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María Blanco Fonseca, Alison Burrell, Hubertus Gay, Martin Henseler, Aikaterini Kavallari, Robert M'Barek, Ignácio Pérez Domínguez, Axel Tonini.
Edited by Alison Burrell

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Impacts of the EU biofuel target on agricultural markets and land use: a comparative modelling assessment

Final report (June 2010)

This report has been prepared through the collaboration of Maria Blanco Fonseca (Chapters 2, 5), Alison Burrell (Chapters 2, 6), Hubertus Gay (Chapter 3), Martin Henseler (Chapter 4), Aikaterini Kavallari (Chapter 3), Robert M'Barek, Ignácio Pérez Domínguez (Chapter 5), Axel Tonini (Chapter 4). Edited by Alison Burrell.

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Abbreviations and Acronyms

AUT	Austria
BE	Belgium
BG	Bulgaria
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regional Impact
CES/CET	Constant Elasticity of Substitution/Transformations
cif	'cost, insurance and freight' (all freight and other charges included in value)
CY	Cyprus
CZ	Czech Republic
DDG	Dried distillers grains
DE	Germany
DG AGRI	Directorate General Agriculture and Rural Development
DK	Denmark
EBA	Everything But Arms
EC	European Commission
ES	Spain
ESIM	European Simulation Model
EST	Estonia
FAO	Food and Agriculture Organization of the United Nations
FAPRI	Food and Agricultural Policy Research Institute
FI	Finland
FR	France
fob	'free on board' (no freight or other charges included value)
GHG	Greenhouse gas
GR	Greece
GSP	Generalised System of Preferences
GTAP	Global Trade Analysis Project
HU	Hungary
IFPRI	International Food Policy Research Institute
iMAP	Integrated Agro-economic Modelling Platform
IRL	Republic of Ireland
LDC	Least Developed Countries
LT	Lithuania
LU	Luxembourg
LV	Latvia
MFN	Most Favoured Nation
MT	Malta
NL	The Netherlands
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Co-operation and Development
PL	Poland
PT	Portugal
RO	Romania
ROW	Rest of the world
SI	Republic of Slovenia
SK	Slovak Republic
SWE	Sweden
TR	Turkey
UAA	Utilised Agricultural Area
UK	United Kingdom

Executive Summary

The EU's Renewable Energy Directive (2009/28) sets an overall binding target of 20% for the share of EU energy needs to be sourced from renewables such as biomass, hydro, wind and solar power by 2020. As part of this total effort, at least 10% of each Member State's transport fuel use must come from renewable sources (including biofuels). The Renewable Energy Directive (2009/28) and the Fuel Quality Directive (2009/30) include criteria for sustainable biofuel production and procedures for verifying that these criteria are met.

The consequent growth in biofuel production may lead to higher agricultural production in the EU and is also likely to trigger indirect land use changes worldwide. There is strong public debate about the extent of the total reduction in greenhouse gas emissions due to switching from fossil fuel to biofuel, especially once account is taken of the global land-use change implications of higher EU imports of biofuel or biofuel feedstocks, and of reduced exports of EU food crops.

The European Commission (EC) must deliver an assessment of the impacts of EU biofuel policies to the European Parliament and the Council in 2010. To underpin this assessment, various research activities have been carried out by different Commission services. This report presents the results of an agro-economic impact analysis prepared by the Institute for Prospective Technological Studies (IPTS) for DG Agriculture and Rural Development (DG AGRI), with the aim of analysing the impacts of EU biofuel policies on agricultural production, trade and land use within and outside the EU, up to the year 2020.

The integrated Agro-economic Modelling Platform (iMAP), coordinated by IPTS in cooperation with DG AGRI, provides an appropriate infrastructure for carrying out this analysis. It directly supports the three models - AGLINK-COSIMO, ESIM and CAPRI – that are used in this exercise. These partial-equilibrium, agro-economic models are robust, scientifically acknowledged tools for simulating policy changes within the agricultural sector. They depict agricultural policy measures in detail and can be used to identify policy impacts on, *inter alia*, supply and demand, trade flows, domestic and world markets. In addition, since indirect land use change in third countries is triggered by price signals transmitted via market interactions, these models have the potential to present an economically consistent global picture of land use change impacts.

The report begins with a background summary of the main policy issues and previous empirical agro-economic analysis on biofuels (chapter 2), after which three chapters (3, 4 and 5) describe how EU biofuel policies were implemented in each of the three models AGLINK, ESIM and CAPRI, and the results that were obtained. This is followed (chapter 6) by a general discussion of the limitations of the modelling approach followed in all three models, and a more technical comparison of the way the models depict biofuel markets and policies. The final chapter (7) summaries the results and draws some conclusions.

How to identify the impacts of EU biofuel policy?

Various policy instruments are used within the EU to promote biofuel use, namely fuel tax exemptions for biofuel producers, blending or use targets, trade measures (import tariffs) and measures to stimulate higher productivity and efficiency in the supply and marketing chain.

In order to quantify the impact of EU biofuel policy in this study, each model was required to simulate two scenarios. The *baseline scenario* depicts the situation up to 2020, assuming that the EU's 10% target for energy use in the transport sector is achieved using both first- and second-generation biofuels, in the ratio 70:30. In the corresponding *counterfactual scenario* there is no mandatory target for the biofuel share of total transport fuel, and no tax exemptions or other fiscal stimuli for biofuels.

Both scenarios adopt the same projections of exogenous trends (population, incomes, total transport fuel demand, crop yields), whilst also assuming that EU trade measures for biofuels remain unchanged and that all countries outside the EU continue with their biofuel policies as already either implemented or announced at the start of 2009. The difference between the simulated outcomes of the two scenarios quantifies the impacts of those specific policy measures that differ between them, holding everything else constant.

Previous empirical work

Our review of prior empirical analysis is selective, focusing on recent studies that examine the future impacts of current or near-current biofuel policies, by means of *ex ante* simulations with either agro-economic partial equilibrium models or general equilibrium models in which the agricultural sector is depicted with an appropriate degree of detail. The seven studies reported all show that biofuel policies will impact on agricultural commodity production, prices and trade flows. Total cropped area is higher with biofuel policies, although the studies differ in their ability to identify the previous use (pasture, non-agricultural) of the additions to cropland, or to locate it with geographic precision.

Rigorous comparisons between the results of the studies reviewed are not possible because of differences in exogenous assumptions, simulation horizons and/or counterfactual policy scenarios. The review is useful, however, in documenting the recent rapid evolution in the state-of-the-art with respect to biofuel policy impact analysis using large-scale models. Despite the short time period covered, significant and relevant improvements in model specification are noted: the most recent studies take account of the use of biofuel by-products for animal feed, and try to allocate land use changes to differentiated agro-ecological zones. This overview provides the context in which the performance of the three model exercises presented in this report should be evaluated.

Present study: biofuel policy implementation and results

AGLINK-COSIMO

The study used the 2009 version of the OECD-FAO AGLINK-COSIMO model, with the baseline extended to 2020 and updated, in agreement with DG AGRI, according to macroeconomic assumptions dating from May 2009. The baseline assumes that the EU's mandated biofuel target will be met in 2020 not only by total biofuel use, but also by each biofuel (ethanol and biodiesel) separately.

AGLINK-COSIMO is a global, dynamic-recursive, partial-equilibrium model. It covers 39 agricultural primary and processed commodities and 52 countries or regions, and includes biofuel modules for a number of countries, the most detailed representations being for the EU, Canada, USA and Brazil. Each biofuel module determines that country's production of biofuels, their use for transport, and the use and production of by-products. The model includes first- and second-generation biofuels; the former is modelled endogenously whilst the latter is treated as exogenous and is assumed to have no land use implications. The supply and demand for biofuel by-products, namely oil meals and distillers grains, are also modelled.

The main effects within the EU of EU biofuel policies, by 2020, are:

- Outputs of ethanol and biodiesel are much higher, by 179% and 586% respectively.
- EU net imports of vegetable oils are 265% higher, whereas net imports of oilseeds are 17% lower.
- Cereals (mainly coarse grains) use for animal feed is 3% lower, due to replacement by dried distiller grains, whose production is 211% higher.
- Biodiesel price is 40% higher, with a smaller difference (about 18%) in ethanol price (similar pattern for world market prices).

- Total pasture area is 0.9% lower.
- Total EU arable area declines less between 2008 and 2020 (-6.5% rather than -8.6%).

EU biofuel policy impacts on world commodity balances and land use by 2020 include:

- EU imports of biodiesel are higher by 407%, with the USA becoming a net exporter.
- EU net imports of ethanol are higher by 614% (+2966 million litres), accompanied by higher Brazilian net ethanol exports (+3065 million litres).
- Total land used for cereals, oilseeds and sugar worldwide is higher by 0.7% (5.214 million hectares, of which 3.752 million hectares are outside the EU).

When EU biofuel policy is in place, there is a strong increase in vegetable oil production in Indonesia and Malaysia, most of which feeds into net exports. Since AGLINK-COSIMO does not simulate land use effects in Indonesia and Malaysia, any land use impact resulting from this output expansion is *not* included in the quantified global arable land use change.

Sensitivity analysis shows that if EU biofuel policies were to stimulate faster crop yield growth, the impact of EU policies on global land use in 2020 would be smaller. By contrast, when the mandated share is applied only to aggregate biofuel use rather than to ethanol and biodiesel separately, the biofuel mix shifts in favour of ethanol, and the global impact on arable land increases by a further 1.1 million hectares. This result does not include any possible accompanying reduction in South East Asian palm oil area.

ESIM

ESIM (European Simulation Model) is a comparative-static, partial-equilibrium, net-trade multi-country model of the agricultural sector. Although its geographical coverage is global, in its current version ESIM includes individual representations of each of the 27 EU member states, Turkey and the USA only. All other countries are aggregated into the single block 'Rest of the World'. ESIM models demand and supply of biofuels and distinguishes four by-products: gluten feed (from wheat and maize) and meals from three different oilseed crops (rapeseed, sunflower seed and soybeans). By contrast, AGLINK-COSIMO models only an aggregate commodity, 'oilseeds', and the corresponding aggregate by-product, 'oil meals'.

As was done for AGLINK-COSIMO, the ESIM baseline assumes implementation and continuation of the CAP as agreed in the Health Check reform of November 2008, no Doha Development Round agreement and thus continuing full implementation of the WTO Uruguay Round Agreement on Agriculture, and macroeconomic trends as agreed with DG AGRI. It assumes that the biofuel target set for 2020 by the Renewable Energy Directives is fully met. Since ESIM only considers first-generation biofuels but maintains the assumption that both first- and second-generation biofuels will contribute to meeting the 2020 target, in the ratio 70:30, this implies a 7% target for the (first-generation) biofuels considered. The basic assumptions of the ESIM counterfactual scenario are the same as for the other two models: no tax concessions for biofuel production or use, and no fuel share target. However, for technical reasons, any initial reaction in 2009 to the announcement of 2020 target is present in the ESIM counterfactual. This is not the case for AGLINK-COSIMO.

The impacts of EU biofuel policy identified by the ESIM simulations include:

- EU prices for biodiesel and ethanol are 13% and 3% higher, respectively,
- EU production of rapeseed and sunflower seed is higher by 6-7%.
- EU prices for rapeseed and sunflower seed are 10-11% higher, and those of rapeseed oil and sunflower seed oil are higher by about one-third. The prices of rapeseed and sunflower seed meals are lower by a third or more, and the EU switches from a net export to a net import position in these two by-products.
- EU production of maize is 7% higher, and that of wheat 3% higher.
- EU prices for the ethanol inputs soft wheat, sugar and maize are up by 8%, 21% and 22% respectively.
- The EU becomes a net exporter of biofuels (about 0.16 million tonnes oil equivalent, compared to negligible imports in the base year)[1].
- Net trade in ethanol feedstocks is significantly different: net sugar imports are 143% higher and net wheat exports are lower by 64%.
- EU area used for agricultural production decreases between 2009 and 2020 by only 0.72% (1.1 million hectares out of a total of 152 million hectares) whereas without EU biofuel policy the decrease would be 1.15% (1.8 million hectares).

CAPRI

CAPRI is a comparative-static, spatial, partial equilibrium model designed to model agricultural commodity markets worldwide, whilst also providing a detailed representation of EU agricultural and trade policy instruments. It consists of two interlinked modules: the *supply module* formed by regional (NUTS 2-level) mathematical programming models for EU

27 that capture detailed farming decisions, policy responses and environmental consequences, and the *market module*, a global, spatial multi-commodity model that recognises about 50 commodities (primary and secondary agricultural products) and 60 countries (grouped into 28 trade blocks). CAPRI distinguishes arable and grass land, and the area of both land types is set exogenously. A single unified market for each commodity within the EU is assumed.

The version of CAPRI used for this study does not include endogenous biofuel production. Instead, the demands for ethanol and biodiesel are set exogenously, and the model (assuming no capacity constraints for biofuel production) determines the consequences for supply, demand, trade (in feedstocks only, as trade in biofuels is not modelled) and prices of agricultural primary and secondary products. The model recognises various feedstocks for biofuel production (six for ethanol and three for biodiesel) and biofuel by-products (two each for ethanol and biodiesel).

The CAPRI baseline used for this study was not fully synchronised with those of AGLINK and ESIM, since it ignores the CAP Health Check reform. In the absence of endogenous biofuels markets, both the baseline and counterfactual scenarios were constructed to meet the EU27 2020 biofuel demands (first- and second-generation) obtained from AGLINK.

Impacts of EU biofuel policy in 2020 obtained from the CAPRI simulations include the following:

- Output of both cereals and oilseeds is higher by 1.4% and 12.3%.
- Producer prices for cereals and oilseeds are higher by 10.2% and 19.5%, respectively, and farm income is 3.5% higher.
- Oilseeds area is 10.5% larger, largely at the expense of fallow land (5.6% lower).
- Cereals and oilseed yields are 1.4% and 1.6% higher, respectively, due to higher-yielding varieties and intensification.
- There is a general tendency towards greater intensification in arable cropping, and higher nitrogen surpluses.
- Within the EU, the distribution of crop outputs shifts, with higher cereal production in southern and south-western Europe, and more oilseed production in north-eastern Europe.
- EU imports of vegetable oils increase and the EU's net export position in cereals declines.

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[1] This result contrasts with that of the AGLINK-COSIMO model, where the EU remains a net importer of both biofuels under both scenarios in 2020 in the baseline simulation.

Discussion of the models

The study discusses a number of limitations of the models used, which are shared by most of the current generation of simulation models available for this type of exercise.

Endogenous energy markets are absent from all the models used in the study[2]. Total transport fuel demand is treated as exogenous, based on projections from the PRIMES model. However, a rising share of biofuel in total transport fuel will alter the average price of transport fuel. If the higher cost of biofuel is not fully absorbed by fiscal measures, average transport fuel prices paid by the user will rise and consumption (including biofuel consumption) will fall. Failure to account for such an effect would bias the simulated land-use implications upwards.

Technological and productivity developments are not treated in depth. A best-guess assumption is made (in the AGLINK-COSIMO and CAPRI simulations) about the timing of market entry of second-generation biofuels. However, since it is not known what feedstocks will be used for these commercial second-generation biofuels, the models assume that their production has no land-use implications. Similarly, exogenous rates of technical progress for first-generation biofuels and their by-products, and for crop yield growth, have been based on past trends, and are subject to considerable uncertainty.

The endogeneity of total agricultural land, and parameters reflecting relative degrees of land scarcity in different regions, are important for obtaining a detailed picture of indirect land use change. None of the models used in this study currently meet this challenge. In particular, AGLINK-COSIMO and CAPRI treat total agricultural land supply as fixed; for example, the results reported for AGLINK-COSIMO relate to changes in *area cropped with cereals, oilseeds and sugar*, and given the assumption of fixed total agricultural area, an increase in the former implies a reduction in other types of agricultural area (permanent crops, pastures). However, in reality this may not be the case, and expansion occur at the expense of land not previously used for agriculture. Moreover, the area devoted to *other* biofuel feedstocks (notably palm oil) is not modelled and not reflected in the reported land-use changes.

Moreover, none of the models can take account of land use constraints that may affect the cost and magnitude of cropland expansion, such as the sustainability criteria given in the EU Renewable Energy Directive, or any climate change commitments affecting land use.

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[2] This shortcoming is a feature of partial equilibrium models. It is overcome in computable general equilibrium (CGE) models, which depict all economic sectors, and will be addressed in CAPRI through linkage to another model.

Model comparison and synthesis of results

The three models used for this study are quite different in their basic specification and their features of particular relevance to modelling biofuel markets. Hence, identical results are not to be expected. However, if this heterogeneity (summarised in section 6.2) is borne in mind when comparing results across models, a deeper understanding of the likely impacts of EU biofuel policy may be obtained.

Despite this heterogeneity, the comparative summary of the main results presented in chapter 7 reveals a striking degree of consensus between the three models regarding the main market and trade outcomes. Differences between the results obtained relate more to the inability of a particular model to simulate certain results rather than to conflicting results regarding the direction and magnitude of impacts in cases where they *are* modelled.

Some general conclusions regarding the impacts of EU biofuel policy in 2020 can be drawn:

- EU production of the two biofuels, and their feedstocks, is much higher.
- The EU remains a net exporter of wheat, although wheat exports are lower.
- Impacts on EU livestock production are negligible in AGLINK-COSIMO, positive but small (around 3%) for intensive livestock in ESIM[3], and also very small in CAPRI (but with a shift of EU production away from the Centre due to higher feed costs).
- Without more detailed analysis, it is uncertain whether, and to what extent, the EU's energy independence might be improved by its biofuel policies, particularly when reliance on imported feedstocks is taken into account.
- The impact of EU policies on EU agricultural area is to slow down the long-run declining trend.
- World market prices for both biofuels are higher, as a response to the simulated increased EU demand for imported biofuel.
- There is minor disruption to world market prices of ethanol feedstocks, but world market prices for biodiesel feedstocks are more sensitive to the EU's biofuel policies. This is because ethanol production is a relatively small component of total demand for the agricultural commodities that also serve as ethanol feedstocks, whereas demand for oilseeds and vegetable oils for biodiesel is a much larger component of total world

demand for biodiesel feedstocks. This suggests that any direct pressure on global food markets due to EU biofuel policies will concern vegetable oils rather than grains or sugar.

- Production of biofuels is higher in third countries, most notably in the USA and Brazil (for ethanol) and in the USA (for biodiesel).
- There are significant changes in cropping patterns within the EU at NUTS 2 level (a shift of cereals away from Central and Central-Eastern Europe, towards the North-Eastern, North-Western and Southern periphery, and higher oilseed production in Eastern, Northern and Central Western Europe).
- The picture of land use change outside the EU is not complete. In particular, AGLINK-COSIMO's estimate of an extra 5.2 million hectares used for cereals, oilseeds and sugar crops globally does not include any land use implications of the higher vegetable oil production in Indonesia and Malaysia.
- Biofuel by-products reduce pressure on crop supplies and arable area coming from the higher demand for biofuel feedstocks, by serving as substitutes in animal feed demand.

[3] Because of unchanged domestic demand, EU pork exports are also higher and the EU shifts from a net import to a net export position for poultry meat.

1. Introduction and objectives of the study

The Renewable Energy Directive (2009/28) has set an overall binding target to source 20% of the EU energy needs from renewables such as biomass, hydro, wind and solar power by 2020. As part of the overall target, each member state has to achieve at least 10% of their transport fuel consumption from renewable sources (including biofuels). The Renewable Energy Directive (2009/28) and the Fuel Quality Directive (2009/30) elaborate sustainability criteria for biofuel production and procedures for verifying that these criteria are met.

The European Commission's Renewable Energy Progress Report[4] elaborates on the economic and environmental aspects associated with the development of biofuels. The report states that agricultural activities related to the renewable energy sector generate a gross value added of well over €9bn per year, contribute to the security of energy supply, and provide additional jobs and net greenhouse gas savings, taking into account that most EU biofuel consumption has been fulfilled through the re-use of recently abandoned agricultural land or through slowing down the rate of land abandonment in the EU.

Nevertheless, the extent of greenhouse gas savings/emissions of imported biofuel or biofuel made from imported raw materials and the related indirect land use changes is currently strongly debated.

Given the plans for further (strong) biofuels growth, which may lead to further intensification of agricultural production in the EU and is likely to trigger indirect land use changes worldwide, the Commission is currently analysing the impacts of its biofuel policies in preparation for submitting a report to the European Parliament and to the Council in 2010. To support this process, various research activities are being carried out by different Commission services.

The Institute for Prospective Technological Studies (IPTS)[5] is providing an agro-economic impact analysis to DG Agriculture and Rural Development within the framework of an Administrative Agreement[6], providing an outlook of agricultural production until 2020 assuming that the biofuel target is met (the so-called baseline) and a counter-factual scenario without any biofuel policies.

[4] Brussels, 24.4.2009; COM(2009) 192 final.

[5] The IPTS is one of the seven institutes of the Commission's research arm the Joint Research Centre

[6] Administrative Arrangement Nr. AGRI-2009-0235, with IPTS AGRILIFE unit (AGRITRADE action).

Agro-economic models are indispensable tools in the preparation and negotiation of (agricultural) policy decisions. They allow agricultural policy measures to be depicted in detail and thereby permit the analysis of their impacts on supply and demand (including land use), trade flows, producer and consumer prices, income indicators and partly also environmental indicators. The need to quantify possible land use changes in the EU and worldwide until 2020 resulting from the biofuel target is a major reason for using agro-economic models.

The integrated Agro-economic Modelling Platform (iMAP) coordinated by IPTS provides an appropriate infrastructure for carrying out such an analysis[7]. The modelling tools used in this exercise are AGLINK-COSIMO (model run by OECD, FAO and EC, covering the EU15, EU12, OECD countries, main developing countries and the rest of the world), ESIM (European Simulation Model, covering the EU member states, EU candidate countries, the USA and the rest of the world), and CAPRI (Common Agricultural Policy Regional Impact model, covering the EU at regional NUTS2 level, 24 other countries or regions, and the rest of the world). These three models are scientifically acknowledged and robust tools for policy simulations.

The present analysis, which was finalised in July 2009, has been prepared within a very tight time frame to feed the ongoing scientific and policy discussions at the right moment. The model team has incorporated the newest policy and economic developments where possible.

The report is structured as follows. After this introductory chapter, chapter 2 provides all necessary background information regarding policy issues, previous empirical work and prospects of agro-economic analysis on biofuels. The chapters 3, 4 and 5 describe the implementation of biofuel policy in the models AGLINK, ESIM and CAPRI, as well as the assumptions and results of the scenarios. Chapter 6 summarises the results from the different models and chapter 7 draws final conclusions.

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[7] For more information about iMAP, see for example Perez Dominguez, I., Gay, S. and M'Barek, R. An Integrated Model Platform for the economic assessment of agricultural policies in the European Union. *Agrarwirtschaft: Zeitschrift für Betriebswirtschaft, Marktforschung und Agrarpolitik* 57 (8); 2008. p. 379-385.

2. Background: Review of EU biofuel policy and previous empirical work

2.1. Introduction

2.1.1. What are biofuels?

In this report, 'biofuels' refers to the two biomass-derived fossil-fuel substitutes *ethanol* and *biodiesel*.[8] Ethanol can be processed from any sugar-rich feedstock, or from any biomass that can be converted into sugar (e.g. starch or cellulose). A litre of ethanol contains about two-thirds of the energy provided by a litre of petrol, but has a higher octane level and therefore improves the performance of petrol when blended. Almost any oilseed crop can be used to produce biodiesel. Its energy content is 88–95% that of diesel, but when blended with diesel it enhances the performance of the latter, resulting in fuel economy comparable with that of ethanol blends.

First-generation biofuels that use sugar and starch crops (ethanol) and oilseed crops (biodiesel) as feedstock compete directly with demand for these crops as food or feed. *Second-generation* biofuels (not yet widely available commercially) use biomass from non-food sources, including lignocellulosic biomass, waste matter from food crops or residues from other non-food processes. It follows that their land-use implications depend strongly on the specific feedstock.

The *biofuel yield* per hectare[9] of first-generation biofuels varies greatly between feedstocks and producing areas, and reflects the trade-offs between crop yield per hectare and the energy yield of specific crops (see FAO, 2008, Table 2, p.16). Currently, ethanol from sugar cane or beet, and biodiesel from palm oil, dominate the biofuel yield rankings (with Brazil achieving 4.34 tonnes of ethanol per hectare from sugar cane and Malaysia reaching 4.17 tonnes of biodiesel per hectare from palm oil). The biodiesel yield of rapeseed (the predominant form of biofuel production in the EU) is typically 0.79-1.27 tonnes per hectare.

Second-generation biofuels promise to deliver higher biofuel yield performance. Dedicated cellulosic energy crops (such as reed canary grass) can produce more biofuel per hectare because the entire crop is used as fuel feedstock. These crops, like food crops, are land-using, although some may be grown on poor land that would normally not be used for food

[8] In broader usage, 'biofuel' can refer to any biomass source that is used for fuel, including firewood and animal dung.
[9] Biofuel yield = crop yield × conversion efficiency.

production. By contrast, in the case of waste products (agricultural and non-agricultural) that would otherwise be disposed of, the *additional* land used to produce the feedstock is negligible, resulting in theoretical very high biofuel yields per hectare and zero competition with food production.

Production of first-generation biofuels results in *by-products* of commercial value. In particular, the production of ethanol from grains, using a dry milling process, yields dried distillers grains (DDG), which is used in pig, poultry and ruminant feeds. Wet-milling processes for grain-base ethanol produce various by-products, including gluten feed and gluten meal, which are both used as animal feed and also demanded by the food industry. The residual cane waste (bagasse) from ethanol production from sugar cane is used in electricity production. By-products of biodiesel production are oil meals and oilcakes (animal feed) and glycerine. The latter has largely replaced synthetic glycerol in the pharmaceutical and the cosmetics industries, and is finding a range of other uses.[10] It is used as a dietary supplement for poultry, and research is underway on its use in ruminant diets.

