices in the seventies which were due to supply restrictions by the OPEC cartel (see, Figure 1). High oil prices induced innovations that saved oil or replaced oil by cheaper or more reliable substitutes, such as biofuels. World bioethanol production grew to about 4 billion gallons in 1985. In the early eighties the oil prices collapsed to their original level and stayed there until the beginning of the new millennium. The level of biofuel production, however, did not collapse but remained almost constant and increased only marginally after 1985. The recent rice in the oil price in combination with environmental concerns lead to the recent biofuel boom.

The only integrated biofuel market in practice is Brazil's cane-based ethanol market. In their ethanol/electricity co-generation system sugar cane becomes a competitive energy provider at petrol prices about US$ 35/bbl (Schmidhuber 2005). The driver for biofuel production in the EU, the USA and Canada is mainly political, including tax exemptions, investment subsidies and obligatory blending of biofuels with fuels derived from mineral oil, while high energy prices further enhance biofuels production and consumption in other countries and regions. Arguments for biofuel promoting policies are reduction of greenhouse gas emissions in the light of climate change, diversification of sources of energy, improvement of energy security and an decreased dependency on unstable oil suppliers, benefits to agriculture and rural areas, etc.

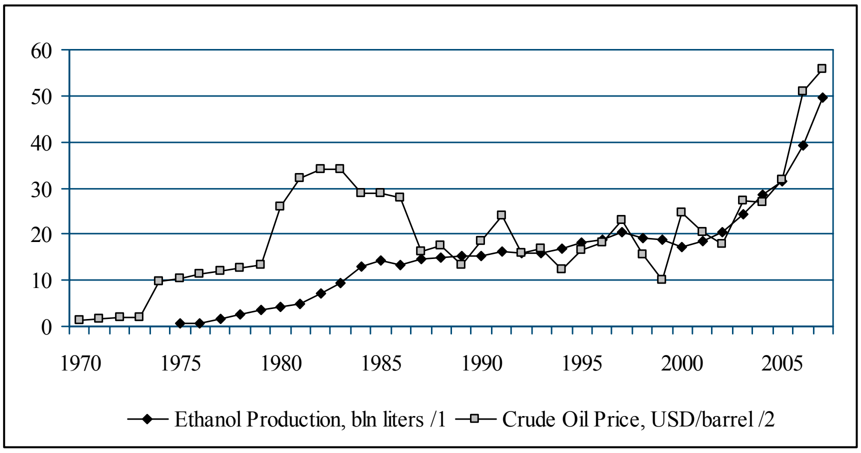


Fig 1: World fuel ethanol production and crude oil prices, 1975 - 2007

/1 F.O. Licht (2007).
/2 Nominal prices. Saudi-Arabian Light-34°API.
Source: http://www.eia.doe.gov/emeu/aer/txt/ptb1107.html (17.07.2007)

Until now biofuels have been produced by processing agricultural crops using available technologies. These so called first-generation biofuels can be used in low % blends with conventional fuels in most vehicles and can be distributes through existing infrastructure. Advanced conversion technologies are needed for a second generation of biofuels. The second generation will use a wider range of biomass resources-agriculture, forestry and waste materials- and promise to achieve higher reductions in greenhouse gas emissions and the costs of fuel production (Smeets et al., 2006 and Hoogwijk et al., 2005).

Given the current policy developments and the availability of jus first generation biofuels an increased biofuel production either due to 'pure' market forces and/or 'policy' might has significant impacts on agricultural markets, including world prices, production, trade flow, and land use. Linkages between food and energy production include the competition for land, but also for other production inputs. The effect of an increasing supply of by-products of biofuel production such as oil cake and gluten feed also affect animal production for instance. Furthermore, the biofuel boom raised concerns such as whether biofuels would hurt poor people by increasing food prices or whether it would lead to loss in biodiversity due to increased land use. All these implications are not well understood and this study tries to address these issues.

More specifically, the purpose of this paper is to assess the global and sectoral implications of the *EU biofuels directive*, European Commission (2003), in a multi-region computable general equilibrium framework. This directive states that the EU Member States should ensure that biofuels and other renewable fuels attain a minimum share of their total consumption of transport fuel, which is responsible for almost 25% of all greenhouse gas emissions in the EU. This share should lie, measured in terms of energy content, at 5,75% by the end of 2010. These goals are not yet mandatory, but this might be changed and a discussion about higher shares in the future is ongoing. With this focus on the impact of the EU Biofuel Directive (BFD) on production, land use and trade this paper contributes to the current discussion on growing competition between agricultural products used for food, feed and fuel purposes.

The economic literature on the impacts of biofuels on agricultural markets is scarce, as the biofuel boom appeared only recently. A partial equilibrium approach with exogenous shifters for biofuel demand, is used by OECD (2006), Elobeid and Tokgoz (2006) and Nowicki et al. (2007). In this paper we use a general equilibrium approach as energy demand and energy or climate change policies might become crucial determinants of agricultural markets. Furthermore, McDonald et al. (2006) point out that substituting biomass for crude oil will have direct effects on the crude oil market and may have indirect effects on the global agricultural markets through exchange rate linkages.

This paper describes the methodological approach to extend a computable general equilibrium model to first generation biofuel production. For this extension the approach separates energy from non-energy intermediate inputs and presents energy inputs in a capital-energy composite(Burniaux and Truong, 2002). It extends this methodology by explicitly depicting the use of cereals, vegetable oils and sugar-beet or –cane as inputs in the production of biofuels in a multi-level structure in the petroleum activity. This extension enables to analyze the impact of targeted policies such as tax exemptions and obligatory blending for the petroleum sector for individual regions and countries

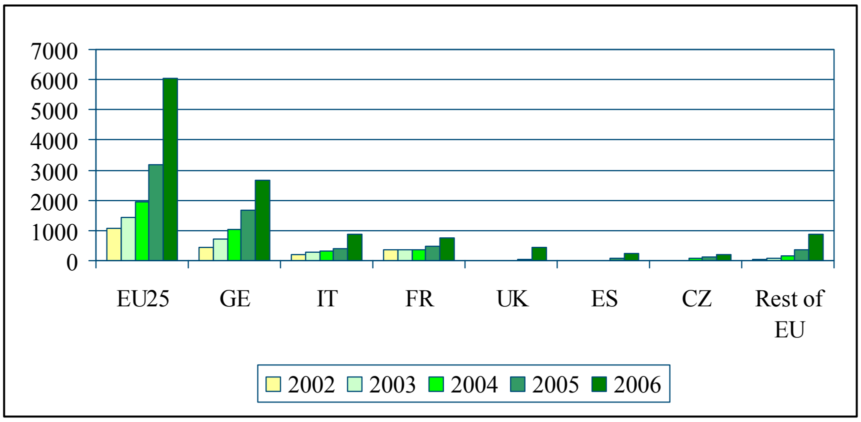
Next to the extensions directly related to modeling biofuels we included some key characteristics of related markets. Particularly the functioning of the land market is crucial. Therefore we included a new demand structure to reflect that the degree of substitutability of types of land differs between land types (Huang, et al. 2004) and we included a land supply curve to include the process of land conversion and land abandonment (Meijl et al. 2006). Furthermore we modeled that agricultural labor and capital markets are segmented from the non-agricultural factor markets.

The general structure of the paper is the following; Section 2 describes the recent developments on the EU biofuel market and related policies and it gives an overview of the literature on biofuels and agricultural markets. The methodological improvements are described in section 3 and section 4 shows the scenario results of implementing the EU biofuel directive and some sensitivity analyses with regard to two key uncertainties: the oil price and elasticity of substitution between biofuels and fossil fuels. The final section summarizes the outcome and results of this paper.

2 EU biofuel markets and policies

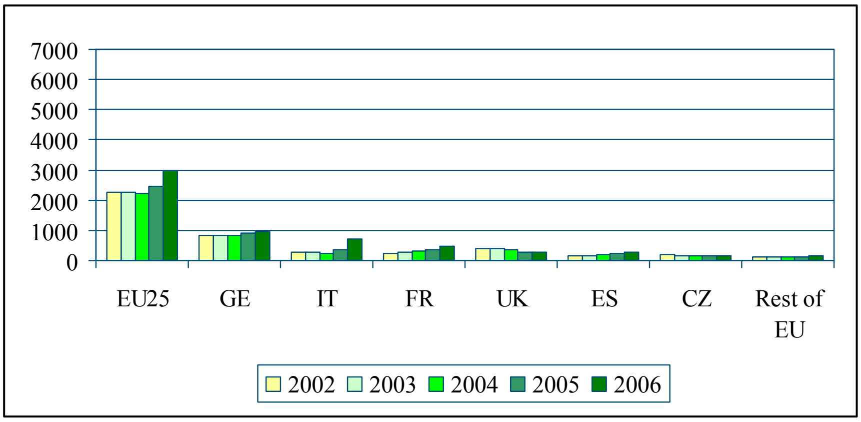
The following graphs illustrate the dynamic development in the market of biodiesel and ethanol in the EU. In Europe the biodiesel is growing stronger compared to ethanol with a current level of more than 6.0 mio t of biodiesel while ethanol production in Europe is about 3.0 mio t. Almost half of the EU biodiesel is produced in Germany were it was stimulated by tax exemptions.

Fig 2: Biodiesel production in the EU, 2005 (1000 t)



Source: Data derived from F.O. Licht (2007).

Fig 3: Bioethanol production in the EU, 2005 (1000 t)



Source: Data derived from F.O. Licht (2007).

Biofuels are just one element in the complex EU strategy to meet the future energy demand. The EU Biofuels Directive presented by the EU Commission in 2003, set out indicative targets for Member States. To help meet the 2010 target – a 5.75% market share for biofuels in the overall transport fuel supply – the EU Commission has adopted an EU Strategy for Biofuels. The '*European Union Biofuel Strategy*', (European Commission, 2006a) and the '*Renewable Energy Road Map*', (European Commission, 2006b) propose an overall binding target of 20% renewable energy by 2020 and a 10% biofuels-target by 2020.

Table 1: Progress in the use of biofuels in the Member States, 2003-2005

	2003	2004	2005
	Member State Biofuel share		National Indicative Target
Austria	0.06	0.06	2.50
Belgium	0.00	0.00	2.00
Cyprus	0.00	0.00	1.00
Czech Republic	1.09	1.00	3.70[1]
Denmark	0.00	0.00	0.10
Estonia	0.00	0.00	2.00
Finland	0.11	0.11	0.10
France	0.67	0.67	2.00
Germany	1.21	1.72	2.00
Greece	0.00	0.00	0.70
Hungary	0.00	0.00	0.60
Ireland	0.00	0.00	0.06
Italy	0.50	0.50	1.00
Latvia	0.22	0.07	2.00
Lithuania	0.00	0.02	2.00
Luxembourg	0.00	0.02	0.00
Malta	0.02	0.10	0.30
The Netherlands	0.03	0.01	2.00 [2]
Poland	0.49	0.30	0.50
Portugal	0.00	0.00	2.00
Slovakia	0.14	0.15	2.00
Slovenia	0.00	0.06	0.65
Spain	0.35	0.38	2.00
Sweden	1.32	2.28	3.00
UK	0.03	0.04	0.19
EU25	0.50	0.70	1.40

[1] 2006; [2] Estimate.

Source: European Commission (2007). Biofuels Progress Report

According to the *EU biofuels directive*, the EU Member States should ensure that biofuels and other renewable fuels attain a minimum share of their total consumption of transport fuel. This share should lie, measured in terms of energy content, at 5,75% by the end of 2010. These goals are not yet mandatory, but this might be changed and a discussion about higher shares in the future is ongoing. Apart from initiative which focus on biofuels other directives try to promote electricity produced from renewable energy sources specifying a target for the shares of 'green electricity' in 2010 (12,5% without hydroelectric energy). These measures were accompanied by measures giving additional leeway to member states for tax exemptions in favour of bioenergy. Germany, for example, subsequently made use of the full tax exemption which has been a key determinant for the remarkable growth of biofuel use in this country (see,

Figure 1).[1] Other national legislation also triggered a lasting boom in the production of biogas from energy crops, in particular maize. Since agricultural land is limited, a substantial expansion of energy maize acreage competes with other objectives, e.g. those of the biofuels Directive.

Apart from these initiative most of the EU member states are far away from reaching the target of 5.75% in 2010. Table 1 illustrates the current situation and the average use of biofuels in transport at EU-25 level is currently (2005) at 1.0 percent. However, in many EU member states the biofuel shares for transportation purposes increased during the last years. This development can be explained by above mentioned introduction of tax exemptions for renewable energies but also by an increase in oil prices which changes the relative prices in favor of biofuels. This endogenous growth can be expected to continue under a continuously increasing price for fossil fuels. However, it is the question whether the objective can be reached in 2010?

As in the EU the main drivers for increased biofuel demand in the USA are high energy prices and incentives provided by the Energy Policy Act of 2005. The EPACT05 requires a minimum of 7.5 billion gallons (approx. 28.7 billion litres) of renewable fuels (ethanol and biodiesel) to be used in the nation's motor fuel by 2012. Apart from the EU and the USA other countries like Canada, Brazil, Australia, India and China also implemented targets for biofuels volumes and market shares.

3 Biofuels and agricultural markets: results from the literature

Modeling of biofuel is a challenge in terms of data availability. Given the current dynamics in the markets for biofuels it is difficult to build a consistent data base which may serve for medium-term projections. Within the last two years many existing model – partial and general equilibrium models – focusing on agriculture and food processing have been extended to represent the production and consumption of biofuels. Most quantitative model results have been based on partial equilibrium models, such as AGLINK, FAPRI, ESIM or AGMEMOD. Given the medium term horizon of the most modeling applications, the focus of these models has been put on first generation energy crops and biofuels are introduced with an exogenous shift in the demand for commodities used in the production of biofuels. With this focus the model results show the impact of an enhanced demand for biofuel crops on agri-food markets at national and/or global scale. Most models do not consider 2nd generation biofuels and or implemented 2nd generation biofuels on a more ad hoc approach.

The Scenar2020 project (Nowicki et al. 2007) identifies the tightness of oil/energy markets as a major uncertainty with regard to all conclusions concerning the future of agricultural markets and rural areas. Therefore the impact of biofuels may be under-estimated. They find, by using exogenous shifters in a partial equilibrium EU model

[1] In Germany this tax exemption will be phased out within the next years.

called ESIM, that meeting 10% of EU energy requirements for transport in 2010 could take up 43% of current land use for cereals, oilseeds, set aside and sugar beet. The 5.75% objective for 2010 in itself will require 15.03 mio tonnes of biofuels. If the feedstocks are all grown domestically, this would be equivalent to 12.02 mio ha, or 9.4% of EU-25 agricultural land demand. It is projected, however, that in 2010 there will be only 6.98 mio ha of agricultural land used to produce biofuels feedstocks, which is equivalent to 8.74 mio tonnes of biofuels, 58% of total biofuels used and 5.5% of total agricultural land demand. A corollary of the increased demand for biofuels is the increased resort to biobased materials (partially motivated to replace plastics, a petroleum derivative); the conjunction between the demand for biofuels and the demand for biobased materials is likely to create competition with other demands for agricultural commodities.