When assessing the impact and future prospects of biofuel production, these commercially valuable by-products should be taken into account, for two reasons. First, if by-products are used for animal feed, the animal feed displaced by using a feedgrain crop as feedstock does not have to be completely replaced by new crops. This has implications for, *inter alia*, land use and food production capacity. Second, the price received for the by-product is part of the supplier's sales revenue, which alters the parameters of the competition between the biofuel and the corresponding fossil fuel. Furthermore, the by-products may themselves be used for energy generation (for example, bagasse, a by-product of ethanol derived from sugar cane, is used to produce steam for electricity generation in Brazil).

2.1.2. Current biofuel production and recent trends

Over four-fifths of global production of liquid biofuels consists of ethanol. However, the share of biodiesel is rising rapidly with the emergence of new producing countries in South East Asia and faster increases in biodiesel production (compared to ethanol) in other producing countries. In 2008, the EU still produced over 50% of the world's biodiesel output, whilst Brazil and the USA together delivered 80% of ethanol production. The EU's estimated installed capacity for both biofuels exceeds its current production, and further increases in capacity are under construction.

Table 2.1: World biofuel production in 2008, and recent trends

Country/ Region	**Ethanol***		**Biodiesel**		**Total**	
	Mn litres 2008	**% change 2005-2008**	**Mn litres 2008**	**% change 2005-2008**	**Mn litres 2008**	**% change 2005-2008**
Brazil	22 239	46	1 089	155 471	23 328	53
Canada	1 083	167	205	388	1 288	188
China	3 964	15	114[1]	n.c.[2]	3 964[3]	15[3]
India	1 725	54	200	900	1 925	69
Indonesia	194	10	356	-[4]	550	211
Malaysia	64	-19	536	-[4]	600	659
USA	34 463	125	2 709	266	37 172	131
EU	5 022	71	8 064	123	13 086	100
Others	1 882	78	1 867	1 029	3 749	206
World	70 636	78	15 140[3]	230[3]	85 776[3]	93[3]

1. Production in 2007. 2. Not calculated. 3. Excludes China's biodiesel. 4. Production was zero in 2005.

*Includes ethanol used for purposes other than fuel.

Source: AGLINK-COSIMO database.

Within the EU, the three largest biodiesel-producing Member States account for two-thirds of production whilst a similar share of ethanol production occurs in the three largest ethanol producing Member States[11]. France and Germany are the largest EU consumers of biofuels.

2.1.3. Aims of the study

This report presents the results of simulation studies, using three different agricultural sector models, designed to analyse the impacts of EU biofuel policies up to the year 2020. The impacts of these policies on commodity production, trade flows (biofuels, biofuel feedstocks and non-energy commodities) and prices are reported. Particular attention is given, to the extent possible with the three models used, to the land use implications of these policies.

Two scenarios are simulated:

a) the situation to 2020, assuming the continuation of all biofuel policies worldwide that were either already implemented or announced at the start of 2009globally[12], plus current projections of exogenous trends (population, incomes, yields etc); the baseline

[10] Most recently, scientists have found a way of converting glycerine to ethanol, although this has not been commercially developed.

[11] In 2008, national shares of biodiesel production were: Germany (36.4%), France (23.4%) and Italy (7.7%) (Source: EBB), and for ethanol: France (35.7%), Germany (20.3%) and Spain (11.3%) (Source: eBIO).

[12] Total transport fuel demand in 2020 is assumed fixed, as given by PRIMES 2007. This baseline, the most recent available, does not take account of the global economic crisis or several other recently announced or applied policy measures that may negatively affect transport fuel demand.

assumes that the EU's target of 10% of energy use in the transport sector is achieved using both first- and second-generation biofuels, the ratio 70:30[13]; and

b) as a), but (for the EU only) without any mandatory target for the biofuel share in the transport fuel market or any biofuel exemptions from fuel taxes.

This chapter discusses the main policy issues relevant for biofuel scenario modelling: their rationale, the various instruments available, and their intended and unintended policy impacts. It then reviews the most recent and relevant biofuel scenario studies, covering work based on the leading sectoral or economy-wide global models.

2.2. Main policy issues relevant for biofuel scenario modelling

2.2.1. Why do countries promote biofuels?

Countries have adopted policies to stimulate biofuel production and consumption for one or more of the following reasons: to reduce dependence on fossil fuels (energy security), to reduce greenhouse gas (GHG) emissions in the transport sector (climate change mitigation), and to create demand for surplus agricultural crops (farm income support).

The objective of energy security has several dimensions: lower dependence on foreign energy suppliers, reduced exposure to energy price volatility and possible supply disruption, and balance of payments issues (for a wider discussion, see for example IEA (2007)). It can be debated, however, whether greater energy independence is *best* achieved by promoting biofuels rather than other forms of domestically-generated renewable energy, when all relevant factors are considered (see, for example, Doornbosch and Steenblik (2007))..

However, in recent years, the contribution of biofuel use to reducing GHG emissions has been strongly contested (see, for example, Searchinger *et al*., 2008). Earlier estimates of GHG savings counted the carbon stored in the biomass crop as a 'costless' GHG reduction, without considering the carbon emissions from the agricultural land used for its cultivation and that might have been converted (for example, forest, pasture or wilderness). According to this view, only the net *additional* carbon storage of the feedstock crop relative to that of the most likely alternative vegetation on the same land is relevant in the calculation. The debate generated by this view has motivated this and other analyses of the land-use impacts of biofuel policies. The apparent ability of some second-generation biofuel crops to flourish on

[13] The Renewable Energy Directive (2009/28/EC, Article 21, para.2) states that the contribution from second-generation biofuels will be counted twice towards the fulfilment of this target. Thus, the assumed 70:30 ratio implies a targeted energy share of 7% from first-generation biofuels, and 1.5% from second-generation biofuels.

marginal land that is unsuitable for food crop production may well reduce competition between food and biomass. Without taking land use changes into account, second-generation biofuels could generate rates of GHG avoidance similar or above those for sugar cane-based ethanol (OECD, 2008, p.91). However, unless the associated land use changes are taken into account, it does not follow that they must always have an advantage over first-generation crops in terms of carbon sequestration.

Regarding the farm income support objective, a new and strongly growing non-food demand for agricultural output will undoubtedly boost farm prices and hence farmers' incomes. However, the desired effect may come at a potentially high cost: a human cost, paid by the world's poorest consumers who may face higher food prices or food shortages, and an environmental cost, particularly in terms of the destruction of rainforest and wilderness, as higher crop prices encourage the expansion of agricultural area worldwide.

2.2.2. Policy instruments within the EU

The current objectives of EU renewable energy policy are stated in the first recital of Directive 2009/28/EC (the 'Renewable Energy Directive) as (i) reducing GHG emissions, (ii) enhancing security of energy supply, (iii) promotion of technological development and innovation, and (iv) provision of opportunities for employment and regional development, especially in rural areas.

Policy measures for promoting the production and use of biofuels can be characterised according to various dimensions: the point at which they are applied in the production and marketing chain, whether they work by altering relative prices or by direct regulation, and whether the cost of the support falls ultimately on the taxpayer or the fuel consumer (see, for example, OECD 2008; Pelkmans *et al*., 2008). Within the EU, it is important to distinguish between policies applied at Union and Member State levels.

Using a categorisation based on the type of instrument uses, four broad groups of biofuel policy measures can be distinguished: *budgetary support*, such as direct support to biomass supply and fuel tax exemptions for biofuel producers; *blending or use targets ('mandates')*, which impose a minimum market share for biofuels in total transport fuel; *trade measures*, in particular import tariffs; and measures to stimulate *productivity and efficiency improvements* at various points in the supply and marketing chain. Most of these measures promote both the production and consumption of biofuels domestically; trade measures that reduce access to domestic markets promote domestic biofuel production, will normally reduce domestic demand (unless it is completely inelastic with respect to price).

Budgetary support

In the past, the CAP has provided direct support for biomass production in two ways. Production of non-food crops on land receiving the CAP set-aside premium began in 1993, and has largely involved crops for liquid fuel production. In addition, an energy crop aid of €45 per hectare with a ceiling of 1.5 million hectares was introduced in 2004; the ceiling was raised to 2 million hectares when the scheme was extended to the 15 new Member States in 2006.[14] This support ended with the CAP 'Health Check' reform (November 2008), which abolished both set-aside and the energy crop payment.

Fuel tax exemptions or reductions have been used by many Member States to stimulate biofuel consumption. The Energy Tax Directive (2003/96/EC) lays down a common EU framework within which Member States may adopt this measure. Preferential tax treatment is considered to have played a crucial role in promoting biofuels in both the EU and the USA (Wiesenthal *et al.*, 2009). Currently, 17 Member States offer tax reductions on low blends of biodiesel and ethanol, and three more for biodiesel blends only (Pelkmans *et al*, 2008). Many Member States now impose a quota on the quantity eligible for preferential tax treatment[15].

Consumption targets

Ten Member States supplement tax policy with mandatory substitution policies (blending targets). Germany, for years heavily committed to tax exemptions, switched to the sole use of mandatory targets in 2006 due to budget losses, but has recently reintroduced tax exemptions for high-blend biofuels. Six Member States use blending targets alone to increase biofuel consumption.[16]

A major difference between tax exemptions and mandatory substitution policies is that the cost of the former is met from public funds whereas the higher fuel cost due to compulsory blending falls on the fuel supplier and hence, most probably, on the fuel user. A benefit claimed for mandatory targets is that, by making market shares predictable, they create a more stable climate for investment. On the other hand, the incidence of the support cost may be more regressive since it hits transport users at all income levels.

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[14] In 2007, energy crops were grown on 4 million hectares of arable land, of which 1 mn was set-aside land. Only 0.2 million hectares of this area was without any direct support (Pelkmans *et al*, 2008).

[15] Member states using tax reductions only (with or without a quota) for ethanol and biodiesel are BE, BG, CY, DK, EST, HU, LV, SWE, as well as MT and PT for biodiesel only.

[16] Member States using blending targets only are CZ, FI, IRL, LU, NL, for both fuels, and IT for ethanol only. Mixed (tax and mandate) systems for both fuels are implemented by AUT, DE, FR, LT, PL, RO, SK, SL, ES and UK, whereas GR has a mixed system only for biodiesel (Pelkmans *et al*, 2008).

The 2003 EU Biofuels Directive (2003/30/EC) invited each Member State to set national targets for the share of biofuel in total transport fuel of at least 2% by the end of 2005, rising to 5.75% by end-2010. These targets were, however, not binding for Member States. The European Council (March 2007) agreed on a mandatory target of at least 10% by 2020[17], subject to sustainability of production, the commercial availability of second-generation biofuels and amendment of the fuel quality directive (98/70/EC).

These targets and conditions are laid down in the Renewable Energy Directive (2009/28/EC), where the sustainability criteria to be met are also spelled out. These criteria, which also feature in the Fuel Quality Directive (2009/30/EC), focus particularly on greenhouse gas emissions, biodiversity protection, respect for the carbon stock of land in its current use (with particular emphasis on the preservation of peat and forested land), quality of soil, water and air, and international labour standards.

Trade measures

Import tariffs on biofuels increase the domestic price above the world market price, resulting in a transfer of income from transport users to domestic biofuel producers. The EU applies an MFN tariff of €0.192 per litre on imported undenatured ethanol[18], €0.102 per litre on denatured ethanol, and 6.5% on ethanol-gasoline blends. Biodiesel imports are subject to a 6.5% tariff[19]. A large number of countries, mainly EBA and GSP countries can have a completely free access to the EU ethanol market. In the mid-2000s, around one third of the EU's ethanol imports have faced the MFN tariff, whereas the rest has entered under preferential trade agreements (Schnepf, 2006). Even with the MFN tariff, Brazilian ethanol remains highly competitive with EU ethanol. Whether the 2020 mandatory targets are met largely by imported biofuels rather than domestic production will be a key determinant of the extent of land-use changes and other knock-on impacts of these targets within the EU.

Efficiency-enhancing measures

This broad class of policy initiatives contains various targeted measures located along the entire biofuel production and marketing chain. They include measures to stimulate research and technological development, promote investment in production capacity, secure agreements with vehicle manufacturers to develop dual- and flexi-fuel models, facilitate the

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[17] Within a mandatory target of a 20% share of energy from renewable sources in total EU energy consumption.

[18] Which implies a tariff of around 50%, assuming a world market price of $0.50 US per litre (FAO, 2008).

[19] In March 2009, the EU imposed an anti-dumping tariff of €68.6-198/tonne net and countervailing duties of €211.2-237/tonne net on US biodiesel, because of high subsidies paid to US producers. In July 2009 these duties were made definitive for a 5-year period.

establishment of distribution networks and retail points for biofuels, formalise and regulate product quality standards in order to increase user confidence, and provide information to consumers. These initiatives are largely at Member State level, and have used a variety of incentive-based and regulatory approaches. Although many of these measures are impossible to quantify either in terms of cost or impact, it is clear that they improve productivity, strengthen the efficiency of biofuel markets and generally help to develop the sector.

2.2.3. Unintended impacts of biofuel policies

Most biofuel production is not competitive with fossil-based gasoline or diesel at current prices for crude petroleum. Biofuel profitability depends heavily on government support, with biodiesel further from being economic without policy support than ethanol (OECD, 2008).

Table 2.2: Impacts of biofuel expansion

Aims/intended effects	Findings and prospects relevant to intended effects	Unintended effects
Energy security	✔ Can reduce ratio of (imported) non-renewable fossil fuels to domestically-produced renewable energy. ? May not be the least-cost way of achieving energy security.	✔ Where biofuel policies result in higher prices to fuel users, this will reduce total fuel demand and the negative externalities of fuel use. ? Other less distorting, less regressive measures could also reduce fuel use.
Greenhouse gas emission reduction	? Possibility that 1st generation biofuels may increase GHG emissions, at least initially, due to lost carbon storage capacity once all land use changes are accounted for. ? Conversion of cropland to forest may generate much greater GHG savings than using the crop biomass for biofuels. ? Differences in terms of GHG implications between 1st generation biofuels according to feedstock and production method. ✔ 2nd generation biofuels appear to have greater GHG-saving potential, especially if made from waste materials that would otherwise cause GHG emissions.	✘ Other possible negative environmental effects: • Higher crop prices may encourage more intensive production methods, leading to more nitrate and phosphate leaching, nitrous oxide emissions, pesticide contamination, soil degradation, loss of biodiversity and landscape deterioration. • Some types of biomass make heavy demands on water resources. • Certain second-generation biomass species are classified as invasive species, whose full implications are not known. ✔ Use of fuel blends may improve general air quality.
Maintaining farm incomes	✔ Crop prices increase due to higher demand for biomass.	✘ Increases in food prices impact most on poorest food consumers. ? Higher feed costs for livestock producers/lower feed costs due to by-products.

✔ / ✘, indicate potentially positive/negative effects linked to the main objectives; ? indicates a caveat or qualification associated with certain effects, or uncertainty regarding their significance.

The removal of biofuel support would substantially affect the private profitability of biofuel production, with negative repercussions on the domestic industry and investments in the development of more efficient and technologically advanced fuels. Because of higher production costs, biodiesel production in general and ethanol production in Europe would be much more affected than ethanol in the US.

At the same time, large-scale implementation of bioenergy production may have global economic, environmental and social consequences, and there are concerns about various potential unintended impacts of biofuel policies. The possible consequences of expanding biofuel production and use, as discussed in the literature on biofuels, are shown in Table 2.2. Some of these impacts are discussed in more detail in the following paragraphs.

Land use changes

Current and future support of biofuels could have important implications for global land use. In particular, it is likely to accelerate the expansion of land under crops particularly in Latin America and Asia. Although this may provide new income opportunities for poor rural populations, it carries the risk of significant and hardly reversible environmental damages. Recently, more attention has been paid to the effects of land use changes by distinguishing between direct land use changes (where land already used for agriculture is switched to produce biofuel feedstock) and indirect land use changes (where land that may or may not be currently used for agriculture is converted to produce non-biofuel crops in response to biofuel-driven displacement of commodity production in a different region, country or even continent) (see, for example, Kim *et al*., 2009). While direct land use changes are considered in various studies, indirect land use changes are more often ignored. In this report, in line with the terminology used in the Renewable Energy Directive (2009/28/EC, Recitals, para. 85), we use the term 'indirect land use change' to mean the *net* change in total area used to produce crops for all uses.

GHG emissions

Measuring the consequences of biofuels for GHG emissions requires consideration of the full life cycle of these products, from biomass production and its use of various inputs to the conversion of bio feedstocks into liquid fuels and then on to the use of the biofuel in combustion engines (OECD, 2008). Generally speaking, and without taking land use changes into account, available studies show greenhouse gas reductions of 80% or more for ethanol based on sugar cane compared to the use of fossil gasoline. The savings in GHG emissions from cereal-based ethanol and of oilseed-based biodiesel, compared to their respective fossil counterparts, are significantly less. Moreover, estimates diverge according to region, type of data, and methodological differences such as the way of allocating GHG emissions between the biofuel and its by-products.

So far, current biofuel support policies in the US, the EU and in Canada appear to reduce GHG emissions very little relative to the emissions projected for 2015 (OECD, 2008). On the other hand, second generation biofuels could possibly achieve GHG emission levels as low as or lower than sugar cane-based ethanol. For example, biodiesel made from used cooking oils or animal fats could provide significant GHG savings (OECD, 2008).

One of the most critical issues in the biofuels debate involves the GHG emissions due to indirect land use changes, when land is converted from non-arable (e.g. forest or grassland) to arable use (Searchinger *et al*, 2008). Particularly when virgin land such as rainforest or peat land is converted to agricultural use, many decades may be needed before the initial induced carbon losses are compensated by the savings due to greater biofuel use.

Effect on farm prices

In the debate surrounding the strong increases in food prices of the last two years, biofuel support policies in Europe and the US have played a controversial role. Various researchers have analysed the impacts of biofuel production on food markets. Most studies agree that the rapid growth in biofuel demand contributed to the rise in food prices over the 2000–2007 period, but that it was not a dominant driving force. The research approaches used range from detailed modelling exercises to rough spreadsheet-derived estimates.

For example, Rosegrant (2008) used the IMPACT model to assess the role of biofuels in food price increases. This partial equilibrium model captures the interactions among agricultural commodity supply, demand and trade for 115 countries and the rest of the world, and includes demand for food, feed and biofuel feedstock. Rosegrant finds that 30% of the cereals price increases between 2000 and 2007 can be attributed to higher biofuel production, but that the price effect is commodity-specific. For maize the impact is relatively high, because most US ethanol production is maize-based. Price effects for other cereals are somewhat lower and mainly due to indirect land use changes and consumer substitution between grains in response to relative price changes.

A number of studies have also investigated this issue *ex ante* by examining the impact of current policies on future price developments. For example, Tyner and Taheripour (2008), using a partial equilibrium model calibrated on 2006, simulated the linkages between agricultural and energy prices for various scenarios involving different biofuel policies and crude oil prices. They found that, once ethanol becomes competitive with fossil fuel, a large share of the growth in maize demand is associated with growth in ethanol production, and the link between crude oil price and maize price is strong. However, in the absence of ethanol subsidies, no ethanol would be produced until the oil price reaches USD 60/barrel, and the link observed over the USD 40-60/barrel range is conditional on ethanol subsidies being in place. Therefore, according to these authors, crude oil price increases are a major driver of maize prices as long as there is a market for ethanol (whether it is free, or artificially maintained by subsidies).

OECD (2008) estimated that current biofuel support policies, including the new US and EU initiatives announced or confirmed in 2008, would increase average wheat, coarse grain and vegetable oil prices for the 2013- 2017 period by about 7%, 10% and 35%, respectively. By contrast, the price of oilseed meals is reduced about 12% by these policies, because of biodiesel-related oilseed processing. When it is assumed that second-generation biofuels become available to consumers at prices comparable to first-generation biofuels, wheat and coarse grain prices are 8% and 13% higher than without any policies, and the reduction in oil meals price is only 10%.

2.3. Previous work: what has been done and what has been found?

This section reviews some recent studies analysing the impacts and consequences of biofuel policies using one or other of the three models that are used for this study (namely ESIM, AGLINK-COSIMO and CAPRI) as well as several studies based on the IMPACT and the GTAP models (not used here) (see Mueller and Pérez Domínguez, 2008, for other relevant models not discussed here). The purpose of this review is to illustrate the kind of output that can be obtained from such exercises, to discuss the strengths and weaknesses of the different models, to compare the scenarios chosen for analysis in previous studies and to provide some results that may be useful reference points for comparing the results reported later in this study. Our selection of studies is not comprehensive. The main selection criteria are that the study should be recent, and that its objective should be relevant to that of the current study.

2.3.1. Description of the models and studies reviewed

Table 2.3 compares some basic features across studies.

The partial equilibrium (PE) ESIM model, in the version used in the study by Banse and Grethe (2008a), contains explicit supply and demand functions for biodiesel and ethanol. It distinguishes three feedstocks for each biofuel and differentiates them further according to

Table 2.3. Review of studies addressing impacts of biofuel policies on agricultural markets

Source	Approach	Country coverage	Horizon	Baseline assumptions	Biofuels policies	Production and land use changes[1,2]	Price effects[1,2]	Trade effects[1,2]
EC DG AGRI (2007)	PE model (ESIM)	MS of EU-27; TR, US modelled separately, ROW	2020	CAP as at 2007; No DDR conclusion Medium term-fall of €/$ rate (1.15 from 2013 onwards) 2nd generation biofuels commercially available, contributing 30% to total use	Biofuels in transport fuel use by 2020 are • 6.9% (baseline) • 10% (alternative scenario)	• 19% of cereal production used as biofuel feedstock; ca. 33% of biofuel production from 2nd generation feedstocks; • 15% of arable area used for biofuel production, increases coming mainly from set-aside;	• Cereals prices 3-6% higher; oilseed rape prices 8-10% higher. • Agricultural prices significantly higher if no 2nd generation biofuels available.	• Cereals exports lower; imports of oilseeds and vegetable oils higher. • Trade effects smaller if all 2nd generation feedstock produced in the EU. • Imported share of biofuels 50% if no 2nd generation biofuels available
Banse and Grethe (2008a)	PE model (ESIM)	MS of EU-27; TR, US modelled separately, ROW	2020	Energy crop premium, milk quotas maintained; Compulsory set-aside removed in 2011; DDR concludes with EU offer on tariffs and export subsidies	Biofuels in transport fuel use by 2020 are • 6.9% (baseline) • 10% (alternative scenario)	• EU biofuel production 27% higher; • EU biofuel use 50% higher; • slightly slower rate of decline in EU's AUA;	In EU: • small increases for arable crops; oilseeds & veg oils +6-7%, biodiesel +15% • livestock prices -2%; World markets: • same direction as for EU, slightly greater in magnitude	80-87% of extra biofuel demand (depending on technology assumption) satisfied by imported biofuel and biofuel inputs

Table 2.3. Review of studies addressing impacts of biofuel policies on agricultural markets (continued)

OECD (2008)	PE model (AGLINK-Cosimo)	52 countries and regions	2017	Crude oil prices remain in the range USD 90-104/barrel 2nd generation biofuels not commercially relevant Other assumptions as for the OECD/FAO Agricultural Outlook 2008-2017	• biofuel support policies as up to mid-2007 (baseline) • **Removal**: Global removal of biofuel policies, in the sequence: (1) budgetary support, (2) blending targets/ mandates; (3) tariffs • **New policies**[3]: Impacts of 2007-2008 changes in US and EU policies	2013-2017 average relative to baseline • **Removal**: Global production: ethanol -14% (ca. 50% of this fall in the EU); biodiesel - 60% (over 80% of which in EU); arable area 6.2 and 2.2 mn ha lower, globally and in the EU respectively. • **New policies**: World (EU) production +16 (16)% for ethanol, +8(6)% for biodiesel	• **Removal**: World prices: wheat -5%, coarse grains -7%; + 14% for ethanol, but -15% and -18% for vegetable oils and biodiesel, respectively; • **New policies**: World prices: + 4% for ethanol and + 5% for coarse grains, +20% and +13-14% for bio-diesel and vegetable oils, respectively.	Not reported.
Britz and Leip (2008)	PE model (CAPRI)	EU-27 (NUTS 2 level) + 40 non-EU regions	2013	No trade in biofuels, but trade in feedstocks allowed. AUA fixed, grass land cannot be ploughed.	• biofuel share of transport fuel market is 2% (baseline) • biofuel share in transport fuel market reaches 10% in 2013	Higher production (+17 mn t of cereals, +7 mn t of oilseeds)	cereals (+13%), oilseed (+32%) and oil prices (+30%) increase by-products (-50%)	Less exports, more imports (net trade changes of -17 mn t cereals, -10 mn t oils)
Rosegrant (2008)	PE model (IMPACT)	115 countries, ROW 40 agricul-tural com-modities	2015	Projections assuming 2007 policies, conditions unchanged	• biofuel demand continues 2000-7 growth (baseline) • production frozen in all countries at 2007 levels • no production after 2007		**World markets Freeze:** maize -14%, wheat -4%, oils -6% **Elimination:** maize -21%, wheat -11%, sugar -12%, oils -1%	

Table 2.3. Review of studies addressing impacts of biofuel policies on agricultural markets (continued)

Hertel *et al.* (2008)	GE model (GTAP)	113 regions, 57 sectors	2015	GTAP-E (version designed specific-ally to examine energy and climate change policies) + AEZ (land use model with 18 agro-ecological zones) No by-products included	• energy policies as in 2006 (baseline) • 2015 targets: 15 bn gall ethanol used (US), 6.25% biofuel market share (EU)	2015 relative to 2006		
						• coarse grain output +16.6% (US), +2.5% (EU), -0.3% (BR); other grain output -7.6% (US), -12.2% (EU), -8.7% (BR); oilseeds output +6.8% (US), +51.9% (EU), +21.1% (BR) • crop area increases in US, EU and BR at the expense of pasture and commercial forest	• coarse grain price +22.7% (US), +23.0% (EU), +11.9% (BR); other grain price +7.7% (US), +13.7% (EU), +8.8% (BR); oilseeds price +18.2% (US), +62.5% (EU), +20.8% (BR)	World exports • Coarse grains fall significantly in US and EU, increase in all other regions • Oilseeds increase by USD 4375 (decrease by 1452 from EU and increase by 1441 from BR) • food products other than coarse grains and oilseeds fall by USD 1,794 million
Taheripour *et al*. (2008)	GE model (GTAP)	113 regions, 57 sectors	2015	GTAP-E (version designed specific-ally to examine energy and climate change policies) + AEZ (land use model with 18 agro-ecological zones)	• energy policies as in 2008, including 2015 targets of 15 bn gall ethanol used (US), 6.25% biofuel market share (EU), no by-products (baseline) • biofuel by-products (DDG and oil meals) included worldwide	2015 relative to 2006 (compared with results of Hertel *et al*. (2008))		
						• coarse grain output +10.8% (US), -3.7% (EU), -2.8% (BR); oilseeds output +8.6% (US), +53.1% (EU), +19.0% (BR) • +ca. 170% in US, +ca. 430% in EU. • reductions in pasture area cut by about two-thirds in US, EU and LAEEX[4], by about half in BR.	• coarse grain price +14.0% (US), +15.9% (EU), +9.6% (BR); oilseeds price +14.5% (US), +56.4% (EU), +18.3% (BR)	US exports • fall in coarse grain exports much less • large increases in other grain and oilseeds exports to Europe disappear, partly diverted to other countries

1. Relative to baseline unless otherwise stated. 2. In 'horizon' year, unless otherwise stated. 3. The study also compares the combined effect of the baseline and 'new policies' against 'removal' in order to assess the total impact of biofuel support policies. 4. LAEEX = Latin American energy exporting countries.

whether or not they have been grown on set-aside land. The model considers four by-products: gluten feed and meals from three different oilseed crops. ESIM models each EU Member State individually, incorporates a wide range of EU agricultural domestic and trade policies, and endogenously determines a very rich set of agricultural prices. However, fossil energy prices are taken as exogenous and, being a comparative static model, it does not allow for any lagged adjustment (adjustments to price changes or other shocks take place within the current year). Net trade flows are endogenous. Crop yields are endogenous with respect to price (that is, crop yields respond positively to output price increases).