According to estimates published by the European Commission (2006), which are based on the same partial equilibrium model, oilseed area would be 0.75 mio ha higher than without biofuel policies and reach 8 mio ha as compared to 7.25 mio ha without the expected increase biodiesel demand. Sunflower seed area would expand by 0.2 mio ha to 1.7 mio ha as compared to unchanged biofuel policies. Rapeseed area would increase by 0.55 mio ha. Also cereal area could expand by 2.5 mio ha to 52.5 mio ha as compared to the baseline. Driven by higher prices cereal production would expand by 6% or 16.2 mio t from 266 mio t in the baseline to 272 mio t under the biofuel scenario in 2010.

The FAPRI biofuel model has been used for simulating the impact of trade policies in the area of biofuel trade, especially the removal of U.S. import tariffs on ethanol as well as the removal of the federal tax credit for refiners blending ethanol (Elobeid and Tokgoz, 2006). The removal of trade distortions induces a 23.2 percent increase in the price of world ethanol relative to the baseline. The U.S. domestic ethanol price decreases by 14.1 percent, which results in a 7.5 percent decline in production and a 3.2 percent increase in consumption. The lower domestic price leads to a 2.5 percent rise in the share of fuel ethanol in gasoline consumption. There is a strong increase in U.S. net ethanol imports increase by 192.8 percent. In Brazil production increases due to the increase in ethanol world prices by 8.8 percent on average with a corresponding decline in Brazil ethanol consumption. The removal of trade distortions and the removal of domestic subsidies in the U.S. to refiners blending ethanol induces a 22.5 percent increase in the world ethanol price.

The OECD AGLINK model has been applied to analyze the impact of biofuel production on land use in Europe and other regions in the world (OECD, 2006). The main findings indicate that the three OECD regions, the US, Canada and EU (15) would require between 30% and 70% of their respective current crop area if they are to replace 10% of their transport fuel consumption by biofuels, assuming unchanged production technologies, feedstock shares and crop yields, and in the absence of international trade in biofuels or use of marginal or fallow land. However, only 3% would be required in Brazil. The additional demand for agricultural commodities resulting from increased biofuel production is likely to substantially affect the world agri-food markets. The major producers of biofuels – Brazil, the US, the EU and

Canada – are expected to significantly reduce their exports of the respective feedstock commodities or to increase their imports. Compared to a situation with unchanged biofuel quantities at their 2004 levels, crop prices in 2014 could increase by between 2% in the case of oilseeds and almost 60% in the case of sugar.

All these studies show that a shift in demand for agricultural products leads to substantially increased agricultural market prices and increased land use. From a methodological point of view this paper contributes to the existing literature by endogenises energy markets, including energy policies, were biofuels compete with fossil fuels. Furthermore, like the OECD study it includes the crucial global dimension but we endogenice international trade and allow for the use of marginal lands.

4 Modeling of biofuels

Biofuels are modeled as a 'blend' of bio-based products and fossil resources used in the production of fuel. We assume that agricultural products, such as vegetable oils, sugar-beet-cane, grains and/or wheat are directly used as intermediate inputs next to crude oil in the fuel production. The relative importance of these two kinds of inputs (corrected for their energy contents) determines the share of biofuels in the production of fuel. We assume that biobased and fossil inputs are substitutes and therefore the biofuel share is dependent on relative prices between bio-based and fossil inputs and on policies. An increasing demand on bio-based products creates the additional demand for land and land flows from food related products to industrial products. To model this process properly we introduced the new land market model taking care of limited substitution of different land types and limited land availability. Since the 2001 GTAP data base does not fully account for biofuel use and its rapid developments in the last years, we adjust the original data.

In this sections we describe the methodological improvements which are crucial for modeling biofuels in a global general equilibrium model. First, the standard general equilibrium model (including the data) that is used as a starting point, secondly the contributions to the energy markets to model biofuel demand and thirdly improvements to the modeling of crucial factor markets. Finally, we describe the adjustments to the data.

Standard GTAP model features

This biofuel implementation uses a modified version of the GTAP multi-sector multi-region AGE model, Hertel (1997). This multi-region model allows us to capture inter-country effects, since the biofuels and the EU biofuel directive influences demand and supply on the world market and therefore world market prices, and hence will affect trade flows and GDP. The multi-sector dimension makes it possible to study the link between energy, transport and agricultural markets.

In the standard GTAP model each single region is modelled along relatively standard lines of multi-sector AGE models. All sectors are producing under constant returns to scale, and perfect competition on factor markets and output markets is assumed. Firms combine intermediate inputs and primary factors (land, labour and capital). Intermediate inputs are used in fixed proportions, but are themselves CES composites of domestic and foreign components. In addition, the foreign component is differentiated by region of origin (Armington assumption), which permits the modelling of bilateral (intra-industry) trade flows, depending on the ease of substitution between products from different regions. Primary factors are combined according to a CES function. Regional endowments of land, labour and capital are fixed. Labour and capital are perfectly mobile across domestic sectors. Land, on the other hand, is imperfectly mobile across alternative agricultural uses, hence sustaining rent differentials. Each region is equipped with one regional household which distributes income across savings and consumption expenditures according to fixed budget shares. Consumption expenditures are allocated across commodities according to a non-homothetic CDE expenditure function.

GTAP data used

Version 6 of the GTAP data for simulation experiments was used. 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. An additional interesting feature of version 6 is the distinction of the 25 individual EU Member States. 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).

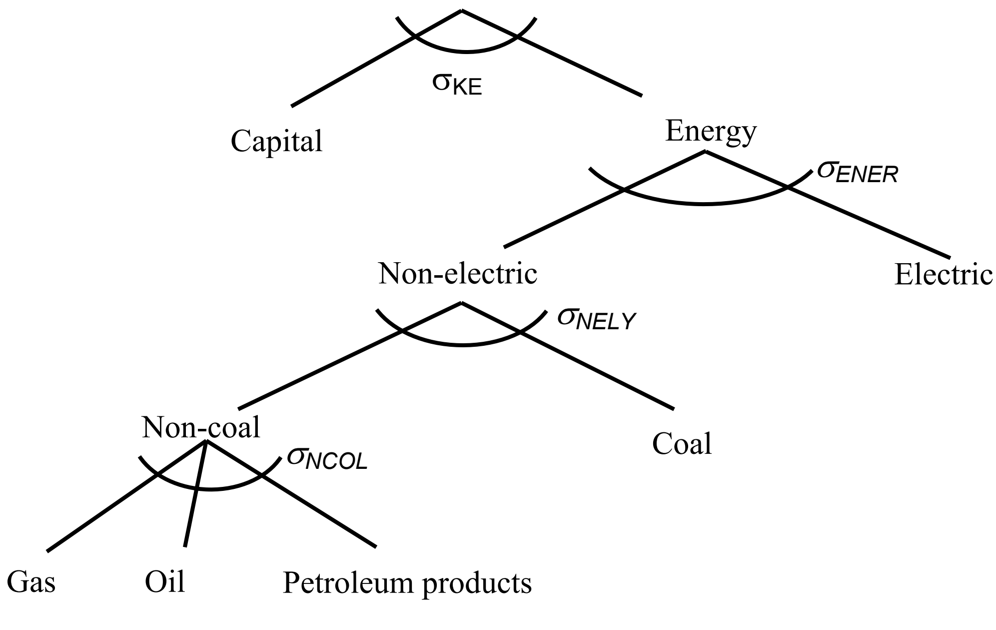
The social accounting data were aggregated to 37 regions and 13 sectors (see Annex Tables A2.1 and A2.2, respectively). The sectoral aggregation distinguishes agricultural sectors that can be used for producing biofuels (e.g. grains, wheat, oilseeds, sugar cane/beet) and that use land, and energy sectors that demand biofuels (crude oil, petroleum, gas, coal and electricity). 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.