AGLINK-COSIMO is a dynamic recursive partial equilibrium model that incorporates a wide range of agricultural and trade policies for 52 countries and regions. Various by-products of biofuel production are distinguished: oil meals, DDG and gluten feed (ethanol) and protein-rich animal feed (sugar beet). Fossil energy prices are exogenous. The EU is modelled as two regions (EU-15 and EU-12 respectively), although biofuel demand and supply functions are modelled only at aggregate EU-27 level[20]. Net trade flows are endogenous. Yields of major crops are price-endogenous.

CAPRI does not include equations for endogenising biofuel production. Rather, the feedstock demands implied by biodiesel and ethanol targets are set exogenously, and the model determines their consequences for supply, demand, trade flows and prices of agricultural products. The version of CAPRI used by Britz and Leip (2008) recognises two agricultural crops as feedstocks for each of the two transport biofuels produced in the EU, as well as by-products in the form of gluten feed and oilcakes. Net trade flows are endogenous. Crop yields are endogenised.

The IMPACT model was developed at IFPRI with the main aim of analysing the effect of policies and other exogenous developments on global food production and availability, and the performance of global food markets. It is a partial equilibrium, comparative static model. Given its primary aim, it contains features not present in the other partial equilibrium models covered in the table (for example, consumer and producer prices are separately modelled, and differ by a marketing margin and a policy wedge; water availability affects both crop areas and yields; malnutrition is modelled).

[20] This means that fuel taxes are set at uniform rates across the EU (€59.6/m^3 and €68.3/m^3 for petrol and diesel, respectively) and a 50% exemption is assumed everywhere for the bioenergy version of the respective fuel.

The version of GTAP used in the studies by Hertel *et al*. (2008) and Taheripour *et al*. (2008), known as GTAP-E, has been specially extended to deal with biofuel and climate change policies. For these two exercises, GTAP-E is linked to AEZ, a global land use model that distinguishes 18 different agro-ecological zones. Unfortunately, the value of this addition cannot be fully exploited since the total land area used for crops, pasture and commercial forestry is forced to remain constant. This means that price-induced increases in cropland must be at the expense of pasture or commercial forests, and depletion of rainforests or other ecologically-valuable non-commercial land cannot be simulated. As it is a general equilibrium model (that is, all economic sectors are represented), the energy sector is endogenised. GTAP-E has been extended to allow substitution between biofuels and fossil fuel for transport use[21]. Three different transport biofuels are explicitly modelled: maize-based ethanol, sugar-cane-based ethanol and biodiesel. Crop yields are endogenous[22].

The standard GTAP model does not allow for joint production, and this limitation means that the version used in the study by Hertel *et al*. (2008) does not include any biofuel by-products. The main purpose of the study by Taheripour *et al*. (2008) was to illustrate how the estimated effects of biofuel polices change when the model is adapted in order to allow two biofuel by-products, DDG (grain ethanol) and oil meals (biodiesel), to be produced and used as animal feed in all biofuel-producing countries. As expected, the inclusion of by-products reduces the extent of indirect land use changes. The differences are striking, affecting primarily the estimated effects of biofuel production on coarse grain and oilseed outputs, prices and trade in the US and the EU, but also with much smaller spillover effects to food grains, to sugarcane, to Brazil and to the group of Latin American energy-exporting (LAEEX) countries. Moreover, without by-products, biofuel policies were estimated to increase US exports of other grains and oilseeds to the EU by 32% and 106%, respectively, whereas with by-products in the model, US exports of other grains to the EU actually fall, and the increase in exports of oilseeds is limited to about 15%. Another effect worth mentioning is that the estimated changes in land cover due to biofuel policies are significantly mitigated: instead of losses in pastureland of 4.9%, 9.7%, 6.3% and 1.9% in the US, EU, Brazil and LAEEX, respectively, these losses are only 1.5%, 3.9%, 3.1% and 0.6%, respectively.

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[21] In the absence of a reliable substitution parameter from the literature, the authors used a 'historic' (2000-2006) run of GTAP to generate a set of country-specific parameters.

[22] The study assumes Keeney and Hertel's (2008) central estimate of 0.4 for the long run yield response to price.

Different models may give different results to the same policy question depending on how they are constructed. Differences between models occur in their underlying philosophy, their level of product and spatial disaggregation, which types of behaviour they include, which variables are endogenous within the model and can therefore be affected by policy changes as well as affecting them, the details of their behavioural and technical specification, the way they are parameterised, and the treatment of trade flows[23], among other things. In addition, when different baselines are used (either by different models, or by the same model but in another simulation exercise) this will also contribute to differences in results.

When different models give conflicting or non-homogeneous answers to the same question, it can undermine confidence in their results and create scepticism on the part of users. However, when the key, relevant differences in model specification are understood and taken into account, divergence in model results can provide additional insights into the workings and impacts of the policies themselves.

In this respect, a comparison of the studies by Hertel *et al*. (2008) and Taheripour *et al*. (2008), which revealed the key role played by commercial by-products in moderating the impacts of biofuel expansion, is very instructive. It is, however, a special case. Since the same model was used in both studies, with the *only* difference being the incorporation of two biofuel by-products, this comparison of results has all the rigour of a sensitivity analysis[24]. In the more usual case, there are many differences between models, and those that are important for one simulation may not play any role for another. One cannot therefore interpret all differences in model results as due to one key specification difference, even if this difference appears to be the most relevant in the context of a particular application. In these cases, more rigorous sensitivity analyses performed *within* each model separately can shed additional light on what drives model results, and hence on *which* differences are likely to have led to differences in results.

Interpreting and analysing differences in model results in terms of model properties is of intrinsic interest to modellers; it is one aspect of the ongoing process of quality control and model improvement. However, differences in model properties may also be interpreted as

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[23] The main options are: only net trade is modelled; two-way trade can occur (based on an Armington-type assumption); bilateral trade between pairs of countries can be separately identified.

[24] A sensitivity analysis involves altering just one parameter or feature of a model, and comparing the simulation results obtained using this variant of the model with those obtained with the original version of the model. By holding everything else constant except the one change introduced, one can identify the extent to which this single feature of the model affects its results.

differences in assumptions about *real world phenomena* – for example, about the existence or not of behavioural linkages, the responsiveness of these links, the presence of feedback loops, the underlying technology, the speed of adjustment of different parts of the system and so on. Differences in model results can help to pinpoint features of the real system that are important, or poorly understood, or in danger of being overlooked by policymakers.

2.3.2. Synthesis of results

The studies summarised in Table 2.3 have been chosen because their scenarios are relevant to those analysed in this report. They virtually all investigate the effect of policies that impose a particular target for biofuel consumption. The studies do not usually report, in technical terms, exactly how these targets are imposed in the model. Some of them also contain changes in other support measures such as preferential tax regimes.

There is strong agreement between the studies shown in Table 2.3 in terms of where the impacts of biofuel policies occur most strongly, and the directions of the changes. Output of cereals and oilseeds increases, as does arable area. Several studies report that these changes are accompanied by a small decline in livestock production. Prices increase for wheat, coarse grains and sugar, and particularly for oilseeds and vegetable oils. The most noteworthy changes in trade flows involve reductions in the net trade balance for cereals and oilseeds/oils for the EU and for cereals in the US.

Alongside this broad agreement, however, the magnitude of these effects differs between the studies reported above because of the following differences (among others):

- model specification (disaggregation level, structure, parameters, other assumptions);
- baseline: differences are due to the timing of the study, and the specific information used to construct the baseline;
- horizon of the simulations:
- scenarios: studies by EC DG AGRI (2007), Banse and Grethe (2008), and Britz and Leip (2008) involve changes to EU policy only; studies by Hertel *et al*. (2008) and Taheripour *et al*. (2008) simulate simultaneous changes in EU and US policy; OECD (2008) and Rosegrant (2008) consider global policy changes.

2.4. Conclusions

There are various competing market and trade simulation models (both partial equilibrium and general equilibrium models) in the literature that are able to represent biofuel markets and biofuel policies, and that have been used to simulate the effects of policies that impose a target share for biofuel in total fuel consumption.

The studies reviewed here tend to report similar results in terms of commodity balances, price movements and trade flows. The results obtained for the main producing and consuming countries, and the differences in the market outcomes for the various biofuel feedstocks, provide important insights and food for thought. However, their ability to simulate many of the impacts of biofuel policies, whether intended and unintended, that are identified in Table 2.2, is incomplete, hardly comparable between models, and for some effects non-existent. For example, regarding the full impacts of mandatory biofuel targets on land use change world wide, there are wide differences between the models in how, and the extent to which, they are able to address this issue. In the case of the richest and most comprehensive treatment discussed (GTAP-E linked to AEZ), the model specification limits the insights available. In another example, none of the partial equilibrium models, which take total transport fuel use as exogenous when imposing a mandated share of biofuel use, are able to simulate the potential of biofuel policies to reduce total fuel demand because of the higher price of blended fuel. Similarly, this type of model is unable to examine some of the unintended negative impacts related to intensification of production and increased demand on water resources. These issues are taken up again in Chapter 6.

3. Results from the AGLINK-COSIMO model

3.1. Introduction

AGLINK-COSIMO is a recursive-dynamic, partial equilibrium, supply-demand model of world agriculture, developed by the OECD Secretariat[25] in close co-operation with member and certain non-member countries. The model covers annual supply, demand and prices for the main agricultural commodities produced, consumed and traded in each of the regions included (OECD, 2006). AGLINK has been developed on the basis of existing country models and thus the model specification reflects the different choices of the participating countries. Efforts have been made to achieve uniformity across the country modules and to keep the modelling approach as simple as possible (Conforti and Londero, 2001). Collaborative discussions between the OECD Secretariat and the Commodities and Trade Division of the FAO (Food and Agricultural Organisation), starting in 2004, resulted in a more detailed representation of developing countries and regions based on the FAO's COSIMO (COmmodity SImulation MOdel) (OECD, 2006). The programming structure of COSIMO was taken over from AGLINK, while the behavioural parameters for the new countries (i.e. for the developing countries, which were covered only by COSIMO) were taken from the World Food Model (WFM) (Adenäuer, 2008).

In its current version, AGLINK-COSIMO covers 39 agricultural primary and processed commodities and 52 countries and regions (Table 3.1 and 3.2). Both models, AGLINK and COSIMO, contain individual modules for each country or region. For AGLINK, these modules are first calibrated on initial baseline projections, derived by the OECD Secretariat from data and other information provided in annual questionnaires provided by each OECD member country. In addition, the model is adjusted regularly so as to reflect all domestic agricultural policies of each member country. The COSIMO initial projections are a combination of views of the FAO market analysts and model-driven projections, as no questionnaires are distributed for those countries.

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[25] The results of any analysis based on the use of the AGLINK model by parties outside the OECD are not endorsed by the Secretariat, and the Secretariat cannot be held responsible for them. It is therefore inappropriate for outside users to suggest or to infer that these results or interpretations based on them can in any way be attributed to the OECD Secretariat or to the Member countries of the Organisation.

In the next step, the country modules are merged to form the complete AGLINK-COSIMO model. The model is solved simultaneously and adjusted where needed to generate a commodity baseline.

Each supply and demand decision is represented by a behavioural equation. The elasticities in these equations are either estimated, assumed or taken from other studies, and determine the degree to which a particular quantity responds to changes in prices or other conditioning factors (Thompson, 2003).

Table 3.1: Country/region representation in AGLINK-COSIMO

AGLINK:	COSIMO:
Argentina	India
Australia	Turkey
Brazil	South Africa
Canada	Ghana, Mozambique, Ethiopia, Tanzania, Zambia, Algeria, Egypt, Nigeria, other West Africa, LDC-West Africa, other southern Africa, LDC-southern Africa, other north Africa, other east LDC-east Africa
China	
EU-27 (EU-15 and EU-12)	Bangladesh, Indonesia, Iran, Malaysia, Saudi Arabia, Pakistan, Philippines, Thailand, Vietnam, other independent states, other Asia and Pacific, LDC-Asia and Pacific
Japan	
South Korea	other east Europe, other west Europe, Ukraine
Mexico	Chile, Colombia, Peru, LDC-central and Latin America, other central America, other southern America, Paraguay, Uruguay
New Zealand	
Russia	
USA	

Source: own compilation

Table 3.2: Commodity representation in AGLINK-COSIMO

Wheat	Milk	Molasses
Coarse grains (barley, maize, oats, sorghum)	Butter	High fructose corn syrup
Rice	Cheese	Inuline
Oilseeds (soya bean, rapeseed, sunflower seed)	Wholemilk powder	Ethanol
Oilseed meals (soya bean meal, rapeseed meal, sunflower meal)	Skim milk powder	Biodiesel
Vegetable oils (oilseed oil: soya bean oil, rapeseed oil, sunflower oil; palm oil)	Fresh dairy products (other dairy products)	Dried Distiller's Grains
Sugar beet	Whey powder	
Sugar cane	Casein	*Plus exogenous representation of*:
Raw sugar	Beef and veal	Petrol type fuel use
White sugar	Pigmeat	Diesel type fuel use
	Poultry meat (chicken meat, other poultry)	
	Sheep meat	
	Eggs	

Notes: For particular countries, additional commodities of national importance are modelled (e.g. manioc and cotton in some COSIMO countries).

Source: own compilation

World market prices are usually the fob or cif prices of a big market player for a particular commodity. The border prices for a country/region are taken to be the world market prices.

AGLINK-COSIMO treats commodities as homogeneous and trade is modelled as net trade, given as the difference of supply and demand. However, both imports and exports are represented, with one of the two generally calculated residually. The other, often the smaller of the two, is either kept as a function of some domestic variables (e.g. Canadian coarse grain exports are a function of domestic barley and oats production) or treated as exogenous (e.g. US wheat imports). In some cases, both exports and imports are modelled separately, with a domestic market price clearing the domestic market (e.g. Chinese rice markets).

3.2. Representation of biofuels in AGLINK-COSIMO: Overview

Biofuel modules have recently been included in AGLINK-COSIMO for certain countries and regions. The regions with the most detailed biofuel representation are the EU, Canada, USA and Brazil. Some developing and emerging economies (e.g. Malaysia, Indonesia, India, China and others) have a simpler representation of biofuels, while exogenous biofuel quantities are included for Argentina and Australia. For Japan, ethanol net trade is represented.

In general, the biofuel module determines the production of biofuels, the use and production of by-products and their use for transport. Non-transport use of ethanol is generally given as an exogenous assumption.

The following sub-sections of this chapter present a general description of the supply and demand for biofuels in AGLINK-COSIMO based on the technical description in OECD (2008, pp. 117-134).

3.2.1. Production of biofuels and biofuel by-products

The model includes first and second generation biofuels, modelling the first endogenously and taking the second as exogenous. The total biofuel production of both ethanol and biodiesel is the sum of the individual quantities by feedstock, where first generation production depends on, *inter alia*, capacity availability.

First generation biofuels production from agricultural commodities is modelled based on two key variables: production capacity and the rate of capacity usage.

Production capacity is a function of the net revenues from biofuel production, and responds with a time lag based on the time required to plan and build new facilities. These time lags have been determined empirically, and are one to 4 years given that it takes 18 months to set up a biofuel plant and that expected returns depend on past returns. Net revenues are given as the difference between the output value and the production costs per unit of biofuels. The output value in turn is determined by the biofuel prices as well as subsidies directly linked to the biofuel production.

The capacity function has been estimated using US data and, in order to overcome the lack of data for other regions, is scaled for other countries by their respective total investment capacities. The capacity use rate depends on variable net cost and does not consider capital fixed costs. Hence, no time lags are included in this function.

Second generation biofuels may be produced from dedicated biomass, which implies that they compete with agricultural commodities for land. However, this version of AGLINK assumes that second generation biofuel feedstock production (whether from dedicated biomass production or non-agricultural sources) is independent of the agricultural sector, and so agricultural markets and land use are not affected by second-generation biofuel production[26].

Detailed tables with baseline assumptions on conversion factors of feedstock into biodiesel as well as on area and yield elasticities for the EU-27 are in the Annex (Tables A3.1 and A3.2).

By-products

Among the by-products relevant for biofuel markets are oil meals and distillers grains in liquid or dried form. Given that biodiesel is modelled as directly using vegetable oils rather than oilseeds as a feedstock, and that the crushing of oilseeds into oils and meals is a standard feature of AGLINK-COSIMO, the oil meals as a by-product of biodiesel production do not need any specific consideration in the model. Dried distillers grains (DDG), on the other hand, require specific modelling and data. Their market price has been derived as a function of the prices for oil meals and coarse grains (the two main feed commodities that distillers grains can replace in animal feed rations), and of the quantity of grains used in ethanol production (used as a proxy for the DDG production quantity) relative to the size of the country's meat production. For lack of country-specific data, the parameters for this relationship across all countries and regions have been estimated based on historical US data (see Table A3.1).

Shares of DDG used for different livestock types (ruminant versus non-ruminants), as well as their rate of replacement for coarse grains and oilseed meals, are assumed exogenously, based

[26] A version of AGLINK under development allows for competition between non-food biofuel crops and food crops by deducting the land used by the former from the total land available for agricultural production.

on work by the Economic Research Service of the US Department of Agriculture. The same parameters are used for the EU and Canada. This assumption might overestimate the replacement of coarse grains relative to oil meals in the EU, due to a higher protein content of the wheat DDG and different market and diet structure. Blended coarse grains and oil meal prices are calculated to take into account the partial replacement by (cheaper) DDG, and are used to calculate specific feed cost indices for ruminants and non-ruminants.

The model includes share estimates for feed use by ruminants and non-ruminants separately, since ruminants can digest higher rations of DDG than non-ruminants and as the replacement is different across the livestock types. It is assumed that 90 % of the DDG is used in ruminant feed and 10 % in non-ruminant feed. In case of ruminants it is assumed that 94% of the DDG replaces coarse grains and 6% oil meals, in the non-ruminant case these figures are 70% and 30%, respectively. The lower blended coarse grains price for feed in ruminant livestock is derived from the coarse grains and DDG prices and the respective feed quantities, and is used for the calculation of the feed cost index. By assumption DDG are not tradable. This might restrict the degree of replacement that can be achieved, and could therefore cause under-estimation of land use change avoided.

An increase in grain-based ethanol would have the following impacts on cereal feed use:

- higher demand for cereals, which increases cereals prices and decreases cereals feed use,
- higher feed costs, which decreases livestock production and the feed use of cereals,
- increased DDG availability, marketed at a discount compared to feed cereals, which would reduce the lower blended coarse grains price, partly offsetting the higher feed costs and thus the reduction in livestock production, and
- increased feed share of coarse grains-DDG at the expense of other feed, due to the decline of the blended price for coarse grain-DDG.

3.2.2. Demand for biofuels

The demand for biofuels is expressed as a share of the total demand for a given type of fuel, depending on the ratio of the biofuel market price to the market price of the respective competitor fossil fuel. The demand for ethanol is split into three components:

- Ethanol as an additive: ethanol in this use does not compete with petrol but it replaces other (chemical) additives in the blend with petrol, to the degree that this is economically and legally feasible. Ethanol replaces other additives when its price is equal to or below the price of the substitute. The price of the substitute in turn is usually related to the petrol price because most additives are crude-oil based products (a sine function mirrors the substitution process). When no alternative additive is available, ethanol use is assumed to be a fixed share of the total petrol use.

- Ethanol in low blends: the lower energy content of ethanol compared to petrol is partly offset by superior qualities like higher octane number and oxygen content, or it may be preferred for non-economic reasons (for example, if it is seen as an environmentally-friendly fuel). Therefore, ethanol competes with petrol but without a price discount (or with a discount lower than suggested by the difference in energy content). In fact, the consumption of ethanol may even be rewarded with a premium over petrol on a per litre basis, but with an increase in the share of ethanol, the lower energy content results in a price discount on a per litre basis. In any case, the decision about low blends is taken by the blenders and the distributors, who have to respect mandatory blending requirements (lower bound constraint) and not by the final consumers.
- Ethanol as neat fuel: in this case, the ethanol is meant for flexi-fuel cars that can run on pure ethanol (or on a high blend such as E85, containing 85% ethanol and 15% petrol), pure petrol or a mixture of the two. It is generally assumed that when the price of ethanol approaches the energy equivalent of the petrol price, then the demand for ethanol will rise. The substitution is again represented by a sine function.

The total demand for ethanol is based on the total use of petrol and equivalent fuels (sum of the three components described above) and the relative energy content of ethanol.

Biodiesel demand is modelled in a more straightforward way than the demand for ethanol, and depends on the price ratio between biodiesel and fossil diesel. Biofuel targets are modelled as minimum biofuel shares, consequently the biofuel demand price ratio is cut unless the demand exceeds the specified minimum level.

3.2.3. Biofuel markets

Markets are cleared by the net trade position, given as the difference between supply and demand, since stock changes are not recognised. Domestic prices are determined by the world market price, taking into account border measures like import tariffs. The price shift due to a possible net trade position change is represented by a logistic function. The price differential between the domestic and world market prices relative to the applied tariff is a function of the net trade position relative to the sum of the domestic production and consumption. It implies that the link to the world market prices for biofuels increases when the trade share rises.

3.3. Representation of EU biofuel policies

In AGLINK-COSIMO, EU biofuel policies are represented at the level of EU-27. The following description of how the various instruments are modelled is based on the technical model description in OECD (2008, pp.117-134) and information from the OECD secretariat.

1. *Import tariffs for ethanol and biodiesel*: the bound tariffs are included in the price transmission function.

2. *Tax incentives and mandatory biofuel targets*: these policies influence the demand for biofuels and are applied at Member State level, with considerable heterogeneity between Member States (see chapter 2). To represent biofuel policies at EU-27 level, various assumptions are needed. For ethanol, it is assumed, based on the 2007 questionnaire, that:

    - The average EU tax reduction compared to petrol is 50%.
    - The tax reduction for Member States that do not apply blending targets is 85%.
    - 87.6% of the EU fuel use is in countries applying ethanol targets.
    - The retail price for ethanol in Member States without mandatory targets is the EU-27 price reduced by 70% of the tax differential between ethanol and petrol at EU-27 level, that is (85%-50%)/(100%-50%).
    - Consequently, in calculating the quantity of ethanol consumed in low blends for the with-target countries, the market-driven level is determined using the average tax reduction and this is subject to the minimum level according to the average targeted share, while in no-target countries a higher tax reduction is used (which results in a lower effective ethanol price).
    - The average tax incentive also influences the use of high ethanol blends in flex-fuels vehicles (third component of ethanol demand).

To allow the model to simulate achievement of the target set in the EU Renewable Energy Directive, a different approach was used because Member States have not yet decided exactly how to implement it. The target can be implemented as a higher blending rate or/and an increased use of flexi-fuel vehicles. To take both possibilities into account, a supplement to the EU petrol margin was calculated that depends on the gap between the targeted and estimated ethanol share in the EU-27. A larger gap implies that ethanol falls further below the target; the larger the gap, the greater the petrol margin and therefore the petrol price, increasing the incentive for ethanol blending and use by flexi-fuel vehicles.

For biodiesel, it is assumed, based on the 2007 questionnaire, that:

- The average tax reduction in the EU-27 is 50%.
- The average tax reduction is 70% in Member States that do not apply biofuel targets.
- Analogous to ethanol, the retail price for biodiesel in no-target Member States is the EU-27 price reduced by 40% of the tax differential between biodiesel and petrol.
- Because biodiesel demand is represented in a simpler way than ethanol demand, when calculating the quantity consumed only average and higher tax incentives are included. The average tax incentive is subject to the target, while both types are weighted by the overall fuel shares.
- Following the EU Renewable Energy Directive, the aggregate biodiesel share is subject to the (higher) target.

3.4. Baseline and scenario assumptions

3.4.1. Baseline

The empirical analysis used version 2009 of the AGLINK-COSIMO model, with the baseline extended to 2020 and updated with macroeconomic assumptions dating from May 2009.