Energy markets

The model is extended by introducing energy substitution in production by allowing energy and capital to be either substitutes or complements (GTAP-E, Burniaux and Truong 2002) . Compared to the standard presentation of production technology the GTAP-E model aggregates all energy-related inputs for the petrol sector, such as crude oil, gas, electricity, coal, petrol products, under the nested structure under the value added side. At the highest level the energy related inputs and the capital inputs are modeled as an aggregated 'capital-energy' composite (See, Figure 4)

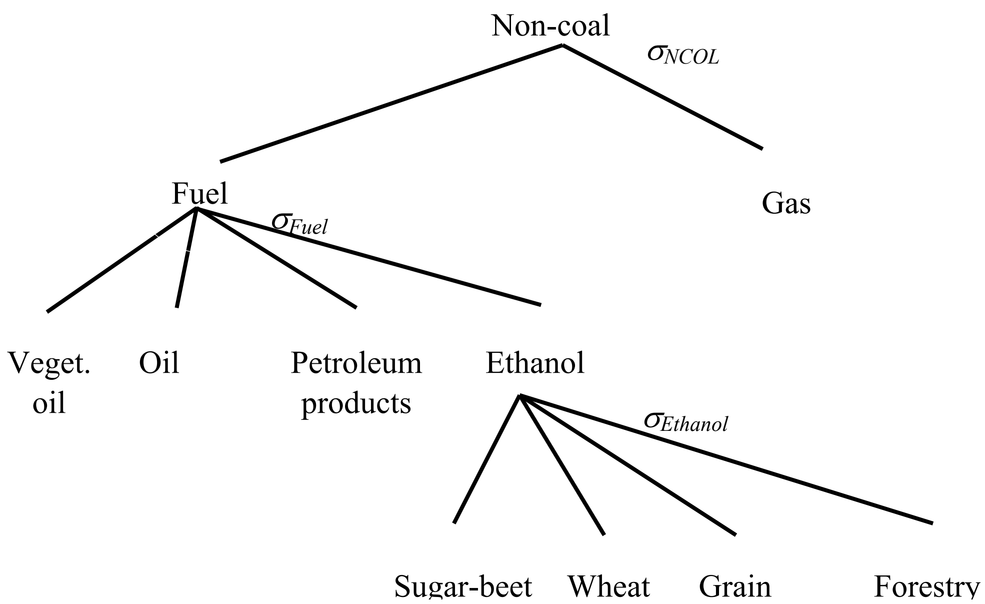
Fig 4: Capital-energy composite in GTAP-E



To introduce the demand for biofuels the nested CES function of the so-called GTAP-E has been adjusted and extended to model the substitution between different categories of oil (oil from bio-crops and crude-oil), ethanol and petroleum products and in the value added nest of the petroleum sector (see, Figure 5). The model presents the fuel production at Non-coal level differently compared to the approach applied under the GTAP-E model. The non-coal aggregate is modeled the following way: 1) The non-coal aggregate consists of two sub-aggregates, fuel and gas. 2) fuel combines vegetable oil, oil, petroleum products and ethanol. 3) Ethanol is made out of sugar-beet-cane, grains and/or wheat.

This approach is able to present an energy sector where industry's demand of intermediates strongly depends on cross-price relation of fossil energy and bio-fuel-based energy. Therefore, the output prices of the petrol-industry will be amongst others a function of fossil energy and bio energy prices. The nested CES structure implies that crucial variables for the demand for biofuels are the relative price developments of crude oil versus the development of the agricultural prices. Also important is the initial share of biofuels in production of fuel. A higher share implies a lower elasticity and larger impact on the oil markets. Finally, the value of the various substitution elasticity's (σ_{Fuel} and $\sigma_{Ethanol}$) are crucial. These represent the degree of substitutability between crude oil and biofuels. For this paper both values are 4, which are based on our focus on the medium term (2001-2010) and the value of the elasticities in the lowest level applied in Burniaux and Truong (2002).

Fig 5: Input structure in the petroleum sector



In addition, prices for outputs of the petroleum industry will depend on any subsidies/tax exemptions in the respective EU Member States which affect the price ratio between fossil energy and bio energy. Finally, and most importantly for current EU policy, the level of demand for biofuels will be heavily determined by any enforcement of national targets through, e.g. mandatory inclusion rates. Possible mandatory inclusion rates of bio-fuels will be implemented as exogenous shifters at the level of the intermediate demand of the petroleum industries which will then lead to an increase in domestic production and/or imports of bio-fuels.

Mandatory blending, such as the EU biofuel directive, is modeled by a subsidy given to the petro-industry to reduce the input prices for biofuel inputs. This subsidy is modeled as an endogenous variable which varies between EU Member States. To implement this incentive instrument as a 'budget-neutral' instrument it is counter-financed by an end user tax on petrol consumption.

Factor markets:

To analyze the impact of biofuels we change the standard GTAP model to included some key characteristics of related markets. Particularly the functioning of the land market is crucial. Therefore we included a new demand structure to reflect that the degree of substitutability of types of land differs between land types (Huang, et al. 2004). The land use allocation structure was extended by taking into account the degree of substitutability of types of land differs between types (Huang et al., 2004). Therefore, OECD's more detailed Policy Evaluation Model (OECD, 2003) structure was used. Moreover, we included a land supply curve, which specifies the relation between land supply and a rental rate, to include the process of land conversion and land abandonment (Meijl et al. 2006). Through this land supply curve an increase in demand for agricultural purposes will lead to land conversion to agricultural land and a modest increase in rental rates when enough land is available, whereas if almost all agricultural land is in use increases in demand will lead to increases in rental rates. In comparison to the Meijl et al. (2006) paper we improved the empirical implementation of the land supply curve by including estimated elasticities for individual EU15 countries (see Cixous, 2006) and a better measurement of the position of the asymptote

Next to these changes to the land market we introduced the stylized fact of factor market segmentation for labor and capital between agricultural and non-agricultural markets. If labor were perfectly mobile across domestic sectors, we would observe equalized wages throughout the economy for workers with comparable endowments. This is clearly not supported by evidence. Wage differentials between agriculture and non-agriculture can be sustained in many countries (especially developing countries) through limited off-farm labor migration (De Janvry et al., 1991). Returns to assets invested in agriculture also tend to diverge from returns of investment in other activities. Factor market segmentation is introduced by specifying a constant elasticity of transformation (CET) structure that transforms agricultural labor (and capital) into non-agricultural labor (and capital) (Hertel and Keening, 2003). The elasticities of transformation can be calibrated to fit estimates of the elasticity of labor supply from Policy Evaluation Model (OECD, 2003).

Agricultural policies are crucial for the development of biofuels. As we focus on the EU biofuel directive, we include some key features of the Common Agricultural Policy such as the introduction of endogenous agricultural quota as a complementarity problem (Meijl and Tongeren 2002).

Adjustment of the GTAP 6 database towards biofuels

Developments in the biofuel sector are extremely fast. Therefore, we updated the GTAP database to include the latest developments. The calibration of the biofuels in LEITAP is based mainly on sources published in F.O. Licht's World Ethanol and Biofuel Reports as well as the F.O. Licht Interactive Database for Ethanol and Biofuels (F.O. Licht 2007). Current use of biofuels at EU member state level are derived from Eurostat and publication of the European Commission (see table 1). For implementing 1st generation biofuels the GTAP data base has been adjusted for the input demand for grain, sugar and oilseeds in the petroleum industry. Under the adjustment process the total intermediate use of these three agricultural products at national level has been kept constant while the input use in non-petroleum sectors has been adjusted in an endogenous procedure to reproduce 2004 biofuels shares in the petroleum sector (corrected for their energy contents).

5 Scenario results

5.1 Scenario description

To assess the impact of biofuels and related polices we use the Global Economy of the EURURALIS project as a reference scenario, (Wageningen UR and Netherlands Environmental Assessment Agency, 2007). This scenario is an elaboration of one of the four emission scenarios of the IPCC, as published in its Special Report on Emission Scenarios (SRES; Nakicenovic et al., 2000) and the Dutch Central Planning Bureau (CPB) detailed focus on Europe with more regional and sectoral disaggregation (CPB, 2003).

Table 2. Scenario assumptions

Trade policies	Stepwise elimination of all trade barriers. • 2010: 25% reduction compared with 2001 • 2020: 50% reduction compared with 2010 • 2030: abolished for all sectors
Domestic support in agriculture	CAP reform 2003: full decoupling • 2010: 25% reduction of domestic support, new EU member states domestic agricultural support agreed by EU minus 25% reduction • 2020: 50% reduction compared with 2010 • 2030: abolished for all sectors
Production quotas	2020: abolished
Bio-Fuels	No blending obligations
Set aside	Abolished in EU15 until 2010, never introduced in New Member States

We use the Global Economy (equivalent of A1 of SRES) scenario which assumes the WTO negotiations are successful, global trade fully liberalized and a further eastwards enlargement of the EU including Turkey (see, Table 2). Technological change is high. This scenario shows the highest income growth for almost all regions (CPB, 2003). In this paper we focus on the medium term of 2001-2010.

In the reference scenario there is a strong in increase in GDP per capita across all regions covered in this analysis. However, growth rates differ between regions from 1.6% p.a. in Japan Korea to 4.4.% p.a. in Asia (see, Table A-3 in the annex).

In the policy scenarios we take the implementation of the EU bio-fuel directive as an example for a mandatory blending obligation and illustrate the consequences of this biofuel policy on the national and international markets for agri-food products. In these scenarios we apply two different rates of mandatory blending in the individual EU member states: a) a 5.75% obligatory blending and b) a 11.5% obligatory blending rate which have to be fulfilled in each individual member state.

As the biofuel market is surrounded with uncertainties we perform sensitivity scenarios with regard to two of the main key factors – the development of the world price of crude oil and the elasticity of substitution between different inputs in biofuel production in the petroleum industry.

The following section will present the results for the reference scenario which does not assume any enforced mandatory blending target. The impact of EU biofuel policies are presented first at global level and then at national level for some selected countries within and outside the EU. Note, that under the policy scenarios only the mandatory blending obligation within the EU are changed. All other policy instruments remain unchanged compared to the reference scenario

5.2 Scenario results

With an enhanced biofuel consumption as a consequence of the EU biofuel directive prices of agricultural products tends to increase. This is especially the case for those products which are directly used as biofuel crops. Under the reference scenario real world prices for agricultural products tends to decline conform their long term trend, see Figure 6. This is caused by an inelastic demand for food in combination with a high level of productivity growth. Under the BFD-5.75% scenario world prices rise relative to the reference scenario. The real price of oilseeds shows a positive development in contrast to their long term trend. Compared to the US and Brazil where ethanol consumption dominates the biofuel sector, the EU biofuel is based on bio-diesel, which is reflected by the increase in prices of these products. Under a more enhanced scenario (BFD-11.5%) prices of sugar and cereals also start to increase. The crude oil price declines a little bit due to the introduction of the biofuel directive as demand for crude oil diminishes.

Fig 6: Changes in real world prices, in %, 2010 relative to 2001

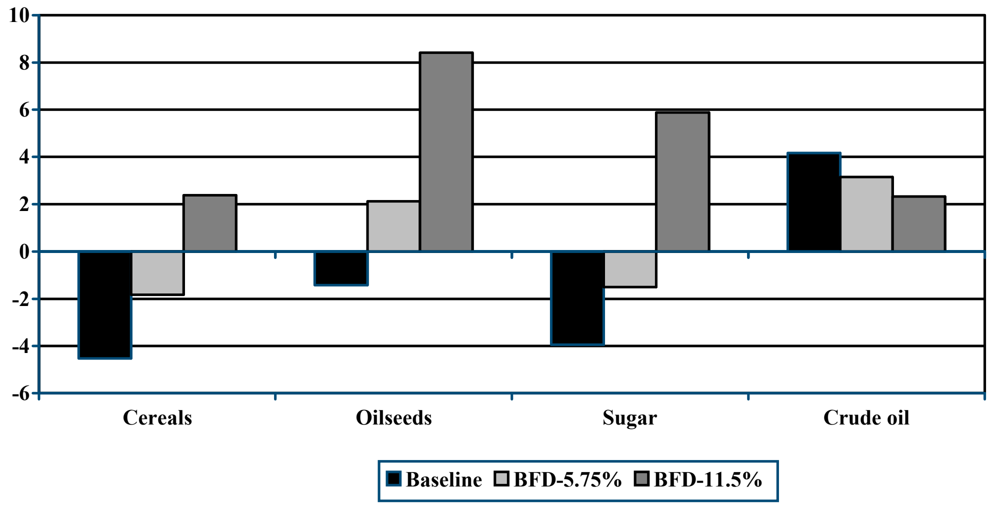
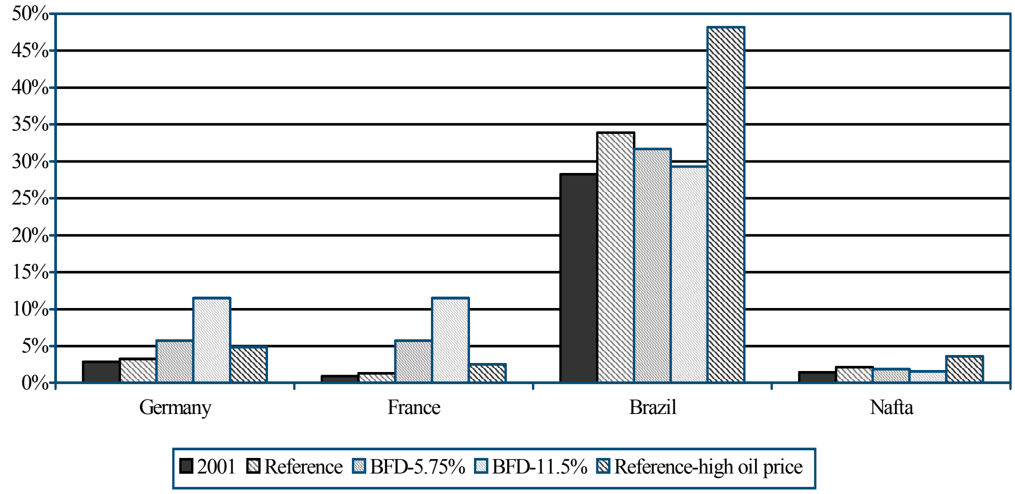


Fig 7: Development of share of biofuels in fuel consumption for transportation for selected regions, in %, 2001 and 2010