Table 3.3: Macroeconomic assumptions for the EU-27 (baseline)

	2008	2009	2010	2015	2020
EU-27 Population (millions)	493.7	497.4	499.4	507.7	515.0
World crude oil prices ($US per barrel)	99.3	52.1	61.7	87.8	104.0
E15					
CPI[1]	3.0	0.6	1.2	1.8	1.9
Real GDP[1]	1.1	-4.0	-0.1	2.0	1.7
Exchange rate (Euro per $US)	0.7	0.8	0.8	0.7	0.7
E12					
CPI[1]	4.7	2.7	2.1	2.4	2.2
Real GDP[1]	1.6	-3.1	0.2	4.1	3.4
Exchange rate[2]	2.5	2.8	2.8	2.5	2.3

Notes: [1]growth from previous year in %. [2]currency basket of the EU-12 per $US
Source: IHS Global Insight, 2009

Table 3.3 summarises the assumptions for EU-27. It should be noted that the same macroeconomic indicators have been updated for all countries and regions of AGLINK-COSIMO, based on the dataset of IHS Global Insight (2009).

Table 3.4 shows the baseline assumptions regarding EU biofuel policies. The energy share of biofuels is assumed to reach 8.5% in 2020, of which 7% consists of first generation and 1.5% second generation biofuels. Consistent with the Renewable Energy Directive, the energy provided by the latter is considered doubled for the purpose of meeting the 10% target. Starting from separate exogenous estimates of petrol and diesel consumption by the transport sector in 2020, the ethanol and biodiesel consumption in 2020 are each fixed at 8.5% of the total 2020 consumption of the corresponding fuel type. Second generation biofuel production is assumed to have no land use implications.

Table 3.4: Biofuel baseline assumptions for the EU-27

	2008	2009	2010	2015	2020
Minimum share of biofuels in total transport fuel, %	1.9	2.3	2.8	6.4	8.5
Minimum share of 1st generation biofuels in total transport fuel, %	1.9	2.3	2.8	6.4	7.0
Minimum share of 2nd generation biofuels in total transport fuel, %	-	-	-	-	1.5
Ethanol tax rebate (difference between ethanol and gasoline tax) (gasoline tax in €/hl)	-29.8	-29.8	-29.8	-29.8	-29.8
Biodiesel tax rebate (difference between biodiesel and diesel tax) (diesel tax in €/hl)	-34.1	-34.1	-34.1	-34.1	-34.1
Gasoline consumption (mill l)	145214	145423	145632	146678	147577
Diesel consumption (mill l)	210347	227826	231726	251561	265374

Source: model assumptions (DG AGRI, Primes (2007))

Furthermore, it is assumed that tariffs are applied for EU imports of ethanol and biodiesel. It is assumed that all ethanol imports will consist of undenatured ethanol facing the specific tariff of €19.2/hl. For biodiesel, the applied tariff is 6.5% (OECD-FAO outlook, 2009). On the supply side, no direct support is given for producing biofuels from specific feedstocks (OECD-FAO Outlook, 2009).

3.4.2. Counterfactual scenario

For the purpose of this study, a counterfactual scenario was developed, which assumes the absence of all internal EU biofuel policies. In particular, it is assumed that the EU does not apply any special policy supporting the production or consumption of biofuels, and thus ethanol and biodiesel are treated as competing unaided with petrol and diesel, respectively. To implement this scenario, the following is assumed:

- The tax credits for the consumption of both ethanol and biodiesel are eliminated. The biodiesel tax is set at the same level as the diesel tax and the ethanol tax at the level of the petrol tax.
- There is no blending obligation in the EU for ethanol and biodiesel, and thus the demand for each type of biofuel is regulated only through the market mechanism.
- The import tariffs are maintained unchanged.

The production of biofuels continues to depend on production capacity and on the capacity use rate of the biofuel factories, as well as on feedstock prices.

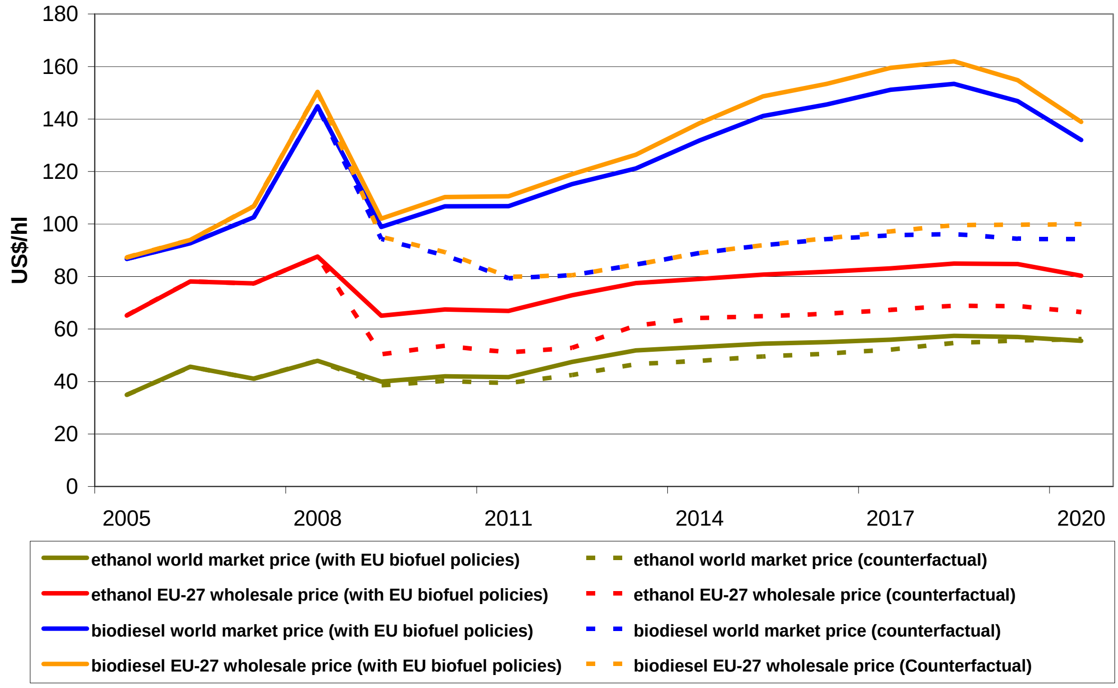
3.5. Results

This section presents the simulation results for the baseline and counterfactual scenarios. In particular, it reports the effects on world market price, on commodity balances of biofuels and feedstock both in the EU and in the rest of the world, and on the use of crop land worldwide. The reader should bear in mind that the baseline assumes that agreed EU biofuel policies are in place whereas the counterfactual scenario serves as a hypothetical 'no-policies' comparison. As the purpose of this study is not to describe the developments as simulated in the baseline scenario, but to report on the impact of the EU biofuel policies, the discussion focuses on comparing the baseline with the counterfactual.

3.5.1. Effects on world market prices

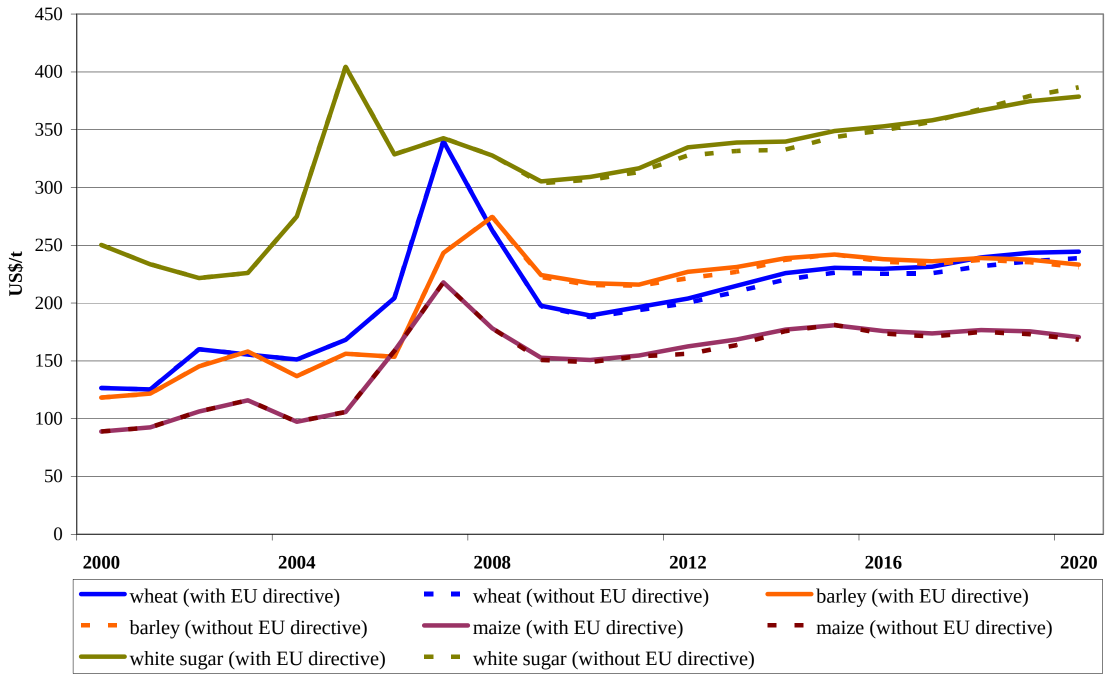
Without biofuel policy support in force, domestic biofuel demand would be much lower, leading to lower prices within the EU (see Figure 3.1), which in turn implies weaker production incentives. These lower prices would be transmitted to the world market, where the effect is greater in the case of biodiesel as the market share of the EU is much larger. Therefore, the impact of EU policies on the world biodiesel market is considerable, leading to further international implications (see below).

Figure 3.1: Impact of EU biofuel policies on biofuel prices



Source: AGLINK-COSIMO simulation results

Figure 3.2: Impact of EU biofuel policies on world market prices of ethanol feedstocks

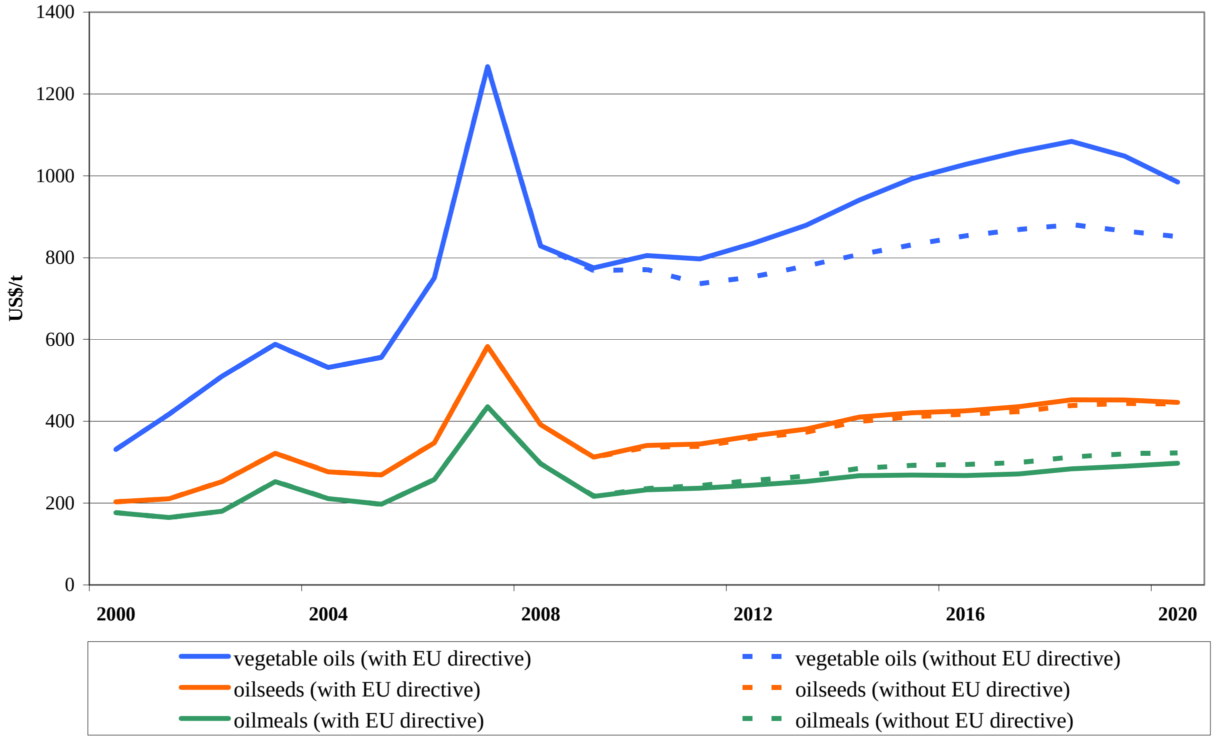


Source: AGLINK-COSIMO simulation results

Differences in EU commodity balances of the main ethanol feedstocks, cereals and sugar, should impact on their world market prices. However, these impacts are very small, due to the low total share of ethanol feedstock demand in these commodity markets (see Figure 3.2).

The effects of EU policies on world market prices for biodiesel feedstocks vary (Figure 3.3). As well as oilseeds, other relevant traded products are oil meals, a major animal protein feed, and vegetable oils, both of which are derived from the crushing of oilseeds. The price differences for oilseeds are marginal, whereas oil meal prices would be higher, but only slightly so, without EU policies. Vegetable oil prices would be much lower without EU policies, since vegetable oils are the feedstock used for biodiesel production. 'Vegetable oils' is the sum of oils produced from oilseeds and palm oil, and oilseeds included are rapeseed, soya beans and sunflower

Figure 3.3: Impact of EU biofuel policies on world market prices of biodiesel feedstocks



Source: AGLINK-COSIMO simulation results

3.5.2. Effects on EU commodity balances and land use

Biofuel commodity balances

Table 3.5 shows the effects on biofuel commodity balances in EU-27. In the baseline scenario, EU demand for biofuels reaches the target, which requires considerable imports of ethanol and biodiesel (16% and 14% of EU demand, respectively). Ethanol imports peak in

2015 at 43% of EU ethanol use and then fall, partly due to the assumption that second generation ethanol is phased in after 2015.

Table 3.5: Effects on biofuel commodity balances in the EU-27 with and without EU biofuel policies (in million litres)

	2008	2009	2010	2015	2020
Ethanol					
Production	5021 *5021*[1]	5513 *5041*	5949 *4952*	9778 *3713*	17790 *6385*
of which:					
1st generation	5021 *5021*	5513 *5041*	5949 *4952*	9778 *3713*	14486 *6385*
2nd generation	0 *0*	0 *0*	0 *0*	0 *0*	3304 *0*
Net trade[2]	-1677 *-1677*	-1876 *-473*	-2633 *-516*	-7467 *-427*	-3449 *-483*
Demand	6698 *6698*	7389 *5514*	8582 *5468*	17246 *4141*	21239 *6868*
Share of energy from ethanol(in %)	1.9 *1.9*	2.3 *1.4*	2.8 *1.4*	6.7 *0.8*	8.5 *2.0*
Biodiesel					
Production	8064 *8064*	8122 *7069*	9293 *5847*	17174 *3173*	24243 *3536*
of which:					
1st generation	8064 *8064*	8122 *7069*	9293 *5847*	17174 *3173*	19268 *3536*
2nd generation	0 *0*	0 *0*	0 *0*	0 *0*	4976 *0*
Net trade	-1136 *-1136*	-1876 *-111*	-966 *-253*	-2931 *373*	-3953 *-780*
Demand	9200 *9200*	8911 *7180*	10259 *6100*	20105 *2800*	28196 *4316*
Share of energy from biodiesel (in %)	3.5 *3.5*	3.1 *2.5*	3.5 *2.1*	6.4 *0.9*	8.5 *1.3*

Notes: 1: the numbers in italics throughout the table refer to the results of the counterfactual scenario
2: net trade calculated as exports – imports; negative (positive) values imply net imports (exports).
Source: AGLINK-COSIMO simulation results

In the counterfactual scenario, the biofuel balances are driven by market forces. The transport fuel share in 2020 of biodiesel and ethanol is only 1.3% and 2.1%, respectively, and there is no production of second generation biofuels (by assumption). First generation EU biodiesel and ethanol production in 2020 is only 18% and 44% of the baseline, respectively. Imports of biofuels are 20% and 14% lower than the baseline for biodiesel and ethanol, respectively, which impacts on non-European suppliers.

Feedstock balances

The only feedstock used in the production of first generation biodiesel in the EU is vegetable oil. In general, three main possibilities exist for obtaining the necessary feedstock for the EU production: vegetable oil produced from EU oilseeds, vegetable oil produced from imported oilseeds, and imported vegetable oil.

AGLINK-COSIMO does not distinguish between the different vegetable oils used as feedstock for biodiesel production. Thus, the production of biodiesel cannot be attributed to any specific vegetable oil. Table 3.6 shows that the EU production of oilseeds expands by 5.5%, but the oilseed crush is down by 3.9% due to a 17% decline in net imports. Both larger production of oilseeds in the EU and lower crush due to smaller crushing margin contribute to a strong decline in oilseed imports. Lower EU crushing is also the result of reduced oil meal demand from the domestic feed market, due to partial replacement by DDG available from higher ethanol production. The main source of the 68% increase in vegetable oil consumption is a more than 2.5-fold surge in net vegetable oil imports from 5.5 to 20 million tonnes.

Table 3.6: EU-27 oilseed and vegetable oil balance (in thousand tonnes)

	2008	2009	2010	2015	2020
Baseline					
Oilseed production	26624	27180	25155	28560	31573
Oilseed: net trade	-17142	-14525	-17243	-15793	-16540
Oilseed: crush	41468	39434	40182	41953	45622
Vegetable oil: production	13110	12477	12732	13278	14436
Vegetable oil: net trade	-7992	-8689	-9555	-17242	-20035
Vegetable oil: consumption	21079	21224	22303	30523	34479
of which: for biodiesel	7522	7576	8669	16020	17973
Counterfactual					
Oilseed production	26624	27167	25043	27233	29931
Oilseed: net trade	-17142	-14661	-18014	-19441	-20004
Oilseed: crush	41468	39549	40806	44270	47495
Vegetable oil: production	13110	12514	12930	14028	15046
Vegetable oil: net trade	-7992	-7697	-6297	-4173	-5489
Vegetable oil: consumption	13110	12531	12948	14045	15064
of which: for biodiesel	7522	6594	5454	2960	3299

Source: AGLINK-COSIMO simulation results

AGLINK-COSIMO recognises three feedstocks for producing first generation ethanol in the EU: wheat, coarse grains and sugar beet. In the case of sugar beet, biofuel production can by assumption only be based on domestically produced beet as there is no trade in sugar beet. Thus, the greater demand for this feedstock for EU ethanol production has to be satisfied by domestically produced sugar beet, which is higher by 10.6%.

EU biofuel policy causes EU production of coarse grains to be only slightly higher in 2020 (by 0.4%), which accounts for about a third of its overall higher consumption (Table 3.7). For the rest, the EU switches to being a net importer. Finally, the largest change occurs in the use of coarse grains, whose non-biofuel use is 3.3% lower than it would be without the policies.

Lower coarse grain feed use can be partly replaced by the increasing availability of biofuel by-products

Table 3.7: EU-27 coarse grains balance (in thousand tonnes)

	2008	2009	2010	2015	2020
			Baseline		
Production	162379	156783	154487	165510	174154
Net trade	7272	221	1372	-1441	-116
Consumption	149627	156795	156018	165896	174339
of which: for ethanol	3400	4006	4258	8415	15150
			Counterfactual		
Production	162379	156748	154345	164423	173468
Net trade	7272	492	1697	-1194	1074
Consumption	149627	156471	155595	164666	172128
of which: for ethanol	3400	3340	3273	3091	7454

Source: AGLINK-COSIMO simulation results

Wheat production in the EU is higher in 2020 by 3.2% in the baseline (Table 3.8). Due to the increase in wheat-based ethanol production, EU consumption of wheat increases by 7.3%, although the consumption of wheat for non-biofuel use is almost constant. Thus, about half of the higher demand for wheat is met by domestically produced wheat, with the other half coming from changes in trade flows. The EU remains in both scenarios a strong net exporter of wheat, but its exports are about a third lower due to biofuel policies.

Table 3.8: EU-27 wheat balance (in thousand tonnes)

	2008	2009	2010	2015	2020
			Baseline		
Production	150243	133990	134323	149244	154049
Net trade	11305	12169	6996	15628	13530
Consumption	129006	123560	126875	132910	140354
of which: for ethanol	2800	3365	4152	7832	11029
			Counterfactual		
Production	150243	133910	133952	145921	149258
Net trade	11305	12294	7492	19729	18364
Consumption	129006	123347	126039	125588	130847
of which: for ethanol	2800	3128	3143	334	1368

Source: AGLINK-COSIMO simulation results

By-products and animal products

With higher EU ethanol production, DDG production as a by-product in the processing of coarse grains and wheat is nearly 6 million tonnes higher due to biofuel policies. This has an impact on the EU animal feed market; the total amount of feed consumed increases marginally but feed use of coarse grains declines by 4.1%.

Table 3.9: Consumption of main feed ingredients in the EU-27 (in thousand tonnes)

	2008	2009	2010	2015	2020
Baseline					
Corn gluten feed	3053	3280	3266	3461	3582
DDG	2099	2497	2867	5528	8815
Oil meals	49745	51169	51742	52772	53712
Wheat	57145	50353	52282	53774	56561
Coarse grains	114893	120556	119635	126112	128148
Counterfactual					
Corn gluten feed	3053	3278	3253	3370	3488
DDG	2099	2201	2186	1090	2836
Oil meals	49745	51187	51777	52722	53760
Wheat	57145	50366	52418	53845	56586
Coarse grains	114893	120888	120187	130192	133595

Source: AGLINK-COSIMO simulation results

By assumption, all domestically produced DDG is consumed as domestic feed. Due to the assumed replacement coefficients, the replacement will be mainly for coarse grains. Table 3.9 shows that higher DDG in 2020 means coarse grain feed use is less by nearly as much. Lower oil meal prices have the effect that the consumption of oil meals remains almost unchanged.

Table 3.10: Production of animal products in EU-27 (in thousand tonnes)

	2008	2009	2010	2015	2020
Baseline					
Milk	148653	147291	147154	148399	150573
Beef and veal	8293	8205	8093	7896	7632
Sheep and goats	1025	985	966	924	885
Pork	22509	21987	22319	23070	23581
Poultry	11671	11952	12327	11986	11403
Eggs	6985	7005	7077	6938	6886
Counterfactual					
Milk	148653	147292	147145	148246	150301
Beef and veal	8293	8207	8100	7921	7679
Sheep and goats	1025	985	966	924	884
Pork	22509	21986	22315	23012	23493
Poultry	11671	11954	12318	11920	11381
Eggs	6985	7005	7076	6929	6874

Source: AGLINK-COSIMO simulation results

EU production of animal products is only slightly affected by EU biofuel policies (see Table 3.10). Non-ruminant animal production (pork, poultry and eggs) is slightly higher (by 0.2-0.4%) in 2020 due to slightly lower feed costs. The increase is even smaller for the ruminant products, whereas beef and veal output is actually lower. This last effect may be linked to the slightly smaller pasture area (Table 3.11) and consequent higher grazing costs.

Land use effects

EU biofuel policies stimulate some changes in EU agricultural land use (Table 3.11). In particular, the total area of cereals, oilseeds and sugar beet is 2.2% higher, implying that the secular decline in total area is more gradual than it would otherwise be (-6.5% rather than -8.6%). The 10.6% increase in sugar beet area means that the fall due to the EU sugar policy reform is less marked (-11% instead of -19%). This area change fully covers the extra demand for sugar beet as feedstock for the EU ethanol production. The effect on coarse grains area is negligible. By contrast, the 3% increase for the most important crop 'wheat' meets half the extra feedstock demand for wheat. It is also a main factor behind the total higher arable crop area in the EU. The 5.6% higher oilseed area shows its competitiveness vis-à-vis coarse grains and non-arable land use. The larger area planted to cereals, oilseeds and sugar beet means a slight reduction in pasture but without reversing the declining trend in arable crop area.

Table 3.11: Land use effects of EU biofuel policies in the EU-27 (in % difference)

	2008	**2009**	**2010**	**2015**	**2020**
Wheat	0.0	0.0	0.1	2.1	3.0
(absolute values, '000 ha, under baseline)	26435	26295	24711	25635	24483
Barley	0.0	0.0	0.1	0.6	0.2
(absolute values, '000 ha, under baseline)	13993	13926	14069	13536	13047
Maize	0.0	0.0	0.1	0.7	0.3
(absolute values, '000 ha, under baseline)	8902	9299	9187	9356	9309
Other cereals	0.0	0.0	0.1	0.7	0.3
(absolute values, '000 ha, under baseline)	10487	10197	8372	8859	8728
Total cereals	0.0	0.0	0.1	1.3	1.5
(absolute values, '000 ha, under baseline)	59818	59718	56339	57386	55567
Oilseeds	0.0	0.0	0.2	4.6	5.6
(absolute values, '000 ha, under baseline)	10182	10103	9249	9639	9928
Sugar beet	0.0	1.2	2.3	10.5	10.6
(absolute values, '000 ha, under baseline)	1640	1555	1496	1497	1467
Total area of the above	0.0	0.0	0.2	1.9	2.2
(absolute values, '000 ha, under baseline)	71639	71376	67084	68522	66962
Pastures (permanent and temporary)	0.0	0.0	-0.1	-0.8	-0.9
(absolute values, '000 ha, under baseline)	120184	120512	125029	123517	124805

Source: AGLINK-COSIMO simulation results

The changes in land use and commodity balances reflect feedstock yields (see Table A3.2).

3.5.3. Effects on commodity balances and land use effects in the rest of the world

Biodiesel and feedstocks

In the baseline, the EU is the largest player on the world biodiesel market, with 48% of the world's 50 billion litres biodiesel consumption. In the counterfactual, the fall of EU consumption by 85% (24 billion litres) leads to a completely different market situation (Table 3.12).

Without EU biofuel policies, the US, which is the main biodiesel exporter in the baseline, reduces production even below its own domestic demand, becoming a net importer. The most important exporters are Malaysia and Indonesia (their production without EU policy is lower

Table 3.12: Biodiesel balances, selected countries/regions (million litres)

		2008	2009	2010	2015	2020
		Baseline				
Production	World	15140	19365	23614	37613	52463
	EU	8064	8122	9293	17174	24243
	USA	2709	2920	3144	4893	5129
	Brazil	1089	3108	4175	2176	3421
	Argentina	1364	1705	2557	3645	4045
	Indonesia	356	417	505	944	1334
	Malaysia	536	543	590	812	987
Net trade	EU	-1136	-790	-966	-2931	-3953
	USA	1326	1193	683	1107	1358
	Argentina	1364	1495	2025	3052	3387
	Indonesia	136	186	263	633	941
	Malaysia	268	221	260	447	586
Consumption	World	13983	16906	21155	35154	50004
	EU	9200	8911	10259	20105	28196
	USA	1383	1726	2461	3785	3771
	Brazil	1089	3108	4175	2176	3421
		Counterfactual				
Production	World	15140	18946	21336	25486	32879
	EU	8064	7069	5847	3173	3536
	USA	2709	2827	2701	2758	2842
	Brazil	1089	3868	5952	6801	7717
	Argentina	1364	1705	2557	3645	4045
	Indonesia	356	408	453	734	1021
	Malaysia	536	531	530	634	747
Net trade	EU	-1136	-111	-253	373	-780
	USA	1326	550	137	-1027	-929
	Argentina	1364	1495	2025	3052	3387
	Indonesia	136	177	211	422	629
	Malaysia	268	209	200	269	347
Consumption	World	13983	16487	18877	23027	30420
	EU	9200	7180	6100	2800	4316
	USA	1383	2278	2564	3785	3771
	Brazil	1089	3868	5952	6801	7717

Source: AGLINK-COSIMO simulation results

by 24% and 23%, respectively). Independently of the lower production of most major traders on the world biodiesel market, Brazil's biodiesel market reacts differently due to the greater difference between world biodiesel and oil prices. Brazil's biodiesel production is higher in the counterfactual[27], probably because of increased competitiveness with fossil fuels due to

[27] The extent of this effect is difficult to simulate for the whole period as hard data on Brazil's very market-driven biodiesel market is available for a few years only. The upper limit on Brazil's biodiesel production of 10% imposed in the model is fully reached in the no-policy scenario.

lower vegetable oil prices. In detail, given the biodiesel tariff in Brazil, the biodiesel market tends to clear internally, and therefore the biodiesel price does not fall far enough to cancel out the higher profitability due to the lower vegetable oil price.

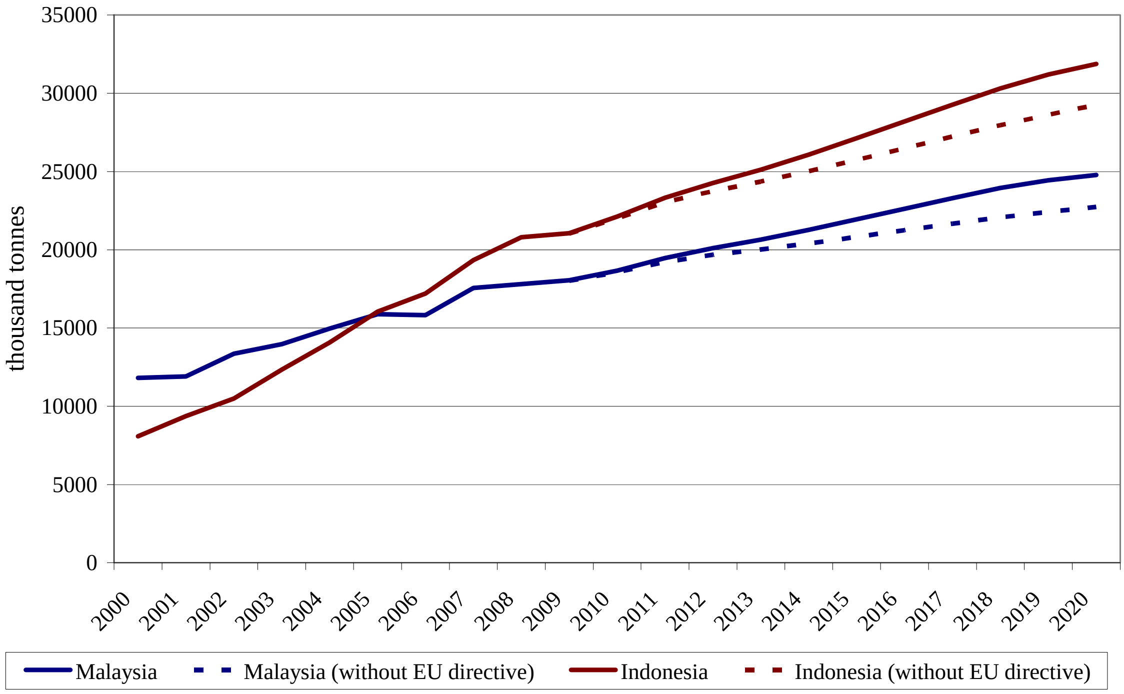
Table 3.13: Vegetable oil balance (thousand tonnes)

		2008	**2009**	**2010**	**2015**	**2020**
		Baseline				
Production	World	111765	115635	119313	137773	156203
	EU	13110	12495	12749	13295	14453
	USA	9244	9366	9282	9986	11034
	Brazil	6216	6503	6730	7659	8673
	Canada	2137	2390	2532	2951	3529
	Argentina	8327	9733	9996	11867	13693
	Indonesia	20804	21059	22135	27141	31876
	Malaysia	17901	18144	18763	22053	24874
Net trade	EU	-7992	-8689	-9555	-17242	-20035
	Brazil	1949	404	-213	3257	3407
	Canada	1215	1332	1441	1677	2213
	Argentina	6169	7807	7406	9181	10631
	China	-9138	-7964	-7110	-8715	-10515
	Indonesia	15753	15831	16396	20488	23984
	Malaysia	15259	15277	15818	18509	20739
Consumption	World	113470	116265	119381	137962	156387
	EU	21079	21224	22303	30523	34479
	USA	10769	10856	10682	11943	12634
	Brazil	4291	6031	6944	4402	5266
	China	20372	20020	19585	23054	25993
		Counterfactual				
Production	World	111765	115593	118984	133796	149569
	EU	13110	12531	12948	14045	15064
	USA	9244	9354	9235	9646	10663
	Brazil	6216	6502	6727	7633	8642
	Canada	2137	2383	2491	2568	3024
	Argentina	8327	9709	9884	11270	13176
	Indonesia	20804	21040	22014	25745	29274
	Malaysia	17901	18128	18661	20924	22842
Net trade	EU	-7992	-7697	-6297	-4173	-5489
	Brazil	1949	-303	-1839	-555	-518
	Canada	1215	1326	1404	1332	1776
	Argentina	6169	7767	7180	8092	9666
	China	-9138	-8103	-7828	-12421	-13933
	Indonesia	15753	15799	16232	19190	21632
	Malaysia	15259	15253	15703	17497	18940
Consumption	World	113470	116183	118904	134107	149999
	EU	21079	20272	19247	18217	20548
	USA	10769	10800	10425	10577	11038
	Brazil	4291	6738	8567	8189	9161
	China	20372	20155	20286	26590	29225

Source: AGLINK-COSIMO simulation results

What do the simulated changes mean for the biodiesel feedstock markets in the rest of world? First, there is a positive output response to EU biofuel policies among the main third-country producers of vegetable oils, and world vegetable oil production by 2020 is 4.2% higher than under the counterfactual. A large share of this additional output is in Malaysia (2032 thousand tonnes higher) and Indonesia (2602 thousand tonnes), both 8.9% higher (see Table 3.13). Other sizeable effects on world production occur in Argentina (517 thousand tonnes, +3.9%), Canada (505 thousand tonnes, +16.7%) and the USA (371 thousand tonnes, +3.5%).

Figure 3.4: Impact of the EU renewable energy directive on the production of palm oil in Malaysia and Indonesia



Source: AGLINK-COSIMO simulation results

Regarding trade in vegetable oil, Brazil is a strong net exporter in the baseline but a small net importer (in order to feed its own higher biodiesel production) in the counterfactual. Brazilian exports, together with the additional exports of other large vegetable oil net exporters Argentina (+10.0%), Malaysia (+9.5%) and Indonesia (+10.9%), satisfy the higher demand for vegetable oils induced by EU biofuel policies; the higher vegetable oil production in Indonesia and Malaysia comes almost entirely from increased palm oil production (see Figure

3.4). Without EU policies, demand for vegetable oils for non-biodiesel use would be substantially higher, especially in China and Argentina[28].

The impact of higher palm oil production in Indonesia and Malaysia on oil palm area is not calculated by AGLINK-COSIMO. Therefore, the following considerations are based on secondary information (www.oilworld.biz). Compared to the 2000-2008 growth rates observed in Malaysia (6.3%) and in Indonesia (13.3%), the annual growth of palm oil production slows down considerably under the baseline to 2.1% and 2.9% (2008 to 2020), respectively, and to only 1.8% and 2.5% in the counterfactual scenario. These simulated growth rates could be achieved solely through yield increases *if* the yield trends of recent years continue or improve[29].

Higher prices due to higher demand for palm oil can effectively stimulate replanting and management improvements due to the expectation of higher future returns. The replanting implies that for three to four years there would be no production on the respective plot which might encourage producers to maintain old plantations even if yields are declining. Moreover, the estimated additional 18% increase in domestic vegetable oil (palm oil) price might further stimulate the increase in palm oil yields. On the other hand, it is also possible that the growth rate might slow down, as has been seen for other crops in recent years. The faster rate of increase in palm oil production in Malaysia and Indonesia (by about 9%) under the baseline may create a certain pressure for area expansion.

The higher vegetable oil production in the other main production countries will occur mainly for the following oilseeds: sunflower and soybean (Argentina), rapeseed/canola (Canada) and a reduction in oilseeds exports (USA). For Argentina, the oilseed area is 2.7% higher under the baseline, but there will be also a larger area planted to cereals area (Table 3.14).

Brazil's 1.4% (1.3 million tonnes) higher oilseed (soybean) production is nearly all exported (1.2 million tonnes extra in net exports). Higher production due to EU biofuel policies adds another 390 thousand ha to Brazil's oilseed area, which grows also under the counterfactual, by 7382 thousand ha (+34%) from 2008 to 2020. In the USA, domestic oilseed production in 2020 is lower by 0.3% due to EU policies, due to competition from cereals for arable land. The higher US vegetable oil production will, thus, involve lower net exports.

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[28] Note that use of vegetable oil for biodiesel production is exogenous, and thus price reactions stemming from changes in vegetable oil net trade, are reflected only in non-biodiesel uses.

Table 3.14: Oilseed area harvested (thousand ha)

	2008	2009	2010	2015	2020
Baseline					
World	151031	153531	153325	162220	170584
- EU	10182	10103	9249	9639	9928
- USA	31554	31152	31017	30526	31266
- Brazil	21431	22197	22473	25202	29223
- Canada	7758	7947	8308	8837	9295
- Argentina	18000	19248	19097	18979	16526
- Russian Federation	7207	7320	7386	8628	9426
Counterfactual					
World	151031	153525	153255	160106	168064
- EU	10182	10103	9228	9219	9406
- USA	31554	31152	31054	30521	31338
- Brazil	21431	22197	22477	24751	28813
- Canada	7758	7948	8303	8481	8894
- Argentina	18000	19248	19097	18767	16090
- Russian Federation	7207	7320	7379	8517	9292

Source: AGLINK-COSIMO simulation results

Ethanol and feedstocks

The impacts on the world ethanol market are much smaller than in the case of biodiesel. The EU accounts for 12.6% and 4.5% of world ethanol consumption with and without biofuel policies, respectively. It follows that the impact of EU policies is less pronounced on world prices for ethanol (Table 3.15).

The only sizeable direct effect on ethanol production and trade outside the EU picked up in the simulation is greater Brazilian ethanol production (+ 3.1 billion litres or 4.8%) (Table 3.15). A similar amount is exported, implying 17% higher net exports of Brazilian ethanol.

AGLINK-COSIMO models biofuels for the main biofuel-producing countries and regions only. If a large share of the extra EU demand is met by ethanol imports, other countries whose output is currently small or as yet non-existent may increase their production. Although these changes may be significant for the countries concerned, they do not greatly affect the simulated world balance or the effect of EU policy reported here, given the small volumes involved. The overall effect of EU policies on the world cereals and sugar markets is smaller than for the biodiesel/oilseed link, as the share of biofuel demand in the overall demand for these crops is smaller on a world scale. A noticeable effect on the ethanol feedstock sugar beet

[29] Between 2000 and 2008 Malaysian and Indonesian yields increased annually by 2.5% and 2.4% respectively.

Table 3.15: Ethanol balance (million litres)

		2008	2009	2010	2015	2020
		Baseline				
Production	World	70636	82072	93578	133606	169207
	EU	5021	5513	5949	9778	17790
	USA	34463	40765	46606	58895	64681
	Brazil	22239	24710	27840	47331	66838
Net trade	EU	-1677	-1876	-2633	-7467	-3449
	USA	-1605	142	-41	-3895	-10298
	Brazil	4393	4333	4889	13421	20958
Consumption	World	70210	81457	92766	132808	168423
	EU	6698	7389	8582	17246	21239
	USA	36069	40623	46647	62790	74979
	Brazil	17846	20377	22951	33910	45879
		Counterfactual				
Production	World	70636	80315	91074	124881	154302
	EU	5021	5041	4952	3713	6385
	USA	34463	39799	45607	59247	64556
	Brazil	22239	24465	27492	45106	63773
Net trade	EU	-1677	-473	-516	-427	-483
	USA	-1605	237	-411	-4153	-10308
	Brazil	4393	3509	4014	10166	17893
Consumption	World	70210	79699	90261	124083	153517
	EU	6698	5514	5468	4141	6868
	USA	36069	39562	46018	63400	74864
	Brazil	17846	20956	23479	34940	45879

Note: the selection of countries is linked to the main findings discussed. In 2008, these countries produced 87% of the world's ethanol output (see Table 2.1).
Source: AGLINK-COSIMO simulation results

and/or sugar cane is observable only in the EU and in Brazil. As AGLINK-COSIMO assumes that sugar cane is the only agricultural feedstock used in Brazil, the higher Brazilian production of ethanol means that 4.1% more land is planted to sugar cane under the baseline. Consequently, combined world sugar-producing area is higher by 2.1% due to EU policies, on account of larger areas of sugar cane in Brazil and sugar beet in the EU.

Lower net wheat exports from the EU in the baseline, combined with almost unchanged world market prices, impact on the world wheat market. World wheat production is higher by 1.1% than in the counterfactual. The only major producing country with lower wheat production is Canada (-0.9%), because the impact of EU policies on the world vegetable oil price makes its rapeseed more competitive. On the demand side, Russian wheat demand would be 3% lower with EU biofuel policies, as it would be more attractive to export and replace EU exports.

The effects of EU biofuel policies on the world coarse grain market are even smaller; world production is only 0.3% higher, with the only considerable increase in Argentina (+ 3.9%).

Summary of worldwide land use effects

Table 3.16 shows the net difference between the simulated area used for cereals, oilseeds and sugar crops in selected years up to 2020 at world level. This difference is broken down across the main producing countries and the main biofuel feedstock crops.

Table 3.16: Difference (%) in cereal, oilseed and sugar crop area between baseline and counterfactual in selected countries

	2008	2009	2010	2015	2020
EU (% difference)	0.0	0.0	0.2	1.9	2.2
baseline ('000 ha)	71640	71375	67084	68522	66962
USA (% difference)	0.0	0.0	0.0	0.3	0.3
baseline ('000 ha)	91848	90367	89799	89507	91034
Brazil (% difference)	0.0	0.0	0.0	1.4	1.6
baseline ('000 ha)	46852	48004	48631	54639	61538
Canada (% difference)	0.0	0.0	0.0	0.3	0.5
baseline ('000 ha)	24127	25076	25523	25429	25549
Argentina (% difference)	0.0	0.0	0.0	0.9	2.3
baseline ('000 ha)	27078	29763	29455	28684	25468
China (% difference)	0.0	0.0	0.0	0.1	0.0
baseline ('000 ha)	72408	72674	72889	72939	73465
Russian Federation (% difference)	0.0	0.0	0.0	0.2	0.3
baseline ('000 ha)	52373	50985	50820	52113	53074
World* (% difference)	0.0	0.0	0.1	0.6	0.7
baseline ('000 ha)	721311	722132	718638	734322	745532
Wheat (% difference)	0.0	0.0	0.0	0.5	0.9
baseline ('000 ha)	225998	223051	219625	219575	219740
Coarse grains (% difference)	0.0	0.0	0.1	0.1	0.0
baseline ('000 ha)	316510	318106	317985	322082	321106
Oilseeds (% difference)	0.0	0.0	0.0	1.3	1.5
baseline ('000 ha)	151031	153531	153325	162220	170584
Sugar cane (% difference)	0.0	0.0	0.0	0.9	2.1
baseline ('000 ha)	22700	22370	22681	25427	28883
Sugar beet (% difference)	0.0	0.4	0.6	2.8	2.2
baseline ('000 ha)	5072	5074	5022	5018	5219

Note: * the world aggregate also includes a large number of regions that are not individually modelled.
Source: AGLINK-COSIMO simulation results

According to Table 3.16, the effects on cereals area due to EU biofuel policies are rather small on the international level, namely increases of just 0.9% for wheat and 0.0% for coarse grains. It follows that, with EU biofuel polices, the total world area planted with cereals, oilseeds (soya bean, rapeseed and sunflower) and sugar crops is only 0.7%, or 5.2 million ha, higher in 2020. The most pronounced increase outside the EU would occur in South America

(Argentina +2.3% and Brazil +1.6%). The land use effect on South East Asia palm oil plantations is not modelled in AGLINK-COSIMO.

Table 3.16 compares the baseline and counterfactual results up to the year 2020. However, it is also useful to consider the changes, *within* each scenario, between 2008 and 2020. These changes are reported in Table 3.17 for ten major producing countries. In the baseline scenario, world area of cereals, oilseeds and sugar crops is estimated to increase to 24.2 million ha by 2020 (a 3.4% increase since 2008). Among the countries individually identified, the largest increase over that period occurs in Brazil (+14.7 million ha or 31.3%). Canada's area of these crops would increase by 5.9%. On the other hand, reductions in the area of these crops would occur in the EU (-6.5%), Argentina (-5.9%) and the USA (-0.9%), whilst increases in China (+1.5%) and the Russian Federation (+1.3%) would be slower than the world average rate.

Table 3.17: Area of wheat, coarse grains, oilseeds and sugar crops, selected countries, 2008-2020, by scenario and between scenarios

	2008	**Change 2020 vs. 2008**				**Policy impact**	
		Counterfactual (CF)		**Baseline (BL)**		**(BL)-(CF), 2020**	
	1000 ha	1000 ha	%	1000 ha	%	1000 ha	%
EU	71639	-6140	-8.6	-4677	-6.5	1462	2.2
USA	91848	-1082	-1.2	-813	-0.9	269	0.3
India	78436	3422	4.4	3598	4.6	176	0.2
China	72408	1027	1.4	1057	1.5	29	0.0
Russian Federation	52373	535	1.0	701	1.3	166	0.3
Brazil	46853	13696	29.2	14685	31.3	989	1.6
Argentina	27077	-2173	-8.0	-1609	-5.9	565	2.3
Canada	24127	1292	5.4	1422	5.9	130	0.5
Ukraine	22260	3166	14.2	3377	15.2	211	0.8
Australia	21820	559	2.6	838	3.8	279	1.2
Africa	96935	3069	3.2	3316	3.4	247	0.2
Other Asia	70648	968	1.4	1541	2.2	573	0.8
Other L. America	14309	1222	8.5	1327	9.3	105	0.7
The Rest	30578	-555	-1.8	-541	-1.8	14	0.0
World	**721312**	**19006**	**2.6**	**24221**	**3.4**	**5214**	**0.7**

Source: AGLINK-COSIMO simulation results

The shift in the underlying trend in total land use caused by the policy is smaller than the annual fluctuations around trend that have been recorded in recent years. However, even if this higher trend is masked in the short term by fluctuations due to market and weather fluctuations, the results indicate that average land use over the medium term is higher with the policy than without it.

It has to be stressed that the scenario approach adopted here compares two policy situations assuming no changes in the remaining exogenous (market and policy) conditions. The comparison therefore provides estimates of the size and direction of the differences between the two policy situations. The magnitude of the simulated market outcomes under each scenario, taken separately, should be interpreted with more caution. It follows that the land use implications of these market outcomes are even less precisely determined, and should be treated as indicative only.

3.6. Sensitivity of AGLINK-COSIMO results

The sensitivity of the simulated policy impacts to several keys assumptions was investigated. In each case, this involved modifying an assumption that is relevant only in the baseline ('with EU policies') scenario, and which does not affect the counterfactual. We then examined whether, and how, the simulated impacts of biofuel policies are affected by the modification. These experiments do not constitute a sensitivity analysis in the strict sense of that term[30], but rather they involve running additional scenarios that are then compared with the unmodified counterfactual.

The first experiment assumes that expectations of higher demand due to EU biofuel policies induce a faster rate of long-run autonomous yield growth for biofuel feedstocks. It should be borne in mind that, as this faster yield growth is not assumed in the counterfactual (where biofuel policies in other countries, notably the USA, remain in place), the implication is that the faster yield growth is attributable specifically to the policies of the EU. The second experiment relaxes the constraint adopted in the baseline scenario that by 2020 first generation biodiesel and ethanol will *each separately* account for 7% of the respective energy type (diesel and petrol/ethanol) used as transport fuel, and replaces it with the weaker assumption that *together* their *combined* share will be 7% of total transport fuel use. The third experiment concerns ethanol by-products, and modifies the baseline's assumptions about the allocation of DDG between ruminants and non-ruminants, and the rate at which DDG replaces conventional animal feeds.

Two additional runs were conducted, involving increases in the crude oil price of 50% and 25%, respectively. These increases were phased in over the first years of the simulation

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[30] Sensitivity analysis typically involves changing a parameter or assumption in *both* the baseline and counterfactual, and investigating whether this affects the comparison between the two scenarios.

period. Even with the smaller of the two increases, some of the model's limits were reached. This is not surprising, as the basic model was calibrated to even lower crude oil prices than those assumed in our two main scenarios. Therefore, the results of these runs are not further discussed.

3.6.1. Faster yield growth

The sensitivity of the simulated policy impacts to assumptions about yield trends was investigated by assuming that expectations of higher demand due to EU biofuel policies induce a faster rate of long-run autonomous yield growth for biofuel feedstocks in the main producing regions. In this faster-yield-growth scenario, grain, oilseed and sugar yields are assumed to grow annually about 0.3% faster due to EU biofuel policies than in the baseline[31], such that by 2020, yields for these crops are about 3.0-3.4% higher than in the baseline. It was assumed that the higher yield growth for wheat, coarse grains and oilseeds induced by the EU biofuel policies occurs in the EU, Argentina, Australia, Brazil, Canada, China, the Russian Federation, Ukraine and the USA, whereas the faster yield growth for sugar crops occurs only in the EU, Brazil and China.

Figure 3.5: Effect of faster yield growth on the simulated impacts of EU biofuel policies in 2020 at world level (solid bars: baseline; shaded bars: faster-yield-growth scenario)

[31] See Table A3.3 for the yield evolution under the baseline, faster-yield-growth and counterfactual scenarios.

Figure 3.5 shows the global impacts of EU biofuel policies under the baseline and the faster-yield-growth scenario, denoted by solid and shaded bars, respectively. Faster yield growth cancels out the policy impact on wheat area, and pushes coarse grain area below that of the counterfactual. However, for both these ethanol feedstocks, the areas are not sufficiently smaller to prevent production increases, with respect to both the counterfactual and even to the baseline. Moreover, this occurs despite the fact that the direction of the impact on prices is reversed under the faster-yield-growth scenario.

The land released by cereals production in the faster-yield-growth scenario permits a slightly greater policy impact on world oilseed area than in the baseline, and this, in conjunction with the yield increase, means higher oilseed production. These effects are more marked within the EU, where oilseeds output is up by 9.9% (relative to the counterfactual) in the faster-yield-growth scenario, as against 5.5% in the baseline[32]. The counterpart of higher EU oilseed production in the faster-yield-growth scenario is much lower oilseed imports, leaving the total EU crush and imports of vegetable oils more or less unchanged. It must be kept in mind that oil palm area is not included in the area changes shown in Figure 3.5 (see Table A3.4 for the increase in palm oil production).

The impact of EU biofuel policies on the aggregated global area planted to wheat, coarse grains, oilseeds and sugar of an increase of 0.7% (or 5.2 million ha) simulated in the baseline is, under the faster-yield-growth assumptions, converted into a virtually negligible impact of 187 thousand hectares (+0.0%) relative to the counterfactual (see Table 3.18).

Considering the policy impacts of yield growth acceleration on individual crops worldwide, the simulations show that these policies actually reduce the area used for coarse grains by -1.1%, rather than maintaining it as under the baseline. The baseline impact of +0.9% on wheat area and of +2.1% on sugar cane area is reduced, assuming medium yield growth acceleration, to nearly zero for wheat and +1.8% for sugar cane. By contrast, with faster yield growth the policy-induced difference in sugar beet and oilseed areas is greater (+2.7% instead of +2.2%, in the case of sugar beet, and +1.8% instead of +1.5% in the case of oilseeds).

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[32] Oilseeds are grown on a much smaller share of cropland than cereals in the EU; therefore, although the land released from cereals looks quite small, as a percentage of total cereals area, it allows the policy impact on oilseeds area to increase from about 5.5% to around 10%, relative to the counterfactual.