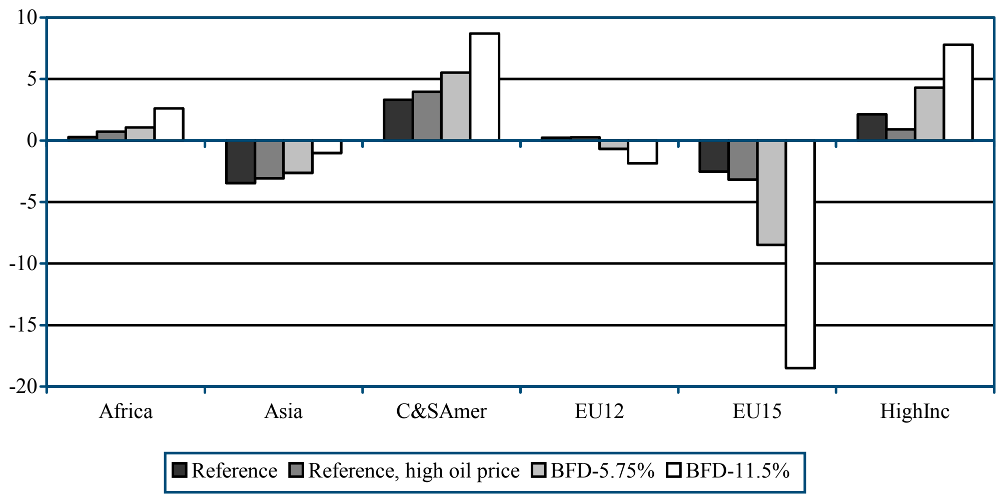


Even without a enforced use of biofuel crops through a mandatory blending the share of biofuels in fuel consumption for transportation purposes increase. This endogenous increase in biofuel production is due to the fact that the ratio between crude oil price and prices for biofuel crops changes in favor of biofuel crops (see, Figure 6). Under the reference scenario biofuel shares increase. The highest increase is in the already integrated market of Brazil where the initial 2001 share of more than 29% expands to more than 33% in 2010. In Germany and France the endogenous growth of biofuel share leads to biofuel consumption for transportation in 2010 of 3.3% in Germany and 1.3% in France. These results reveal that without a mandatory blending the 5.75% biofuel share will not be reached in the member states of the EU. Even under a scenario with a strong increase in crude oil price (Reference-high oil price, increase in oil price is 20% higher than in reference scenario) the shares in biofuel use in transportation will remain below 5.75%. Higher oil prices affect Brazil biofuel consumption significantly. Here biofuel shares increase above 48%

With a mandatory blending the EU member states fulfill the required targets of 5.75% under BFD-5.75% and BFD-11.5%. However at the expense of non-European countries. Under the BFD-5.75% scenario the share of biofuel use declines in Brazil by 7% and under the BFD-11.5% scenario by almost 15%. This decline in biofuel production non-European countries is due to the increase in relative prices between biofuel crops and crude oil. The enhanced demand for biofuel crops in the EU under the BFD scenario leads to an increase in world prices for these products and hence to a decline in the profitability in fuel production compared to crude oil. However, the increase in biofuel crop demand in the EU over-compensates the decline in non EU countries and at global level the use of biofuel crops for fuel production increases under the BFD scenarios. A good indicator for this development is the decline in crude oil price under the BFD scenarios compared with reference scenario, see figure 6. Given the assumption that biofuels lead to less CO2 emissions than fossil fuel the decline in the world oil price also indicates that the EU biofuel directive leads to less CO2 emission on the global level.

Figure 8 shows that the EU – both EU12 and EU15 – will become net-importers of agricultural commodities used for the production of biofuels under the biofuel scenarios. South and Central America as well as other high income countries expand their net-exports in agricultural products for biofuel production.

Fig 8: Changes in net biofuel crop trade, in bill. US$, 2010 versus 2001 (in %)



Compared to world income growth the annual growth rates of agricultural production are quite moderate in the reference scenario. In the EU and in the region of high income countries agricultural production is also negatively affected by the liberalization which is implemented in the Global Economy or reference scenario. At aggregated level total agricultural production increases in the reference and both policy scenarios. In all regions mandatory blending also leads to an increase in total agricultural output, see Table 3. Comparing the BFD-5.75% scenario with the reference the strongest relative increase in agricultural output takes place in the EU15 and South and Central America .

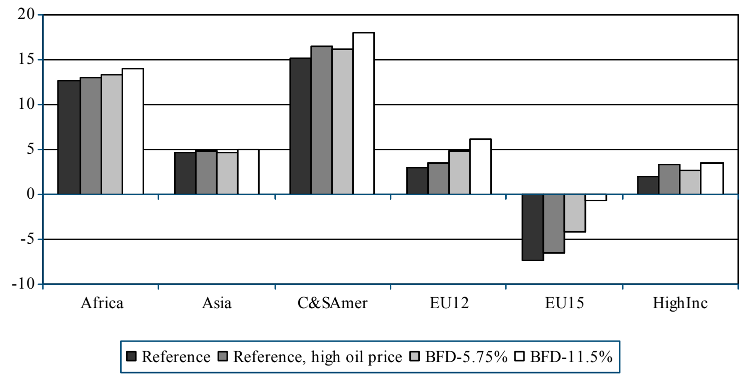
Table 3: Changes in agricultural production, in %, 2010 relative to 2001

	Africa	Asia	C&SAmer	EU12	EU15	EU27	HighInc	World
Arable Crops								
Reference	28.4	22.1	21.8	10.0	8.6	8.7	11.3	17.2
BFD-5.75%	28.7	22.2	23.8	11.2	10.8	10.7	11.8	17.8
BFD-11.5%	29.2	22.4	26.3	12.1	12.4	12.2	12.8	18.6
Reference, high oil price	28.8	22.6	24.4	10.2	9.3	9.3	13.3	18.2
Biofuel Crops								
Reference	40.9	27.2	30.6	12.4	-7.0	-4.5	12.4	17.9
BFD-5.75%	44.0	28.4	35.3	19.2	5.9	7.6	13.5	21.3
BFD-11.5%	50.6	30.5	42.7	26.5	16.0	17.3	15.7	25.7
Reference, high oil price	43.4	31.2	41.7	14.1	-2.3	-0.2	17.8	22.8
Oilseeds								
Reference	35.8	24.8	27.4	3.0	5.4	5.0	25.5	23.3
BFD-5.75%	41.6	26.3	35.8	17.0	31.1	28.7	28.8	29.1
BFD-11.5%	51.0	28.2	46.3	28.8	48.8	45.4	35.2	35.7
Reference, high oil price	43.9	30.5	38.2	10.4	15.2	14.4	40.2	32.6

Table 3 presents the results for changes in oilseed production which strongly expands under the policy scenarios. Oilseed production in the EU27 increases from 5% in the Reference to 29% in the BF-5.75% and to 49% in the BF-11.5%.

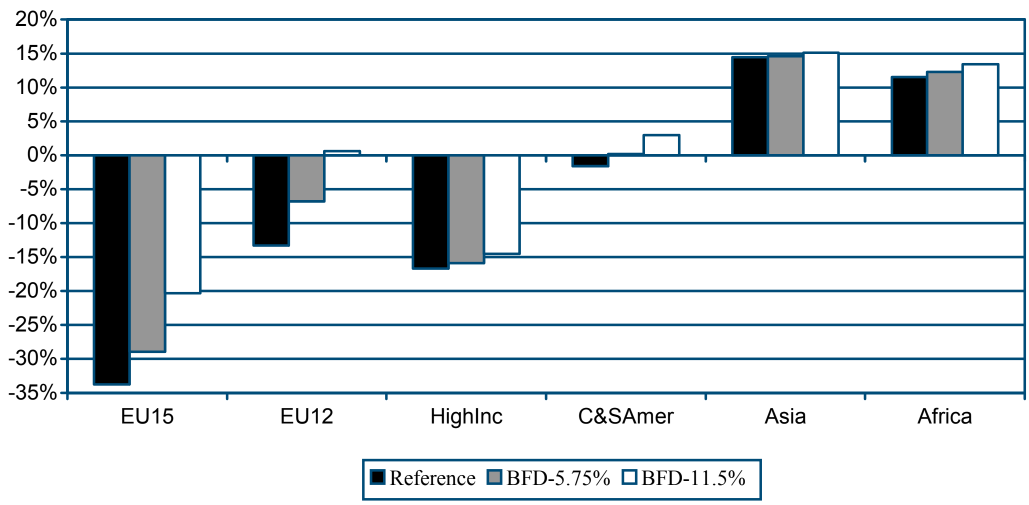
This production developments lead to a similar pattern of land use developments (Figure 9). Land use increases in all regions compared with reference and therefore also at the global level if the biofuel target are implemented by a mandatory blending commitment. In the EU15 the decline in agricultural land use, as a consequence of the liberalization in the reference scenario, almost reverses under the BFD-11.5% scenario. This expansion of agricultural land use on a global scale and especially in Southern America might indicate a decline in biodiversity in these countries as land use is an important driver for biodiversity, see CBD, 2006.

Fig 9: Changes in agricultural land use, in %, 2010 relative to 2001



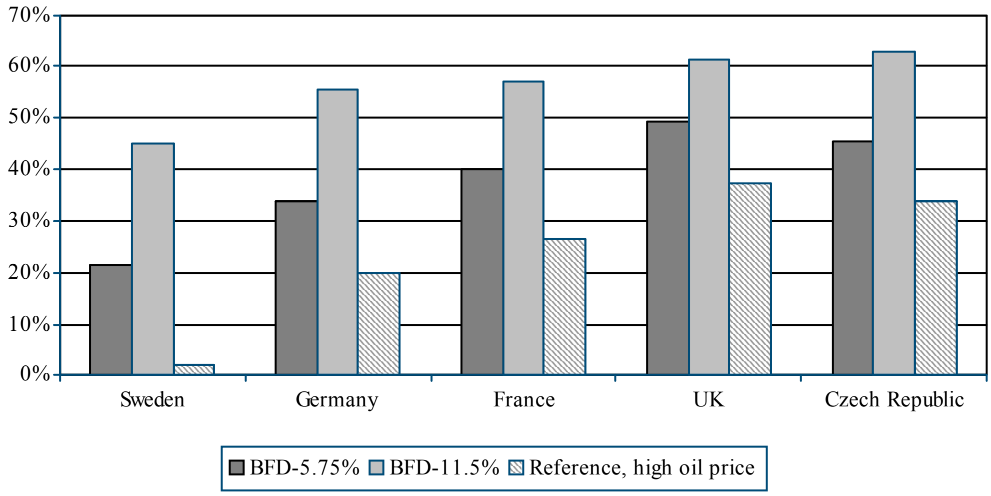
Apart from the direct impact of an increase in biofuel demand on prices and production, the changes in agricultural income from agricultural are significant (Figure 10). The EU farm income increases relative to the reference scenario where farm income declined after reduction of income and price support. The positive development in incomes is mainly due to higher agricultural prices. Agricultural income outside the EU increase; in South and Central America by almost 5% under BFD-11.5% relative to reference scenario.

Fig 10: Development in agricultural income, in bill USD, 2001 and 2010



As outlined above the targets set in the two biofuel scenarios are (endogenously) enforced through a subsidy on biofuel crops use as intermediates in the petroleum sector. To obtain budget neutrality this subsidies are financed by a user tax on petrol consumption. Overall the petrol prices increase with about 2% to meet the 5.75% mandatory blending obligations and with about 8% to meet the 11.5% BFD as feedstocks are more expensive than crude oil to produce fuels. Figure 11 illustrates the internal subsidies on biofuel crops in the petroleum sector which are required to fulfill the given targets by making feedstocks competitive with crude oil. The subsidies are high and rank from 20% in Sweden till almost 50% in the UK. The level of the subsidies is determined by the initial biofuel share and the availability of feedstock to make biofuels. If the 11.5% biofuel directive is mandatory in 2010 than the subsidies increase to the range of 45% to 65%. The required subsidies to meet the targets are very high indicating that fulfilling the targets is a challenge for the EU countries.

Fig 11: Subsidy rates on biofuel crops required to meet the BFD target, in%, 2010



These subsidies indicate the difficulties most EU member states will face to meat the targets given in the EU biofuel directive. The difficulties might be surpassed by making biofuels more competitive due to higher levels of technical change to produce biofuels. Higher yields and especially more efficient conversion technologies are needed to make biofuels competitive (Dale, 2003).

The importance of changes in oil prices on the results of this analysis is given in Figure 11. Under high oil prices the subsidies required to implement the biofuel target will drop significantly. In Sweden – the current front-runner in terms of biofuel use in the EU – the subsidy is almost zero.

Fig 12: Annual growth in GDP per capita, in %, 2001-2010

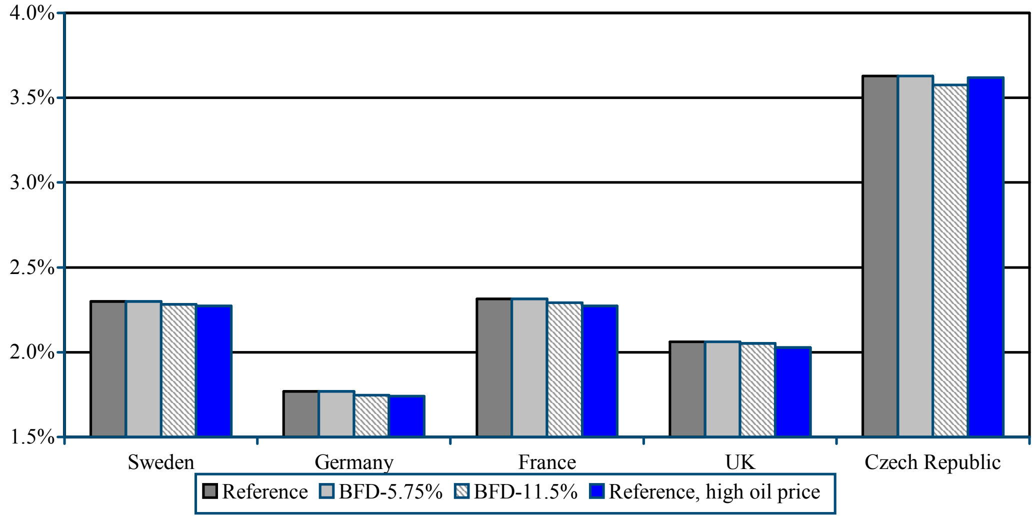


Figure 12 shows that the macroeconomic costs in terms of a lower GDP per capita growth are limited in the EU countries.

5.3 Sensitivity analyses

As the biofuel market is surrounded with uncertainties we perform sensitivity scenarios with regard to two of the main key factors. Section 4 pointed out that for the biofuel development the development of the world price of crude oil and the elasticity of substitution between fossil fuels and feedstocks in the petroleum industry are crucial and surrounded with uncertainty. In section 5.2 we already included some sensitivity analyses with regard to a higher oil price. Table 4 confirms that a higher oil price of 20% induces substitution away from fossil fuels to biofuels, as biofuels become relatively cheaper. The higher share of biofuels in fuel production increase demand for agricultural products world wide which lead to higher world price, biofuel production and land use.