Table 3.18: Area of wheat, coarse grains, oilseeds and sugar crops, selected countries, 2008-2020, by scenario and between scenarios

	2008	Change 2020 vs. 2008				Policy impact	
		Counterfactual (CF)		Faster yield growth (FYG)		(FYG)-(CF), 2020	
	1000 ha	1000 ha	%	1000 ha	%	1000 ha	%
EU	71640	-6140	-8.6	-5332	-7.4	808	1.2
USA	91848	-1082	-1.2	-1222	-1.3	-140	-0.2
India	78436	3422	4.4	3527	4.5	105	0.1
China	72408	1027	1.4	668	0.9	-359	-0.5
Russian Federation	52373	535	1.0	720	1.4	185	0.4
Brazil	46852	13697	29.2	14203	30.3	506	0.8
Argentina	27078	-2173	-8.0	-1657	-6.1	516	2.1
Canada	24127	1292	5.4	1371	5.7	79	0.3
Ukraine	22260	3166	14.2	3177	14.3	11	0.0
Australia	21820	559	2.6	688	3.2	129	0.6
World	**721311**	**19007**	**2.6**	**19194**	**2.7**	**187**	**0.0**

Source: AGLINK-COSIMO simulation results

This assessment of the sensitivity of the results to assumptions about yield growth suggests that if EU biofuel policies induce much faster yield growth for the major feedstocks, then the pressure on land could be reduced or even reversed. However, this development is accompanied by falling prices, particularly in the case of coarse grains, which may reduce the rate of the yield increase by acting to slow down yield-enhancing technological investment, for example in plant breeding.

3.6.2. Least-cost combination of the two biofuels

For the main analysis, it was assumed that by 2020 first generation biodiesel and ethanol would account for 7% of each respective energy type (diesel and petrol) used for transport in EU-27. Here, this assumption is replaced by the weaker constraint that first generation biofuel *in aggregate* will be 7% of the total transport fuel demanded, but with their share of the respective fuel type determined endogenously within the model. The assumed 1.5% of second generation biofuels remains unchanged. The model finds the lowest-cost combination of the two biofuels that satisfies the overall quantity constraint, and this determines the quantities of the two separate biofuels in 2020. Thus, the relative proportions of the two biofuels are driven by the policies in force (differential tariffs and tax exemption rates), but mostly by the relative production costs of the two biofuels. As expected, given the production cost differential between the two fuels, demand for ethanol is higher and that of biodiesel lower compared to the fixed shares imposed in the main analysis. In particular, ethanol demand increases by almost half in terms of volume (by 2020, the percentage change in the energy share of ethanol in petrol is 12.5), which is met by a higher level of production and imports. In order to achieve this share, either the maximum in low-ethanol blends would have to exceed 10% or a significant flex-fuel car fleet would be needed. Table 3.19 compares the two scenarios and highlights the shift between the two biofuels in the EU.

Table 3.19: Effects on biofuel commodity balances in the EU-27 with EU biofuel policies fixed shares (baseline) and endogenous allocation (in million litres)

	2008	2009	2010	2015	2020
Ethanol					
Production	5021	5513	5949	9778	17790
	5021[1]	*4429*	*4761*	*10395*	*20436*
of which:					
1st generation	5021	5513	5949	9778	14486
	5021	*4429*	*4761*	*10395*	*17132*
2nd generation	0	0	0	0	3304
	0	*0*	*0*	*0*	*3304*
Net trade[2]	-1677	-1876	-2633	-7467	-3449
	-1677	*40*	*-1780*	*-14540*	*-9627*
Demand	6698	7389	8582	17246	21239
	6698	*4389*	*6541*	*24935*	*30063*
Energy share (in %)	1.9	2.3	2.8	6.7	8.5
	1.9	*0.9*	*1.9*	*10.3*	*12.5*
Biodiesel					
Production	8064	8122	9293	17174	24243
	8064	*8125*	*8820*	*11283*	*18020*
of which:					
1st generation	8064	8122	9293	17174	19268
	8064	*8125*	*8820*	*11283*	*13054*
2nd generation	0	0	0	0	4976
	0	*0*	*0*	*0*	*4976*
Net trade	-1136	-1876	-966	-2931	-3953
	-1136	*-790*	*-880*	*-1731*	*-2786*
Demand	9200	8911	10259	20105	28196
	9200	*8914*	*9701*	*13014*	*20806*
Energy share (in %)	3.5	3.1	3.5	6.4	8.5
	3.5	*3.1*	*3.3*	*4.1*	*6.3*

Notes: 1: the numbers in italics throughout the table refer to the results of the endogenous allocation scenario
2: net trade is calculated as exports – imports; negative values denote net imports and positive net exports

Source: AGLINK-COSIMO simulation results

This shift between the two biofuels also implies differences in feedstock demand from both within the EU and from the world market. Inevitably, demand is higher for ethanol feedstocks and lower for biodiesel feedstocks. Within the EU, oilseed area is lower by 2.9%, whereas the areas planted with wheat, coarse grains and sugar beet are higher by 1.6%, 0.4% and 3.2%, respectively. The net effect is that total EU area planted with cereals, oilseeds and sugar crops is 0.4% higher when the allocation between the two first-generation biofuels is unconstrained. The shift towards ethanol, and here especially imported ethanol, also has implications for the area planted to cereals, oilseeds and sugar crops worldwide, in particular a much higher area of sugar cane in Brazil (4.6% or 0.6 million hectares) to produce ethanol for export.

Generally, the area effects are positive for wheat and negative for oilseeds due to small changes in world prices. Globally, the additional area planted to wheat exceeds the saving in oilseeds area. Thus, the global area of cereals, oilseeds and sugar crops is greater by 0.1% or 1.1 million hectares. It has to be recalled that oil palm area is not included in this total, and that palm oil demand and consequently supply will be lower in the case of the unconstrained allocation between the two first generation biofuels in the EU. Table A3.4 (Appendix) shows palm oil production in Malaysia and Indonesia for all the scenarios examined.

3.6.3. Feed displacement by DDG

The baseline assumptions regarding the use of DDG as animal feed in the EU are mainly based on observations in the USA. Data on DDG use in the EU are scarce. However, it is likely that in the EU, where animal diets and the structure of feed markets are different, and given the significant vegetable protein deficit, protein-rich wheat DDG replaces a higher proportion of protein in animal diets. To explore the sensitivity of the simulated impacts to these assumptions, the original displacement rates have been modified in order to match more closely conditions in the EU and recent experimental data.

The shares of DDG allocated to ruminant and non-ruminant feed were set equal to the shares in total EU compound feed use of these two sectors, namely 0.321 and 0.679, respectively[33]. In both cases, one kilogram of DDG is assumed to replace 0.68 kilogram of coarse grains and 0.60 kilogram of oil meals[34]. Due to the higher displacement rate of oil meals and the overall more effective feed replacement by DDG represented by these new coefficients, relative to the baseline, feed demand is slightly higher for coarse grains and lower for oil meals. Consequently, compared to the baseline scenario, the total EU area planted with grains, oilseeds and sugar beet is slightly higher (+0.2%) as more coarse grains (+0.4%) are demanded. On the other hand, the oilseed area is a little lower (-0.1%). At the same time, since a high share of EU oil meal demand is met by domestically processed oil meal from

[33] Source: AGLINK data base

[34] High end of range given in Birkelo *et al*. (2004).

imported oilseeds, the reduction in oilseed imports is more pronounced (-8.9% net trade). At world level, the downward adjustment in total oilseed area produced by the modified assumption is a little larger than the expansion in the world area of coarse grains. The overall effect on the global area of bioenergy crops (of grains, oilseeds and sugar crops) of modifying the assumptions for the EU regarding DDG use and displacement rates is a small reduction (-0.05%, or -410 thousand hectares).

3.7. Summary and concluding remarks

AGLINK-COSIMO is designed to model market outcomes, which are driven by price signals. Land use changes are the consequence of decisions to supply more or less of particular commodities to the market, given current technological conditions. Thus, reported land use changes are derived from simulated changes in market outcomes; their credibility depends on that of the market activity that drives them. This section summarises the main market and land use results, first for the EU and then for third countries and/or globally.

The main effects of EU biofuel policies on EU markets and commodity balances by 2020 are:

- Large effect on EU output of ethanol (+179%) and biodiesel (+568%) , and on imports of both biofuels (+614% for ethanol and +407% for biodiesel),
- Much higher imports of vegetable oils (+265%), lower imports of oilseeds (-17%),
- Important role of DDG as a replacement for cereals in the animal feed market,
- Biodiesel price is 40% higher, ethanol price is about 18% higher (similar pattern for world market prices).

Main effects of EU biofuel policies on EU land use:

- Slower decline of the total arable area over the period 2008-2020 (-6.5% instead of -8.6%. That is due *inter alia* to 1.5% higher cereals area and 5.6% higher oilseeds area,
- Total pasture area is 0.9% lower in 2020 with EU policies than without them.

The main effects of EU biofuel policies on world commodity balances and land use by 2020 are:

- With much higher EU imports of biodiesel and higher biodiesel prices, the USA becomes a net exporter to satisfy extra world market demand.

- With higher EU imports of ethanol (by 2966 million litres) and the rise in ethanol price, Brazil's ethanol exports are higher (by 3065 million litres).
- Total land used for cereals, oilseeds and sugar crops worldwide is 0.7% (5.314 million hectares) higher, implying an expansion in cropland expansion over the period 2008-2020 of 3.4%.
- The resulting land use changes due to EU biofuel policies for the total area of wheat, coarse grains and oilseeds are smaller than the year-on-year fluctuations of cropland during the period 2000-2008.
- The largest proportionate differences in total arable area occur in the EU and Argentina (+2.2% and +2.3%, respectively), although in both regions cropland still declines even with EU policy in place.
- Sugar (cane and beet) area higher by 2.1-2.2%, also oilseed area (1.5%) and wheat (less than 1%).

Several other important observations should be made regarding land use:

- If EU biofuel policies stimulate a faster rate of crop yield growth, the impact of EU policies on global land use would be smaller. In particular, if it is assumed that EU biofuel policies alone have an additional impact on yield growth rates of 0.3% per year, this is sufficient to fully counteract the expansionary impact of these policies on the global area of wheat, coarse grains and sugar.
- The use of by-products as animal feed also plays a role in reducing the land required to meet the biofuels demand.
- Land use effects in Indonesia and Malaysia are not simulated; however, vegetable oil production in both these countries is much higher due to EU biofuel policies, virtually all of which feeds into net exports. The land use implications depend crucially on yield growth in these countries, which might accelerate to meet the extra demand induced by EU biofuel policies.

The simulated effects of EU biofuels policies imply a considerable shock to agricultural commodity markets, but precise magnitudes need to be treated with some caution. In particular, various assumptions were needed for calibrating behaviour in biofuel markets, for lack of sufficient historic information. As for the simulated land use effects in third countries, we point out that AGLINK-COSIMO does not consider multi-cropping. Moreover, certain crops are not modelled. If their area is lower as a result of relative price changes set in train by EU biofuel policies, this could compensate for some of the land expansion of the crops simulated in the model. Furthermore, the stronger demand for land-using commodities resulting from the higher demand for biomass for biofuel production may induce stronger technological progress and investment than assumed in the present structure of the model, which is normally used for more gradual changes. An idea of the importance of the latter has been given in the sensitivity analysis. Finally, the model cannot take account of the effects of land use constraints, such as the sustainability criteria set out in the EU Renewable Energy Directive, or any climate change commitments affecting land use. Such constraints may significantly affect the cost and magnitude of cropland expansion.

The AGLINK-COSIMO model is currently under review by the OECD, its members and the FAO. The outcome could result in a further integration of biofuels, feedstocks and by-products into the model. Finally, other factors and policies may affect significantly the result, among which trade policy, technological change, change in the structure of the agricultural commodity market, oil price, macro-economic context, environmental policies.

Annex Chapter 3

Table A3.1: Conversion factors of feedstock into biofuels

	2008	2009	2010	2015	2020	2008	2009	2010	2015	2020
	EU					Canada				
into ethanol										
coarse grains	0.248	0.246	0.245	0.239	0.232	0.254	0.254	0.254	0.254	0.254
molasses	0.440	0.440	0.440	0.440	0.440					
sugar beet	1.010	1.008	1.005	0.993	0.980					
wheat	0.271	0.269	0.268	0.261	0.255	0.270	0.270	0.270	0.270	0.270
into biodiesel										
vegetable oils	0.093	0.093	0.093	0.093	0.093	0.084	0.084	0.084	0.084	0.084
into DDG										
coarse grains	0.077	0.077	0.077	0.075	0.073	0.076	0.076	0.076	0.076	0.076
wheat	0.100	0.100	0.099	0.097	0.094	0.100	0.100	0.100	0.100	0.100

	2008	2009	2010	2015	2020
	USA				
into ethanol					
biomass	0.330	0.323	0.315	0.282	0.250
coarse grains	0.269	0.267	0.265	0.254	0.244
crop residuals	0.330	0.323	0.315	0.282	0.250
wheat	0.271	0.269	0.268	0.261	0.255
into biodiesel					
vegetable oils	0.093	0.093	0.093	0.093	0.093
into DDG					
coarse grains	0.084	0.083	0.083	0.079	0.076

Notes: 1. *Units of measurement*: **for biofuels**, the conversion factors are measured in tonnes of feedstock per hectolitre of fuel. A factor of 1 would mean, for example, that from 1000kg sugar beet one can get 100 litres ethanol. The EU's conversion factor from wheat to ethanol in 2020 (0.255) means that 100 litres of ethanol can be derived from 225 kg of wheat; **for DDG**, the conversion factor indicates how much DDG in t is produced while producing 100 litres of biofuel from the respective feedstock. Thus, for the EU in 2020, production of 100 litres of ethanol (which requires 255 kg of wheat feedstock) yields 94 kg of DDG.

2. *Technological change*: For the EU and the US, the biofuel conversion rates decline over time on the assumption that past trends in technical progress observed in each country/region will continue.

Source: model assumptions (OECD and FAO, 2009)

Table A3.2: Elasticities of harvested area with respect to (lagged) return for the EU-27

area \ return	barley	maize	oats	rye	other CG	Wheat	soybean	rapeseed	sunflower	pasture	sugar beet
EU-15											
Barley	0.452					-0.047	0.021	-0.041	-0.095		-0.015
Maize		0.452				-0.047	0.021	-0.041	-0.095		
Oats			0.452			-0.047	0.021	-0.041	-0.095		-0.015
Wheat	-0.129	-0.081	-0.014			0.539	-0.020	-0.041	-0.095		-0.015
Soybean	-0.166	0.108	-0.022			-0.261	0.836				
Rapeseed	-0.166	0.108	-0.022			-0.261		0.836			-0.015
Sunflower	-0.166	0.108	-0.022			-0.261			0.836		
EU-12											
Barley	0.394	-0.001		-0.007	-0.018	-0.090	-0.000	-0.004	-0.001	-0.019	-0.030
Maize	-0.001	0.206		-0.000	-0.001	-0.034	-0.002	-0.002	-0.009	-0.006	-0.030
Rye	-0.024	-0.003		0.409	-0.054	-0.044	-0.000	-0.004	-0.000	-0.016	-0.030
Other CG	-0.020	-0.002		-0.018	0.406	-0.085	-0.000	-0.003	-0.001	-0.010	-0.030
Wheat	-0.037	-0.024		-0.006	-0.034	0.469	-0.000	-0.010	-0.017	-0.038	-0.030
Soybean	-0.003	-0.033		-0.000	-0.001	0.015	0.567	-0.008	-0.059	-0.023	
Rapeseed	-0.007	-0.012		-0.002	-0.005	-0.055	-0.001	0.919	-0.022	-0.051	-0.030
Sunflower	-0.002	-0.021		-0.000	-0.001	-0.056	-0.007	-0.011	0.733	-0.021	

Source: model assumptions (OECD and FAO, 2009)

Table A3.3: Yield for the EU-27 in t/ha

	2008	2009	2010	2015	2020
Baseline					
Wheat	5.68	5.10	5.44	5.83	6.29
Barley	4.67	4.32	4.38	4.62	4.89
Maize	7.21	6.88	7.14	7.82	8.61
Rye	2.74	2.54	2.52	2.53	2.52
Oats	2.47	2.70	2.78	2.93	3.06
Other cereals	3.40	3.53	3.67	3.72	3.84
Oilseeds	2.61	2.69	2.72	2.96	3.18
Sugar beet	62.2	62.7	63.1	65.6	68.0
Faster yield growth scenario					
Wheat	5.68	5.11	5.46	5.92	6.47
Barley	4.67	4.33	4.40	4.71	5.05
Maize	7.21	6.90	7.17	7.95	8.89
Rye	2.74	2.54	2.54	2.57	2.60
Oats	2.47	2.71	2.79	2.98	3.16
Other cereals	3.40	3.53	3.67	3.73	3.85
Oilseeds	2.61	2.71	2.73	3.02	3.28
Sugar beet	62.2	62.8	63.5	66.8	70.2
Counterfactual					
Wheat	5.68	5.09	5.43	5.81	6.28
Barley	4.67	4.32	4.38	4.62	4.89
Maize	7.21	6.88	7.13	7.81	8.60
Rye	2.74	2.54	2.52	2.53	2.52
Oats	2.47	2.70	2.78	2.92	3.06
Other cereals	3.40	3.53	3.67	3.73	3.84
Oilseeds	2.61	2.69	2.71	2.95	3.18
Sugar beet	62.2	62.7	63.1	65.4	67.8

Source: AGLINK-COSIMO simulation results

Table A3.4: Palm oil production in Indonesia and Malaysia

	absolute values in thousand tonnes					annual rate of increase, %	difference from CF, %
	2008	**2009**	**2010**	**2015**	**2020**	**2020 vs. 2008**	**2020**
			Counterfactual (CF)				
Indonesia	20800	21033	22005	25734	29263	2.9	0.0
Malaysia	17800	18025	18557	20819	22734	2.1	0.0
Total	**38600**	**39058**	**40563**	**46553**	**51997**	**2.5**	**0.0**
			Baseline				
Indonesia	20800	21052	22126	27129	31865	3.6	8.9
Malaysia	17800	18041	18660	21949	24768	2.8	8.9
Total	**38600**	**39093**	**40786**	**49079**	**56633**	**3.2**	**8.9**
			Faster yield growth				
Indonesia	20800	21082	22170	27151	31812	3.6	8.7
Malaysia	17800	18067	18697	21967	24727	2.8	8.8
Total	**38600**	**39150**	**40867**	**49117**	**56539**	**3.2**	**8.7**
			Endogenous allocation				
Indonesia	20800	21051	22121	26755	30770	3.3	5.1
Malaysia	17800	18041	18655	21646	23912	2.5	5.2
Total	**38600**	**39092**	**40776**	**48401**	**54682**	**2.9**	**5.2**
			High DDG displacement				
Indonesia	20800	21058	22139	27192	31996	3.7	9.3
Malaysia	17800	18046	18671	22000	24871	2.8	9.4
Sum	**38600**	**39104**	**40810**	**49191**	**56867**	**3.3**	**9.4**

4. Results from the ESIM model

4.1. Introduction

4.1.1. Integration of energy crops: overview

ESIM (European Simulation Model) is a comparative static partial equilibrium net-trade multi-country model of the agricultural sector. It covers supply and demand for agricultural products, with a detailed specification of cross-commodity relationships, and some first-stage processing activities. Although its geographical coverage is global, not all countries are individually represented. Some countries are explicitly modelled and others are combined in the aggregate 'rest of the world' (ROW). In its current version, ESIM includes individual representations of each of the 27 EU member states, Turkey and the USA. All other countries are aggregated into the ROW.

In ESIM, market outcomes are driven by prices[35], conditional upon a rich specification of relevant EU agricultural policies, including trade policy instruments and direct payments. Since ESIM is mainly designed to simulate the outcomes in agricultural markets in the EU and accession candidates, policies are modelled only for these countries. For the USA and the ROW, production and consumption are assumed to take place at world market prices.

The production of agricultural products for biofuel production (oilseeds/plant oils for biodiesel; wheat, maize and sugar for ethanol), as well as the processing of these products and the production of biofuels, have been explicitly included in ESIM since 2006. In addition, market demand for biofuels is modelled, and various biofuel policies are also represented. Thus, ESIM can treat both prices and quantities of biofuels endogenously, and is able to simulate them jointly under alternative sets of assumptions. For the purpose of this study, however, the aim is to simulate the consequences of reaching a given, politically-determined quantitative target for demand. This is achieved by treating biofuel demand as exogenous, fixed as a given share of total transport fuel demand.

ESIM depicts the use of oilseeds for biodiesel production and cereals and sugar crops for ethanol production. The production of each biofuel crop is modelled by a yield function and an area allocation function. The production of each biofuel is modelled as an isoelastic function of the respective biofuel price, and the weighted net prices of the respective inputs.

Net prices are defined as market prices minus the related feed output price, which is for gluten feed in case of corn and wheat, multiplied by the technical extraction factor which describes how much gluten feed results from the processing of cereals to ethanol. Finally, the production of gluten feed is defined as the sum over cereals used in biofuel processing multiplied by the respective extraction factors.

4.1.2. Supply of biofuel inputs

The supply of crops used as biofuel feedstocks is modelled in ESIM in a similar way to the supply of other crops, as described in Banse, Grethe and Nolte (2005). For European countries, crop supply functions are separated into two components, corresponding to capacity (area) and intensity (yield). The supply of each biofuel crop (sunflower seed, rapeseed, soybeans, maize, wheat, sugar) in the EU is modelled by one isoelastic yield function and one isoelastic area allocation functions for each biofuel crop[36]. Area is a function of input prices, direct payments, output prices for all other crops and the special energy crop premium. In the ROW and the US, the supply of each biofuel crop is modelled by isoelastic supply functions that do not distinguish between a yield and an area component.

Oilseeds are not direct inputs into the biofuel production activity, but are first crushed and yield plant oils and meal.

Processing demand (PDEM) for each oilseed is defined as

$$PDEM_{cc,oilseed} = cr\_int_{cc,oilseed} \bullet \prod_{ospro} PD_{ospro}^{elast\_cr_{oilseed,ospro}} \bullet PD_{oilseed}^{elast\_cr_{oilseed,oilseed}} \bullet pdem\_tr_{cc,oilseed} . \qquad (1)$$

Explanatory variables are wholesale prices (PD) for processing outputs (meal, oil), contained in the subset "ospro", and the processing input (the respective oilseed). The intercept (cr_int) as well as the elasticities of processing demand with respect to input and output prices (elast_cr) are exogenous parameters, the former being calibrated according to base-year data. The parameter (pdem_tr) is a time trend to represent the evolution of the oilseed processing

[35] Product prices for tradable products are treated as identical across EU Member States and are defined for the model base period according to the approach described in Banse, Grethe and Nolte (2005).

[36] The model recognises two isoelastic areas: non-set-aside area and set-aside area. However, now that obligatory set-aside has been abolished, the distinction is no longer operative in the baseline. The area for biofuel crops produced on set-aside area was a function of input prices, direct payments, and output prices only for those crops used for biofuel production, which could alternatively have been grown on non-set-aside area

capacity. Equation (1) is restricted to be homogeneous of degree zero in all input and output prices[37].

The supply (SUPPLY) of processed oilseed products (meal, oil) is defined as processing demand multiplied by the respective extraction factor, called in the model a technical parameter for oilseed processing (oilsd_c):

$$SUPPLY_{cc,ospro} = PDEM_{cc,oilseed} \bullet oilsd\_c_{cc,ospro,oilseed} \quad . \qquad (2)$$

The oilseed extraction coefficients are 0.82 for soybean, 0.68 for rapeseed and 0.76 for sunflower seed. The calculation of crushing parameters for oilseeds to oil and meal is based on FAO data.

Palm oil is produced in the ROW only and the supply of palm oil is modelled without consideration of by-products such as palm kernel oil, palm kernel meal, tree stem and skin. The supply of palm oil is a direct function of its own domestic price and the prices of competing outputs, and of technical progress.

4.1.3. Production of biofuels and biofuel by-products

The production of each biofuel is modelled as an isoelastic function of its own price, and the weighted net prices of the respective inputs:

$$SUPPLY_{cc,energ} = sup\_int_{cc,energ} \bullet PI_{cc,energ}^{elastp_{energ,energ}} \bullet BCI^{elast\_en\_inp_{energ}} \bullet pdem\_tr_{energ} , \qquad (3)$$

where (sup_int) is an intercept, (PI) is the respective biofuel price, (BCI) the price index of inputs in biofuel production and (pdem_tr) a trend for the production of biofuels.

ESIM distinguishes four by-products: gluten feed (in the case of wheat and maize) and meals from three different oilseed crops. The production of gluten feed is defined as the sum the different cereals used in biofuel processing each multiplied by its respective technical extraction factor. The extraction factor describes how much by-product results from the processing of the feedstock to the corresponding biofuel. The gluten feed extraction coefficients are 0.230 and 0.285 for processing ethanol from maize and soft wheat respectively. The conversion coefficients for rape seed, soy bean and sunflower seed to the corresponding oil seed meal are 0.68, 0.81 and 0.77.

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[37] Price elasticities with respect to inputs other than oilseeds are taken into account in imposing the homogeneity condition.

The net price of a feedstock crop is defined as its market price minus the price of the related feed by-product derived from its processing into biofuel, multiplied by its technical extraction factor. The unscaled input shares (i.e. shares of feedstocks) in biofuel production are determined by a CES function based on net energy crop prices:

$$\begin{aligned} \text{QUANCES}_{\text{cc,energ,i\_biofuel}} &= \left[1 \big/ \text{biof\_CES\_int}_{\text{cc,energ}} \right] \\ &\bullet \left[\text{biof\_CES\_shr}_{\text{cc,energ,i\_biofuel}} \Big/ \text{NetPD}_{\text{cc,energ,i\_biofuel}}^{\text{biof\_CES\_el}_{\text{cc,energ}}} \right] \\ &\bullet \left[\sum_{\text{i\_biofuel}} \left[\text{biof\_CES\_shr}_{\text{cc,energ,i\_biofuel}} \bullet \text{NetPD}_{\text{cc,energ,i\_biofuel}}^{(1-\text{biof\_CES\_el}_{\text{cc,energ}})} \right]^{\frac{\text{biof\_CES}_{\text{cc,energ}}}{(1-\text{biof\_CES}_{\text{cc,energ}})}} \right] \end{aligned} \quad (4)$$

where (biof_CES_int) is an intercept in input shares in biofuel production, (biof_CES_shr) is a share parameter of biomass inputs in biofuel production, (NetPD) are net prices for inputs in biofuel production, (biof_CES_el) are the CES elasticities of substitution among inputs. (biof_CES_el) and (biof_CES_shr) are calibrated parameters of the CES function.

In addition, equation (5) scales the unscaled quantities such that they add up, after technical conversion, to the total quantity of biofuel production:

$$\frac{\text{PDEM\_BF}_{\text{cc,energ,i\_biofuel}} \Big/ \text{convbfcc}_{\text{cc,energ,i\_biofuel}}}{\text{SUPPLY}_{\text{cc,energ}}} = \frac{\text{QUANCES}_{\text{cc,energ,i\_biofuel}}}{\sum_{\text{i\_biofuel}} \text{QUANCES}_{\text{cc,energ,i\_biofuel}}} \quad (5)$$

where (PDEM_BF) is the demand of inputs in biofuel production and (convbfcc) is the relevant conversion factor. The full set of these coefficients is given in Table 4.1.

Table 4.1: Conversion factors in ESIM

		Conversion of 1 ton of input into 1 ton of output		
		Oilseed to oil	**Oilseed to meal**	**Oil to biodiesel**
Oilseeds	**Rape seed**	0.32*	0.68*	1.00
	Soy bean	0.18*	0.81*	1.00
	Sunflower seed	0.24*	0.77*	1.00
			Grain to gluten feed	**Grain to ethanol**
Cereal/sugar	**Soft wheat**		0.29	0.29
	Maize		0.23	0.30
	Sugar			0.39
*average values because of small deviations between single MS and aggregated countries (US, ROW)				

4.1.4. *Human demand for biofuels*

Human demand for each biofuel is a function of the respective biofuel price, the price of crude oil, and the tax rates on biofuels and on mineral oil.

4.2. Implementation of biofuel policies

The main biofuel policy assumptions include:

1. The price of crude oil in USD per barrel and the related annual increase;

2. The tax reduction on biofuel relative to tax on mineral oil in percentage;

3. The special biofuel crop premium, which is modelled as a subsidy for the production of biofuels, assuming that it accrues largely to biofuel producers, as it results in lower prices of biofuel inputs (this premium is discontinued after 2009).

In addition, EU targets with respect to the share of biofuels in total transport fuels as set out in the Renewable Energy Directive of December 2008 are met. This is achieved in the baseline simulation with the use of shift variables ('shifters'). The shifters enter as multiplicative factors attached to the trend parameters in the human demand functions, and in the oilseed crushing and biofuel production activities

4.3. Data needs

In the EU project AGRI -2006-G4-01, data for production of oil and meal were separated into production of energy oilseed and oilseed for food production based on plausibility assumptions. FAO data on production of rape meal and rape oil include both meal and oil production from energy and food rapeseed. This is also the case for sunflower seed.

Price information is generally obtained from EUROSTAT. For energy crops, producer and market prices are the same regardless of whether the output is used for food or feed purposes, or as a fuel feedstock. Prices of palm oil and ethanol are obtained from the FAPRI Outlook database. Quantity data for first generation biofuels is based on data published in F.O. Licht's Interactive Data and World Ethanol and Biofuels Report. Extraction coefficients for the processing of cereals and sugar are taken from KTBL (2006).

4.4. Baseline construction

4.4.1. Baseline assumptions

This section explains the assumptions regarding agricultural and trade policies, and the macroeconomic environment, that have been incorporated into the baseline. These working hypotheses were defined on the basis of exchanges with DG AGRI according to what was considered to be most plausible at the time the analysis was conducted.

(1) A continuation of the Common Agricultural Policy (including Health Check decisions adopted by the Agricultural Council in November 2008) until 2015, including notably:

(a) **Phasing out milk quotas**: Milk quotas are increased by 1% per quota year between 2009/10 and 2013/14. For Italy, the 5% increase is introduced immediately in 2009/10. Milk quotas are abolished by April 2015.

(b) **Intervention mechanisms:** Intervention is set at zero for barley and sorghum. For wheat, butter and skimmed milk powder intervention purchases are possible at guaranteed buying-in prices up to 3 million t, 30 thousand t and 109 thousand t respectively. Beyond these limits, intervention is possible by tender.

(c) **Decoupling:** The coupled payments retained by some Member States after the 2003 CAP reform are assumed to be decoupled and moved into the Single Payment Scheme (SPS) by 2010 for arable crops, durum wheat, olive oil and hops, and by 2012 for processing aids and the remaining products. Member States are assumed to keep current levels of coupled support for suckler cows, goats and sheep.

(d) The Member States currently applying the **single area payment scheme (SAPS)** are assumed to adopt the regionalised system from 2014 onwards.

(e) **Set-aside:** The requirement for arable farmers to leave 10% of their land fallow does not apply within the simulation period.

(f) The **energy crop premium** is abolished following the 2009 Health Check reform.

(h) **Modulation** (shifting money from Pillar I to Pillar 2): direct payments exceeding an annual €5,000 are progressively reduced each year, starting with 7% in 2009 and reaching 10% in 2012. An additional cut of 4% is made on direct payments above €300,000 a year. 'Effective' country-specific modulation rates are introduced in the model taking into account the franchise level.

(2) All commitments made in the **Uruguay Round Agreement on Agriculture** regarding market access and subsidised exports are assumed to be fully respected. No assumptions are made about a possible conclusion to the Doha Development Round.

(3) Assumptions regarding the macro-economic environment consider the following variables. The country-specific average annual rate of change of real GDP between base and 2020 is equal for the EU to 1.37 %. The country-specific average annual rate of change of Consumer Price Index between base and 2020 is equal for the EU to 1.73 %. EU population projections have been revised on the basis of the latest population statistics and the Eurostat projection EUROPOP2008. On average, for EU27 as a whole, population growth is expected to slow down gradually from 0.4% p.a. in the period 2009-2014 to 0.3% p.a. in the period from 2015-2020. The average price of crude oil is assumed to be 76 USD per barrel in the base year, and increases thereafter to about 80 USD per barrel in 2020.

4.4.2. Simulating the baseline

Once the agricultural and trade policies, and the macro-economic environment assumptions, have been incorporated into the model, the **biofuels shifters** for the EU are adjusted. The shifters to be adjusted are: human demand shifters for biodiesel and ethanol, shifters of biodiesel and ethanol processing capacities and shifters of oilseed crushing capacity. The biofuel shifters are adjusted in order to meet the biofuel target percentage over total fuel consumption used for transport as set by Renewable Energy Directive of December 2008. The projections used for total fuel consumption are from PRIMES 2007. Biofuel shifters are adjusted in order to meet a 7% target from first generation biofuel by 2020. Adjusting the with-policy baseline so as to reach fixed quantity targets is quite labour-intensive, as it involves considerable fine tuning of the shift parameters.

Once the biofuel shifters have been adjusted, the following aspects are checked:

(a) Are the biofuel consumption targets reached?

(b) Do the price margins between (i) oilseeds and oils, and (ii) biofuel inputs and biofuels on world markets and EU markets, evolve “reasonably” over the period? These margins are expected to increase with higher biofuel targets, but not too much, as supply is probably very elastic in the long run with respect to the processing margin.

(c) How do world market prices compare with the latest FAPRI projections? If large discrepancies occur, the model is calibrated to FAPRI projections relying on specific demand and supply shifters. Then steps (a)-(c) are repeated.

(d) Is the simulated behaviour plausible with respect to results for supply, demand, and net imports of biofuels and biofuel inputs?

4.5. Counterfactual construction

The counterfactual scenario involves the absence of most biofuel policy measures in the EU. However, a small initial impact of the 2009 Renewable Energy Directive may be incorporated in the behavioural equations for supply and demand of biofuels. This is explained below. In particular, the counterfactual incorporates the following specific assumptions:

(a) The tax reduction on biofuels relative to the tax on mineral oil is set to zero for the years after 2009.

(b) Shifters in the biofuel equations are maintained at their values for 2009. This means that, for the years after 2009, the effect of the Renewable Energy Directive stays at its 2009 level. Thus, the counterfactual simulated by ESIM includes the initial effect of the announced 2020 target for biofuel use, but limited to its first-year impact.[38] By contrast, in the counterfactual used with the AGLINK model, the effect of the biofuel target is totally removed.

4.6. Results

Figure 4.1 shows the trends in EU biofuel consumption as a percentage of total transport fuel consumption in the EU-27 under the baseline and the counterfactual scenario. Until 2009, the trends in EU demand for biofuels under both scenarios are rather similar. However, after 2009, the demand is much lower under the counterfactual reaching a share in total transport fuel consumption of only about 3.7% by 2020. Biofuel shifters in the baseline are set as to meet a first generation biofuel share in total EU transport fuel consumption (as projected by PRIMES 2007) of 7% by 2020, whereas in the counterfactual biofuel shifters are set to zero after 2009.

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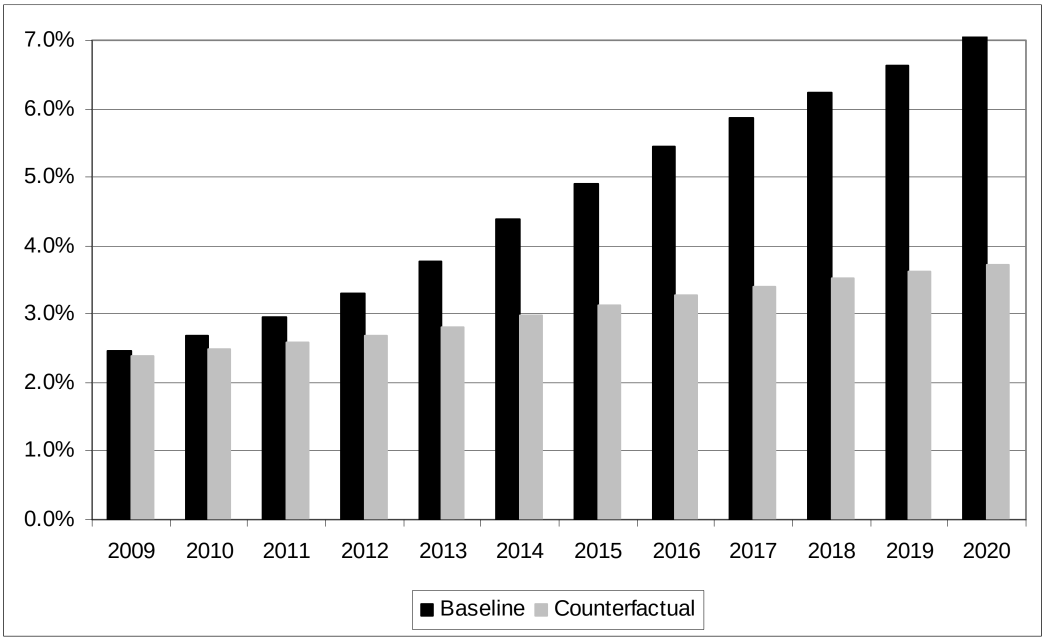
[38] The biofuel shifter simulated in 2009 increase the share of biofuels of total transport fuels only 1% (from 1% in the base year 2005 to 2% in 2009). Thus, the impact of biofuels shifter in 2009 can be regarded as very small.

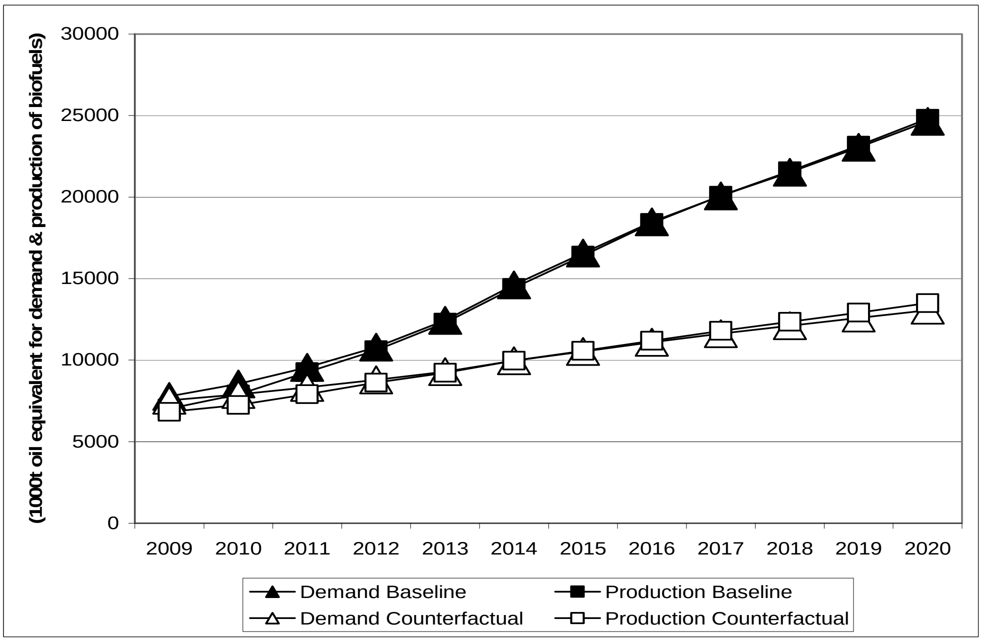
Figure 4.1: Share of EU biofuel consumption in total transport fuels in the EU-27.



Source: ESIM simulations.

Figures 4.2 and 4.3 show the evolution of biofuel demand and production in the EU, and of EU net exports, respectively, under both scenarios over the simulation period.

Figure 4.2: Biofuel demand and production of biofuels in the baseline and in the counterfactual in EU27 (2009-2020).

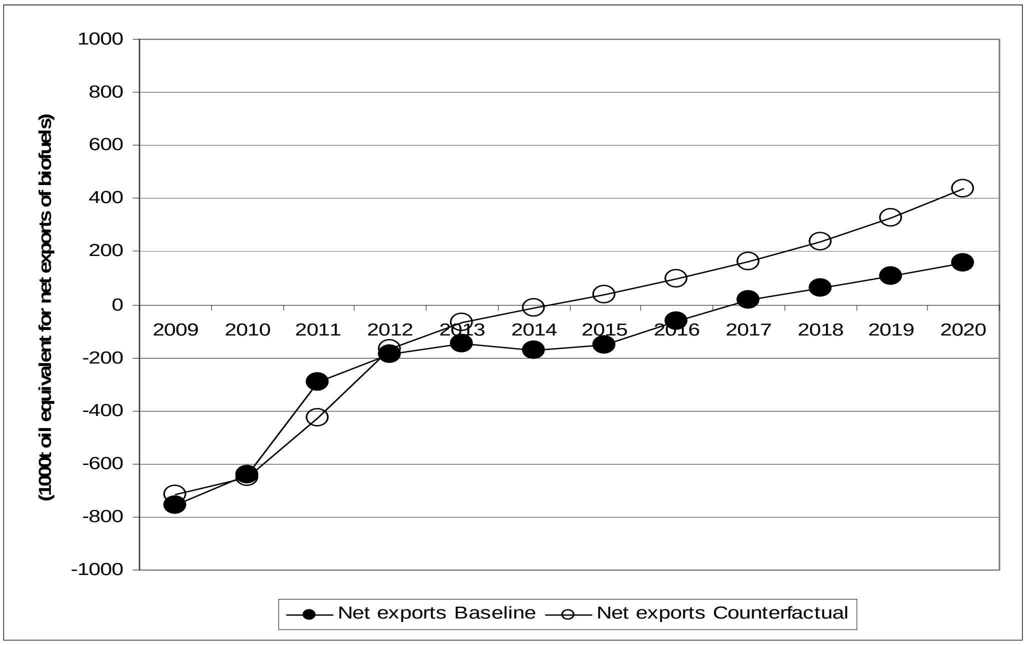


Source: ESIM simulations.

Biofuel demand in the baseline is simulated to increase to about 24.6 million tonnes oil equivalent by 2020, which corresponds to 7% of total transport fuel consumption[39]. The shares of biodiesel and ethanol demand in total biofuel demand are about 60% and 40% respectively by 2020. [40] Biofuel demand in the counterfactual is simulated to increase to about 13 million tonnes oil equivalent by 2020, which corresponds to 3.7% of total transport fuel consumption. Under the counterfactual, the share of biodiesel demand in total biofuel demand is about 90% and that of ethanol is about 10% by 2020.

Biofuel production in the baseline also increases to about 24.8 million tonnes oil equivalent by 2020, which exceeds actual demand and results in the EU becoming a net exporter of biofuels (about 0.16 million tonnes oil equivalent, compared to negligible imports in the base year) (see Figure 4.3). Net imports of ethanol in 2020 in the baseline scenario are about 0.15 million tonnes whereas for biodiesel the EU starts to be a net exporter after 2013, with 0.3 million tonnes of net exports by 2020[41].

Figure 4.3: Net exports of biofuels from EU27 for both scenarios (2009-2020).



Source: ESIM simulations.

[39] Conversion factors from litres to tonnes of oil equivalent are: biodiesel 0.93, ethanol 0.64

[40] The share refers to the quantity converted into tonnes of oil equivalent. Unlike the baseline simulation with AGLINK-COSIMO, the consumption of first generation biofuel corresponding to each fuel type (petrol/diesel) was not forced to be 7% of the corresponding fuel type: rather, the sum of the two biofuels had to reach 7% of total transport fuel demand. However, the shares generated by ESIM are largely dependent on the way the shifters in various equations of the model have been changed in order to achieve the policy target.

[41] This result contrasts with that of the AGLINK-COSIMO model, where the EU remains a net importer of both biofuels under both scenarios in 2020 in the baseline simulation.

Net imports of products that can be used as biofuel inputs are also much higher in the baseline. For example, EU net imports for rapeseed and sunflower oil are projected to increase respectively from 1 million tonnes in the base year to 19 million tonnes by 2020 and from about 2 million tonnes in the base year to 11 million tonnes by 2020. Therefore, the EU in the baseline scenario is characterised by strong net imports for biofuel feedstocks.

The effect of EU biofuel policies on total EU area used for agricultural production is very small. In the baseline, the area used for agricultural production decreases between 2009 and 2020 by 0.72% (1.1 million hectares out of a total of 152 million hectares). Under the counterfactual scenario, agricultural land use would decrease by 1.15% (1.8 million hectares). Thus, the decrease in agricultural land is only slightly greater under the counterfactual than in the baseline.

Table 4.1 illustrates the impact of EU biofuel policies in 2020 on EU production of the most relevant commodities. In the with-policy scenario, 19% (39.5 million tonnes) of the total 211 million tonnes demanded of cereals (including maize) are used for ethanol production (processing demand), which is significantly higher than under the counterfactual.

While the human demand (i.e. human consumption) of both ethanol inputs is hardly changed, the use of maize as fodder is lower by 13.6% (7.6 million tonnes). Due to higher demand for wheat and maize for ethanol production, domestic supply increases (by 3.2% and 6.8% respectively). These increases are partly achieved by area increases of 2% and 4%, respectively, which together amount to 0.4% of the UAA. Soft wheat net exports are lower by 64% (17.4 million tonnes), while net imports of maize are higher by 0.8 million tonnes. The demand for sugar for ethanol production is more than four times higher, and imports double (up by 7.5 million tonnes) to accommodate the stronger domestic demand. The prices for the three ethanol feedstock crops are also higher: by 8% for soft wheat, and by 20% each for maize and sugar.

Table 4.1: Impact of EU biofuel policies in 2020

		Difference between baseline and counterfactual results								Net exports (+) and net imports (-)	
		Human demand	Processing demand for biofuel production	Feed demand	Total use	Supply	Wholesale price	Area	Share of UAA	Counterfactual	Baseline
	Change/ value in:	per cent							percent -age points	1000 t	
Ethanol feedstock	Soft wheat	-0.3	1053.6	-0.5	19.0	3.2	8.3	2.0	0.2	27467	10015
	Maize	-0.6	612.4	-13.6	7.7	6.8	22.2	3.9	0.2	-2558	-3382
	Sugar	-2.1	414.5		35.9	0.1	20.7	0.3	0.0	-5256	-12776
Biodiesel feedstock	Soybean	0.0	-6.2	-6.4	-6.1	-3.2	0.5	-3.4	0.0	-18700	-17518
	Rapeseed		11.9		11.9	6.7	9.7	5.2	0.1	-5686	-6922
	Sunflower seed	0.0	12.4	-8.1	10.2	6.4	11.2	4.4	0.1	-3490	-4061
By-products	Soybean			6.7	6.7	-6.2	-11.9			-18712	-21796
oil meals	Rapeseed			60.9	60.9	11.9	-38.3			3165	-394
	Sunflower seed			57.6	57.6	12.4	-33.8			49	-2614
grains	Gluten feed			668.0	668.0	856.6	-84.0			-3604	-25611
Fodder crops	Maize silage			-0.9	-0.9	-0.9	1.5	-1.1	0.0		
	Other fodder crops			-0.5	-0.5	-0.5	3.1	-0.7	-0.1		
	Grass			-0.5	-0.5	-0.5	2.1	-0.5	-0.4		
Livestock	Beef	0.0			0.0	0.9	1.2			-2218	-2154
	Pork	0.4			0.4	3.3	1.3			498	1165
	Poultry	0.0			0.0	3.2	1.6			-254	152
Vegetable oils	Soybean	-0.2			-0.2	-6.2	17.4			690	502
	Rapeseed	-0.5	21.3		16.6	11.9	34.9			-10003	-11911
	Sunflower seed	-0.6	19.5		6.4	12.4	35.8			-1421	-1401
	Palm	0.0	368.8		1.5		1.3			-4076	-4137
Biofuels	Biodiesel	24.0			24.0	21.6	13.2			480*	301*
	Ethanol	660.0			660.0	673.9	3.2			-43*	-145*

Source: ESIM simulations. Note: net export figures include stock changes. * see footnote 36 for conversion factors.

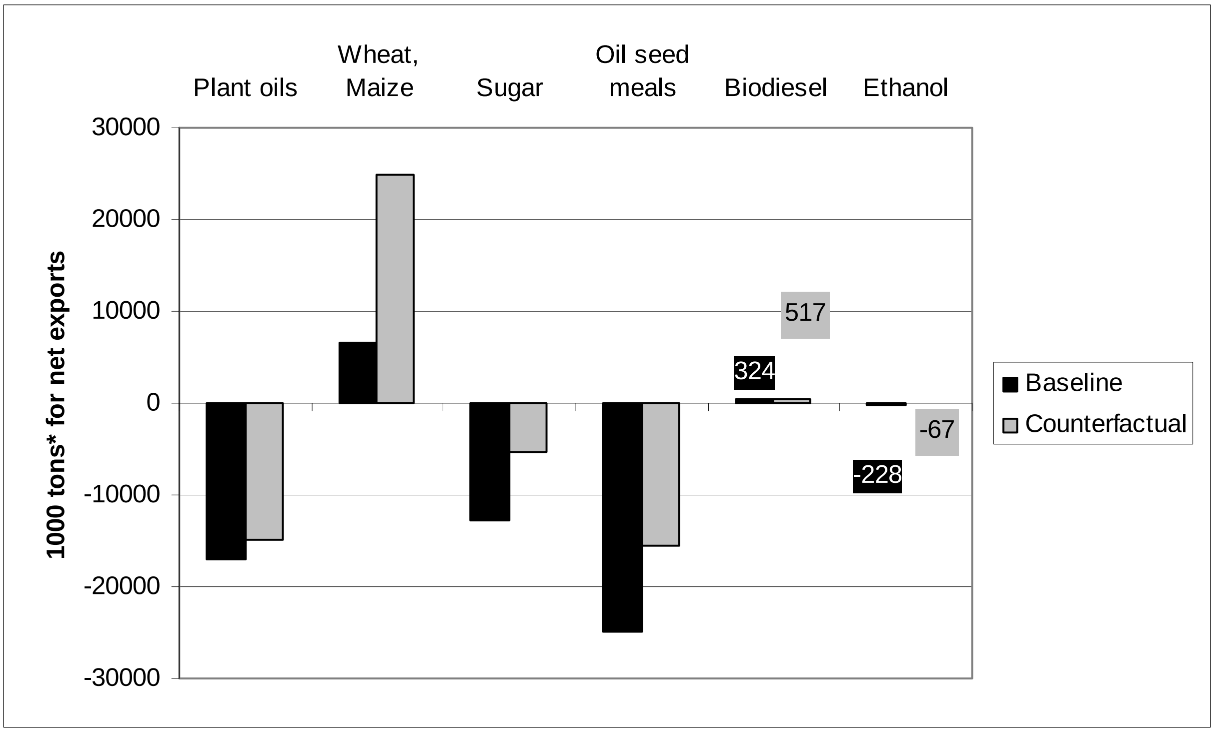
Processing demand for biodiesel feedstocks is also much higher under the baseline. Rapeseed processing demand is 11.9% (18.5 million tonnes) higher, and that of sunflower seed 10.2 % (8.8 million tonnes) higher. Higher domestic supply means that the share of UAA growing rape and sunflower increases by 0.2 percentage points; the rest of the additional demand is met by higher imports. Wholesale prices for both these oilseeds are about 10% higher due to EU biofuel policies.

The average increase in domestically produced oilseeds (rapeseed, sunflower seed and soybean) is 7%. The average price increase of domestically produced plant oils (soy oil, rapeseed oil and sunflower seed oil) is 30%.

The supply, demand and trade of soybeans are only slightly affected by the biofuel policies.

Due to a greater supply of biofuels, the supply of the by-products gluten feed, rape meal and sunflower seed meal is also higher. The prices of these animal feedstuffs are significantly lower, and they partly substitute in livestock rations for maize, maize silage, soybean and sunflower seed, the use of which in animal feed is lower by 13.6%, 0.9%, 6.4% and 8.1%, respectively. The use of these fodder substitutes helps to keep the markets for livestock products quite stable: prices change only marginally.

Figure 4.4: EU-27 net exports in 2020 of biofuels and potential inputs.



Source: ESIM simulations. * tonnes oil equivalent for biofuels: biodiesel and ethanol.

Figure 4.4 presents total EU-27 net exports in 2020 for biofuels and the most important biofuel inputs.

Net imports of ethanol, plant oils, oilseeds, sugar and meals are higher with the EU biofuel policy in place than under the counterfactual scenario. By contrast, net exports for wheat and maize are lower, given that their demand as a feedstock for ethanol is much higher because of the higher domestic ethanol production.

Finally, the results presented here should be accompanied by a few caveats regarding both the model's behavioural functions and the underlying assumptions regarding technology and macroeconomic developments.