Table 4: Sensitivity analyses with regard to crude oil prices and the elasticity of substitution between fossil and biofuels, in %, 2010 relative to 2001

	standard	high oil price	high elasticity of substitution
World price change			
Cereals	-5.4	-3.2	-3.7
Oilseed	-1.7	3.7	-0.1
Share of Biofuels in Fuel Consumption for Transportation			
Germany	3.3	4.8	3.6
France	1.3	2.5	2.1
Brazil	33.9	47.9	41.1
Nafta	2.1	3.6	2.7
Oilseed production			
Africa	35.8	43.9	37.9
Asia	24.8	30.5	24.3
C&S America	27.4	38.2	32.8
EU12	3.0	10.4	5.3
EU15	5.4	15.2	6.7
High income countries	25.5	40.3	31.5
Agricultural land use			
Africa	12.7	12.9	12.8
Asia	4.7	4.9	4.7
C&S America	15.1	16.4	15.8
EU12	3.0	3.5	3.2
EU15	-7.2	-6.4	-6.9
High income countries	2.0	3.3	2.6

The substitution elasticity between fossil and biofuels indicates how easy fossil fuels can be replaced by biofuels. In the paper we assume a value of 4 conform the value used in Burniaux and Truong (2002) at that level. This value is surrounded with uncertainty but not unrealistic given the short run until 2010 as production process have to be adjusted and capacity has to be build. From a pure technological point fossil and biofuels are close substitutes indicating a higher substitution elasticity in the long run. Table 4 shows the results with high elasticity of substitution of 20. The relatively price increase of fossil fuels to biofuels in the reference run now induces more replacement of fossil fuels by biofuels, implying higher biofuel shares, world prices, biofuel production and land use.

6 Summary and conclusions

This analysis shows that enhanced demand for biofuel crops under the EU biofuel directive has a strong impact on agriculture at global and European level. The long term trend of declining real world prices of agricultural products slows down or might even be reversed for the feedstocks used for biofuels. The incentive to increase production in the EU will tend to increase land prices and farm income in the EU and other regions. The EU will not be able to produce the feeding stocks needed to produce the biofuels according to the BFD domestically and will run into a higher agricultural trade deficit. Biofuel crop production expands in other highly industrialized countries and especially in South and Central America (Brazil). The results heavily depends on the development of crude oil price. The higher the crude oil price the more competitive biofuel crops become in petroleum production.

Without mandatory blending or subsidies to stimulate the use of biofuel crops in the petroleum sector the targets of the EU Biofuel directive will not the reached in 2010. A mandatory blending leads to higher petrol prices as feedstocks are not profitable to use in fuel production given the current technologies. The increased demand for feedstocks raises their price relative to the oil price and adds therefore to the challenge of making biofuels competitive. Therefore, if biofuels have to be competitive in the long run investments in R&D are needed to obtain higher yields or better conversion technologies. However, in this paper the analyses focuses only on 1st generation bio-fuels as we focus on the period until 2010. Decisions on R&D investments should take into account the 2nd generation biofuels as these promise to be more cost effective and more effective in reducing greenhouse gas emissions.

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Annex:

Table A1. Region aggregation

Regions	Original GTAP v 6 regions
Belu	Belgium; Luxembourg.
Dnk	Denmark.
Deu	Germany.
Grc	Greece.
Esp	Spain.
Fra	France.
Irl	Ireland.
Ita	Italy.
Nld	Netherlands.
Aut	Austria.
Prt	Portugal.
Fin	Finland.
Swe	Sweden.
Gbr	United Kingdom.
Euba	Estonia; Latvia; Lithuania.
Euis	Cyprus; Malta.
Cze	Czech Republic.
Hun	Hungary.
Pol	Poland.
Svn	Slovenia.
Svk	Slovakia.
Apeu	Bulgaria; Romania.
Reur	Switzerland; Rest of EFTA; Rest of Europe; Albania; Croatia.
Fsu	Russian Federation; Rest of Former Soviet Union.
Tur	Turkey.
Meast	Rest of Middle East.
NAFTA	United States, Canada, Mexico
Ram	Rest of North America; Colombia; Peru; Venezuela; Rest of Andean Pact; Argentina; Chile; Uruguay; Rest of South America; Central America; Rest of FTAA; Rest of the Caribbean.
Bra	Brazil
Oce	Australia; New Zealand; Rest of Oceania.
Jp_ko	Japan; Korea.
Chi	China; Hong Kong; Taiwan; Rest of East Asia.
Ras	Indonesia; Malaysia; Philippines; Singapore; Thailand; Vietnam; Rest of Southeast Asia; Bangladesh; India; Sri Lanka; Rest of South Asia; Canada.
Naf	Morocco; Rest of North Africa
Ssaf	Botswana; Rest of South African CU; Malawi; Mozambique; Tanzania; Zambia; Zimbabwe; Rest of SADC; Madagascar; Uganda; Rest of Sub-Saharan Africa.
Saf	South Africa

Table A2. Sector aggregation

Sectors in GTAP	Original GTAP v 6 sectors
Pdr	Paddy and processed rice
Wht	Wheat
Grain	Cereal grains nec
Oils	Oil seeds
Sug	Sugar cane, sugar beet
Hort	Vegetables, fruit, nuts
Crops	Plant-based fibers; Crops nec.
Cattle	Cattle,sheep,goats,horses; Wool, silk-worm cocoons; Meat: cattle,sheep,goats,horse
Oap	Animal products nec; Meat products nec.
Milk	Raw milk
Dairy	Dairy products
Sugar	Sugar
Vol	Vegetable oils and fats
Ofd	Food products nec.
Agro	Fishing; Beverages and tobacco products
Frs	Forestry
C_oil	Oil
Petro	Petroleum, coal products
Gas	Gas; Gas manufacture, distribution
Coa	Coal
Ely	Electricity
Ind	Minerals nec; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Chemical,rubber,plastic prods; Mineral products nec; Ferrous metals; Metals nec; Metal products; Motor vehicles and parts; Transport equipment nec; Electronic equipment; Machinery and equipment nec; Manufactures nec.
Ser	Water; Construction; Trade; Transport nec; Sea transport; Air transport; Communication; Financial services nec; Insurance; Business services nec; Recreation and other services; PubAdmin/Defence/Health/Educat; Dwellings

Table A3. Annual Change in Total GDP, in %, 2001-2010

Regions	Reference	BFD-5.75%	BFD-11.5%	Reference, high oil price
apeu	6.53	6.53	6.53	6.54
aut	2.18	2.18	2.14	2.16
belu	2.10	2.10	2.07	2.08
bra	1.52	1.52	1.52	1.49
chi	5.29	5.29	5.28	5.27
cze	3.63	3.63	3.58	3.62
deu	1.77	1.77	1.75	1.74
dnk	2.37	2.37	2.34	2.32
esp	2.87	2.87	2.84	2.85
euba	4.50	4.50	4.39	4.48
euis	2.82	2.82	2.75	2.82
fin	2.32	2.32	2.27	2.30
fra	2.31	2.31	2.29	2.27
fsu	5.15	5.15	5.15	4.95
gbr	2.06	2.06	2.05	2.03
grc	2.40	2.40	2.36	2.36
hun	3.48	3.48	3.43	3.46
irl	2.96	2.96	2.91	2.94
ita	1.73	1.73	1.69	1.69
jp_ko	1.44	1.44	1.44	1.43
me	0.35	0.35	0.35	-0.04
naf	1.84	1.84	1.83	1.71
nafta	1.77	1.77	1.77	1.76
nld	2.36	2.36	2.33	2.33
oce	1.01	1.01	1.01	0.98
pol	4.02	4.02	3.97	4.02
prt	2.31	2.31	2.28	2.28
ram	1.62	1.62	1.62	1.55
ras	2.39	2.39	2.39	2.36
reu	2.27	2.27	2.27	2.17
saf	0.81	0.81	0.81	0.81
ssaf	1.20	1.20	1.19	0.96
svk	4.39	4.39	4.31	4.38
svn	2.93	2.93	2.86	2.94
swe	2.30	2.30	2.28	2.27
tur	3.19	3.19	3.15	3.13