It should be borne in mind that the relative magnitude of changes in production and trade for oilseeds, vegetable oils, ethanol and biodiesel are largely driven by the adjustment of the processing demand shifters (c.f. Section 4.4.2). The model's ability to depict the location of processing industries endogenously at member state level is poor; however, this does not affect the results reported here for EU 27.

Furthermore, technological developments and various aspects of the economic outlook involve a number of uncertainties. This analysis assumes first-generation technologies only for biodiesel and ethanol production. If second-generation technologies were to take off during the projection period, they may offer an alternative characterised by higher yields and/or that use land poorly suited for food production. As for the uncertainties in the economic outlook, the ESIM simulation results, like those obtained with AGLINK and CAPRI, are sensitive to unexpected exchange rate developments and trade policy changes.

4.7. Sensitivity of ESIM counterfactual results

The sensitivity of the simulated outcomes under the counterfactual was investigated. In particular, it was assumed that, instead of the assume crude oil price of 80 USD per barrel maintained in both the baseline and counterfactual reported above, the crude oil price is 50% higher (at 120 USD per barrel). Table 4.2 compares the results for the counterfactual with the higher oil price against those for the counterfactual with the lower price. Outcomes under the baseline are not involved in this comparison.

Table 4.2: Impact of a 50% crude oil price increase in 2020 on counterfactual outcomes.

	Ethanol	Biodiesel
Production	8%	7%
Net exports	96%	6%
Demand	11%	7%
Wholesale price	7%	10%

Source: ESIM simulations.

Note: Percentages show the change due to the higher oil price (120 USD), relative to the counterfactual with the lower oil price (80 USD).

If the crude oil price is 50% higher than assumed under the counterfactual, the ESIM model simulates production levels for ethanol and biodiesel that are 8% and 7% higher, respectively, and wholesale prices that are about 7% and 10% higher, respectively. Given the higher domestic ethanol price (now 661 EUR/ton as compared to 619 EUR/ton with the lower oil price), imported ethanol starts to be more competitive even with the tariff, as the price of ethanol on the world market is about 305 EUR/ton. The additional demand for ethanol is greater than the extra supply, the difference being met by a higher level of imports.

4.8. Summary of key findings

The key results of these simulations, using the ESIM model, of imposing a 7% share of biofuels in total transport fuels in the EU by 2020 (instead of a 3.7% share, as shown in the counterfactual scenario), are the following:

- EU prices for biodiesel and ethanol are 13% and 3% higher, respectively,
- EU production of rapeseed and sunflower seed is higher by 6-7%.
- EU prices for the main EU-produced biodiesel inputs (oilseeds, plant oils) increase. The prices of rapeseed and sunflower seed increase by 9.7% and 11.2% respectively, and those of rapeseed oil and sunflower seed oil by just over one-third. The prices of rapeseed and sunflower seed meals fall by a third or more.
- EU production of maize is 7% higher, and that of wheat 3% higher.
- EU prices for ethanol inputs are higher, by 8%, 21% and 22% for soft wheat, sugar and maize respectively.
- The markets for livestock products are hardly affected by EU biofuel policies, and livestock prices differ only marginally.
- In order to meet the 7% target share in 2020, there will be a strong increase in imports especially for sugar for the production of ethanol.
- EU area used for agricultural production decreases between 2009 and 2020 by only 0.72% (1.1 million hectares out of a total of 152 million hectares) whereas without EU biofuel policy the decrease would be 1.15% (1.8 million hectares).
- The EU switches from a net export to a net import position in oil meals (rapeseed and sunflower seed).

- The EU becomes a net exporter of biofuels (about 0.16 million tonnes oil equivalent, compared to negligible imports in the base year)[42].
- Net trade in ethanol feedstocks is significantly different: net sugar imports are 143% higher and net wheat exports are lower by 64%.

[42] This result contrasts with that of the AGLINK-COSIMO model, where the EU remains a net importer of both biofuels under both scenarios in 2020 in the baseline simulation.

5. Results from the CAPRI model

5.1. Model overview

CAPRI is a comparative-static, spatial, partial equilibrium model specifically designed to analyse CAP measures and trade policies for agricultural products (Britz and Witzke, 2008). CAPRI models agricultural commodity markets worldwide, whilst also providing a detailed representation of the diversity of EU agricultural and trade policy instruments. It consists of two interlinked modules, the supply module and the market module, such that production, demand, trade and prices can be simulated simultaneously and interactively.

The supply module consists of regional agricultural supply models for EU27, which capture in detail farming decisions at the NUTS II level (cropping and livestock activities, yields, farm income, nutrient balances, GHG emissions, etc.). Its mathematical programming approach allows a high degree of flexibility in modelling CAP measures as well as in capturing important interactions between production activities and between agricultural production and the environment.

Table 5.1. Regional disaggregation in the market module (trade blocks)

1	European Union 15, broken down into MS	15	Argentina
2	European Union 10, broken down into MS	16	Brazil
3	Bulgaria & Romania (2)	17	Chile
4	Norway	18	Uruguay
5	Turkey	19	Paraguay
6	Morocco	20	Bolivia
7	Other mediterranean countries	21	Rest of South America
8	Western Balkan countries	22	Australia & New Zealand
9	Rest of Europe	23	China
10	Russia, Belarus & Ukraine	24	India
11	United States of America	25	Japan
12	Canada	26	Least developed countries
13	Mexico	27	ACP countries which are not least developed
14	Venezuela	28	Rest of the world

The market module is a spatial multi-commodity model with worldwide coverage, where about 50 commodities (primary and secondary agricultural products) and 60 countries (grouped into 28 trade blocks) are modelled as a square system of equations. Within the EU, there is a perfect market (for both primary and secondary products) so that prices for all Member States move in unison. The parameters of the behavioural equations for supply, feed demand, processing industry and final demand are taken from other studies and modelling systems, and calibrated to projected quantities and prices in the simulation year. Major outputs of the market module include bilateral trade flows, market balances and producer and consumer prices for the agricultural commodities and world country aggregates.

Table 5.2. Indicators in CAPRI

Features covered by CAPRI	Features not covered by CAPRI
Land use changes in Europe	Land use changes outside Europe
Substitution between feed, human consumption and biofuel processing	
GHG inventories for agriculture in Europe Ammonia emissions, nitrogen and phosphate balances	GHG emissions in other sectors linked to agricultural input use (e.g. fertiliser industry)
Changes in agricultural trade flows including vegetable oils	Changes in GHG emissions outside the EU linked to changes in agricultural trade flows
	Biofuel production and trade (including substitution between feedstocks, substitution between domestically produced biofuel and imports, effect of energy prices on biofuel production)
GHG-life cycle analysis for farm inputs up to the farm gate, by agricultural activity	Life cycle analysis beyond the farm gate
Changes in farm income and impact on consumers	

Table 5.2 shows which of the features identified as relevant to a model-based analysis of biofuel policies can currently be handled in CAPRI.

5.2. Integration of biofuel activities in CAPRI

To analyse the effects of EU biofuel policies on agricultural land use and commodity markets, the global agricultural sector model CAPRI has been extended to include various biofuel activities. CAPRI was originally designed to model agricultural commodity markets and biofuel markets are not currently endogenous in the model. Demand for biofuels is treated as exogenous and it is assumed that all biofuels consumed in the EU are produced domestically. Only first generation biofuels (ethanol and biodiesel) are considered in the model, and exogenously given biofuel quantities can be linked to the corresponding feedstock input from cereals and vegetable oils. However, CAPRI models the production of agricultural biofuel feedstocks and their trade flows.

In the simulation framework, CAPRI allows the effects of a shift in biofuel demand to impact on food production and prices, the potential use of by-products in the feed chain, the changes in land use in the EU and the share of imported feedstocks for biofuels.

5.2.1. Supply of biofuel feedstock

The biofuel module considers the production of both ethanol and biodiesel. Ethanol is produced from wheat, coarse grains and sugar, while biodiesel is produced from vegetable oils (rapeseed oil and sunflower oil). The biofuel feedstocks[43] modelled by CAPRI are shown in Table 5.3.

Table 5.3. Product coverage in the biofuel module

Biofuel	**Feedstock**	**By-product**
Ethanol	Wheat Coarse grains (maize, barley, oats, sorghum) Sugar	DDG Gluten feed
Biodiesel	Oilseeds ((rapeseed, sunflower), palm oil	Oil meals and cakes

The production of biofuel feedstocks is modelled within the supply module. For each region, the supply module model maximises regional agricultural income at given prices and subsidies, subject to constraints on land, policy variables and feed. The land balance plays an important role in explaining the interactions between activities in the supply module. CAPRI distinguishes arable and grass land, and both land types are set exogenously.

5.2.2. Production of biofuels and biofuel by-products

CAPRI does not currently include an endogenous module for biofuel production. Neither the costs of production nor the prices of biofuels are considered in the current CAPRI system. Instead, the demands for ethanol and biodiesel are set exogenously, and the model determines the consequences for supply, demand, trade and prices of agricultural primary and secondary products, including feedstocks for biofuel production and biofuel by-products. It is assumed that there are no capacity constraints for biofuel production. Since CAPRI does not have a

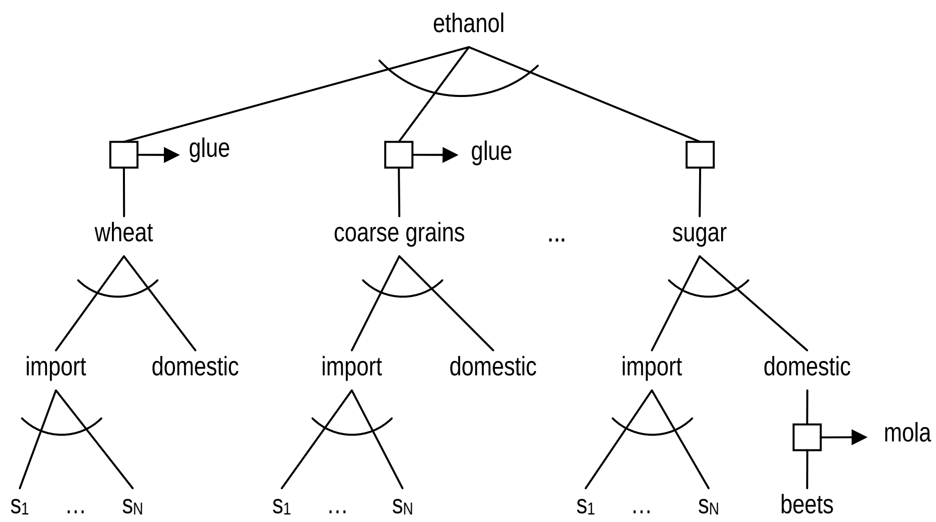
[43] Agricultural feedstocks for biofuel production are modelled in CAPRI in the same way as any other agricultural commodity.

bioenergy industrial sector, a simplified processing sector for biofuels in the EU was assumed. Extraction coefficients for the processing of the different vegetable oils to biofuels and from cereals to ethanol are taken from AGLINK (see Table A3.1).

Previous applications of CAPRI for biofuels modelling assumed a Leontief processing technology, i.e. fixed coefficients determine the share of feedstock necessary to produce a unit of biofuel and the output of by-products. In the current version of the model, the processing technology is modelled by means of a Constant Elasticity of Substitution (CES) function.

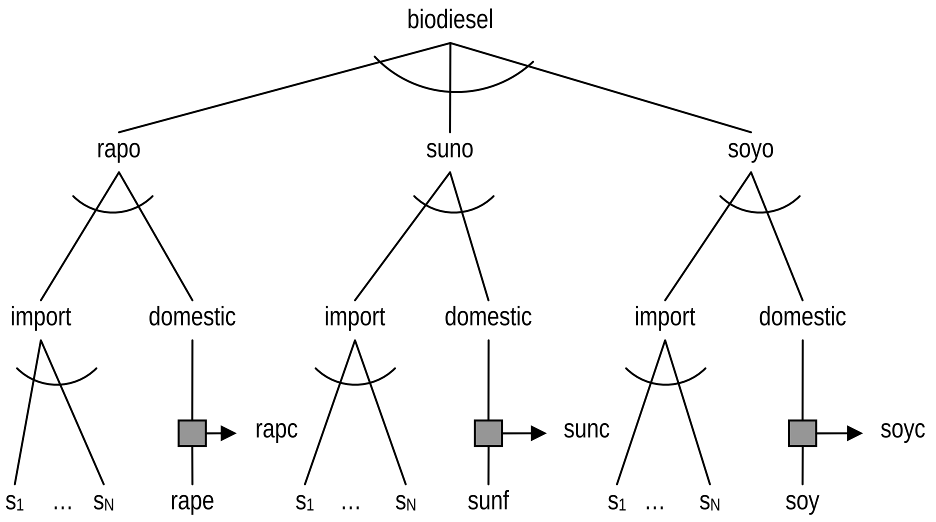
It is assumed that ethanol can be produced in the EU27 from cereals (wheat and coarse grains) and sugar beet. Biodiesel is assumed to be produced from vegetable oil (from rapeseed, sunflower and soya) and, therefore, two processing levels (oilseeds to oil and oil to biodiesel) are modelled. Processing firms are assumed to choose the cost-minimising mix of inputs to produce an exogenously given amount of biodiesel or ethanol, conditional on prices and technical coefficients. The processor does not mix the raw feedstock directly, but instead optimises a mix of processing lines, each using a single input. Feedstock for biofuel production may be either supplied domestically or imported, and imports are modelled in a two-stage budgeting system (Armington assumption). The set-up for ethanol is illustrated in Figure 5.1, and for biodiesel in Figure 5.2. The choice of an appropriate functional form for the processing industry is an empirical issue, which we do not attempt to address in this study. Instead, and as mentioned above, a simple CES function is assumed, as in Banse *et al* (2008a).

Figure 5.1. Ethanol industry



Comment: glue = gluten feed, mola = molasses and s_1 to s_N all possible sources of imports

Figure 5.2. Biodiesel industry and input use



Comment: rapo = rapeseed oil, suno = sunflower oil, soyo = soy oil, rapc = rapeseed cake, sunc = sunflower cake, soyc = soy cake, rape = rapeseed, sunf = sunflower seed and soy = soybeans.

In Figures 5.1 and 5.2, an empty square box denotes a fixed relationship between input use, given the output demand, and the production of some by-product (e.g. wheat used in ethanol production implies production of gluten feed). A filled box denotes a price-dependent relationship between output, inputs and by-products, modelled by a normalised quadratic profit function approach. The arcs placed below certain words, e.g. the one below "biodiesel", denote a cost minimisation problem based on a CET technology.

The microeconomic cost-minimisation problem of the processor, either for ethanol or for biodiesel, is specified as follows:

$$\text{Minimise } \sum_i x_i \left(p_i + v_i - b_i p_b \right)$$

$$\text{subject to } y = a\left[\sum_i \left(d_i c_i x_i \right)^{\rho} \right]^{\frac{1}{\rho}}, \text{ where} \qquad (1)$$

i : inputs (cereals and sugar for ethanol, oils for biodiesel)
p_i: price of input i
b_i: amount of by-product produced per unit of input
p_b: price of by-product
y: amount of ethanol or biodiesel to produce
a: Hicks-neutral technical change parameter
d_i: parameter determining the distribution of inputs or input saving technical change.

c_i: technical conversion factor from input i to ethanol or biodiesel
v_i processing gross margin per input
ρ: parameter determining the elasticity of substitution.

The first-order conditions for an optimal solution of the optimisation problem are stated in equations (2) and (3). The parameter ρ is related to the elasticity of substitution, σ, by the expression $\rho=(\sigma-1)/\sigma$. The technical coefficients b_i and c_i are taken from AGLINK. The processing gross margins v_i were computed as the value of outputs minus the value of inputs using baseline prices. The parameters *a* and d_i are calibrated by solving equations (2) and (3) for baseline values of x_i, *y* and *p*.

$$x_i\left(p_i+v_i-b_i p_b\right)^{\frac{1}{1-\rho}}\left(d_i c_i\right)^{\frac{\rho}{\rho-1}}=x_j\left(p_j+v_j-b_j p_b\right)^{\frac{1}{1-\rho}}\left(d_j c_j\right)^{\frac{\rho}{\rho-1}} \qquad (2)$$

$$y=a\left[\sum_i\left(d_i c_i x_i\right)^{\rho}\right]^{\frac{1}{\rho}} \qquad (3)$$

Since the CES function exhibits constant returns to scale, the first order conditions (2) come in pairs and are not sufficient in order to find a unique solution. Thus, equation (2) is dropped for one input, called the *numeraire,* and the constraint (3) is used to determine the level of production. Equation (2) is implemented for all i ≠ “numeraire” and j = “numeraire”.

The volumes of ethanol and biodiesel needed to reach the 2020 baseline target shares are exogenous. Given these volumes, CAPRI determines the quantities of feedstocks used and the production of by-products (oil cakes and gluten feed, with endogenous prices). Feed composition changes according to the cost minimisation while protein/energy balances in the animal diets are met.

5.2.3. Demand for biofuels

CAPRI models the production and trade of agricultural feedstock for biofuel production, but no trade of biofuel was considered in this study. Demands for each biofuel are exogenous, and are taken from AGLINK. CAPRI is able to translate the exogenously fixed biofuel demands into demands for agricultural feedstocks. The model does, however, determine endogenously how much of the biofuel demand will be met by EU production and how much will be met from imports from outside the EU.

5.3. Implementation of biofuel policies

Biofuel support policies in the EU are currently modelled in CAPRI as a shift in demand for first generation biofuels[44]. This simplistic and widely applied approach assumes: (a) a CES processing technology for biofuel production, (b) fixed conversion rates from feedstock biomass to biofuels and to by-products, and (c) no consideration of raw oil prices. For the moment, only biofuel feedstocks and by-products are traded in CAPRI.

The CAPRI biofuel module will be further developed in the near future. A link to the energy model PRIMES is foreseen, which, by relaxing many of the previously stated assumptions, would allow energy taxes and raw oil prices to be included in the analysis.

5.4. Scenario construction and assumptions

Two scenarios have been considered in this study: a baseline scenario assuming a biofuel share of 8.5% in total transport energy in 2020 (consistent with the Renewable Energy Directive) and a counterfactual scenario assuming the absence of all internal EU biofuel policies. However, since the CAPRI baseline is currently built on trend estimators and results from other modelling systems (including AGLINK and ESIM), it has not been possible to update the CAPRI baseline in the time frame of this study. Therefore, the CAPRI baseline used here is not fully synchronised with those of AGLINK and ESIM, the most relevant difference being that the CAP Health Check reform (2008) has not been integrated into CAPRI[45]. Our baseline reflects policies in force just prior to the CAP Health Check, including biofuel policies agreed in the Renewable Energy Directive. Since CAPRI does not have so far endogenous biofuels markets, both scenarios (baseline and counterfactual scenario) were constructed in order to meet the EU27 2020 biofuel demands obtained from AGLINK (see Table 5.4)

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[44] Second generation biofuels cannot be analysed within the current framework. Having said this, specific assumptions on penetration of second-generation biofuels can be made (i.e. lower additional demand for first generation feedstocks) and the economic consequences for the agricultural and energy sectors assessed.

[45] In the coming months, an updated CAPRI baseline for year 2020 in line with the results from the AGLINK and ESIM baselines will be available.

Table 5.4. EU biofuel demand in 2020

	Baseline		Counterfactual	
	Ethanol	Biodiesel	Ethanol	Biodiesel
Production (million litres)	17790	24243	6192	1664
Consumption (million litres)	21239	28196	6680	1995
From first generation biofuels	17935	23220	6680	1995
From second generation biofuels	3304	4976	0	0

Source: AGLINK-COSIMO simulations.

5.5. Results

A comparison of the baseline results with those of the counterfactual in 2020 yields the main impacts of EU biofuel policies in that year. Impact indicators at regional level include agricultural production, feedstock and by-product production, land use and agricultural income. European-level indicators include trade flows and welfare changes. Environmental indicators at regional level include land use, energy balances, nutrient balances and greenhouse gas emissions from agricultural sources.

5.5.1. Main findings at EU level

Table 5.5 shows the impacts of EU biofuel policies on the key economic variables that are most directly affected.

Table 5.5. Impacts of EU biofuels policies on feedstock and by-product markets (% difference in 2020)

	Production	Net trade	Consumption	Biofuel use	Price
Cereals	1.42	-68.98	6.87	161.61	10.18
Soft Wheat	5.23	-74.30	10.03	160.40	12.52
Rye and Meslin	-3.06	-13.57	-1.70	168.01	8.99
Grain Maize	4.88	111.43	13.45	161.09	7.95
Other cereals	-7.70	-622.63	0.49	208.77	6.05
Sugarbeet	-1.00	-2.52	-1.01	-1.54	1.95
Oilseeds	12.27	-9.37	0.33		19.48
Rapeseed	23.46	50.12	31.63		29.02
Sunflower	6.50	-36.63	1.99		12.01
Vegetable oil	12.22	-3894.85	109.40	929.65	27.11
Rapeseed oil	49.04	937.62	217.04	1371.17	203.10
Sunflower oil	7.90	248.41	87.45	419.78	41.35
Gluten feed	159.52	-2153.33	159.52		-40.86
Oil cakes	-3.84	-41.83	-13.18		-22.09
Rapeseed cake	28.18	28.46	28.08		-30.66
Sunflower cake	1.60	6.65	2.34		-23.39

The impacts of EU biofuel policies on production and market balances for the two categories of biofuel feedstock are very different in magnitude, although in the same direction: cereal production is higher by only 1.4% whereas oilseed production is 12.3% higher. Price differences for the main cereal energy crops (+10.2%) are less marked than for oilseed energy crops (19.5%). This reflects the fact that, compared with oilseeds, demand for cereals as a feedstock is a much smaller share of total demand. By contrast, on the demand side, total demand for cereals is higher by 6.9% (slightly lower for human consumption but much higher for biofuel processing) whereas total oilseed demand is only 0.3% higher. This is explained largely by the much higher level of imported vegetable oil feedstock (especially palm oil).

Overall, farm incomes in EU27 in 2020 are simulated to be 3.5% higher with EU biofuel policies than without these policies.

Table 5.6 shows the differences in land allocation to the main agricultural crops under the two scenarios. Cereals area is hardly affected, being only 0.05% higher, whereas oilseeds area is 10.5% higher with the biofuel polices. These higher rates of land use for energy crops are at the expense of land devoted to fodder activities and to fallow, which is lower by 0.2% and 5.6%, respectively. Yields for the main energy crops are also somewhat higher in the baseline compared with the counterfactual, reflecting a shift from lower- to higher-yielding crop varieties and a greater degree of intensification of production systems.

Table 5.6. Impact (%) of EU biofuel policies on land use and production, EU27

	Area	Yield	Production
Cereals	0.05	1.37	1.42
Soft Wheat	4.07	1.12	5.23
Durum Wheat	-0.08	0.27	0.19
Rye and Meslin	-3.26	0.21	-3.06
Barley	-4.05	-0.57	-4.59
Oats	-4.41	0.20	-4.23
Grain Maize	3.18	1.65	4.88
Other cereals	-7.34	-0.40	-7.70
Paddy rice	-1.23	0.02	-1.20
Sugarbeet	-1.09	0.08	-1.00
Oilseeds	10.51	1.60	12.27
Rapeseed	23.05	0.33	23.46
Sunflower	6.07	0.41	6.50
Fodder activities	-0.23	0.07	-0.15
Set-aside and fallow land	-5.65		

This evidence suggests that EU biofuel policies will not be environmentally neutral, due to more intensive production, and in particular to higher nitrogen surpluses as a result of greater use of inorganic fertiliser - a consequence of changes in crop shares and higher crop yields.

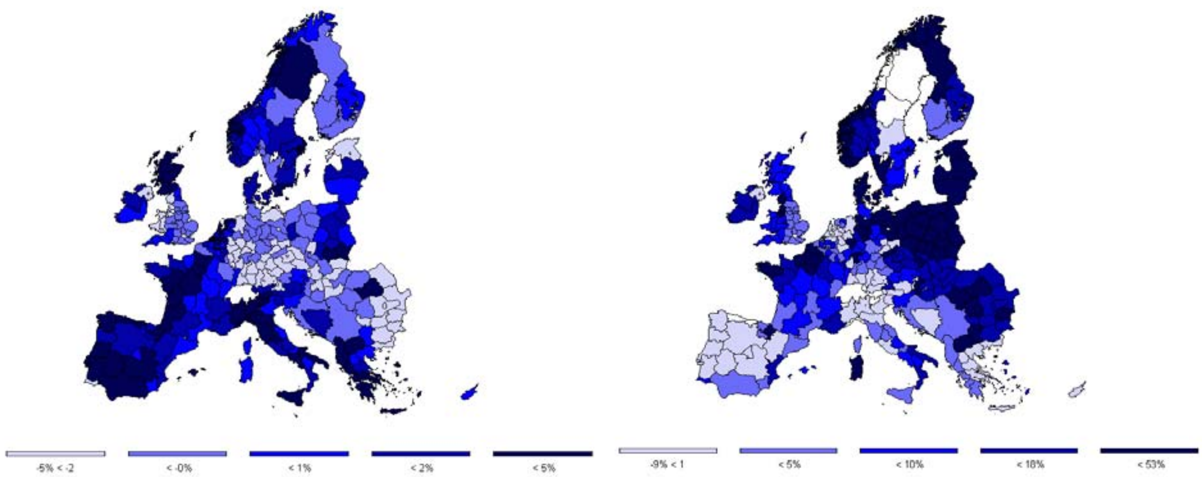
5.5.2. Regional impacts of the EU biofuels target

In this sub-section, the results for the EU27 are broken down to the NUTS 2 level.

Although, for the EU as a whole, the simulated net effect on cereal area of EU biofuel policies is almost negligible (+0.05%), clear regional effects can be observed (see Figure 5.3). The area used for cereal production is higher in Spain, France, Italy and Greece (by +2% to +5%) and lower for most German regions, Bulgaria and Romania (with differences in the range -3% to -5%). An opposite effect on oilseeds area can be observed, with the strongest area increases in eastern and north-eastern parts of EU27. Thus, EU biofuel policies introduce changes in the regional specialisation relating to oilseeds (mainly rapeseed) and cereals depending on the different production structures and agro-climatic conditions.

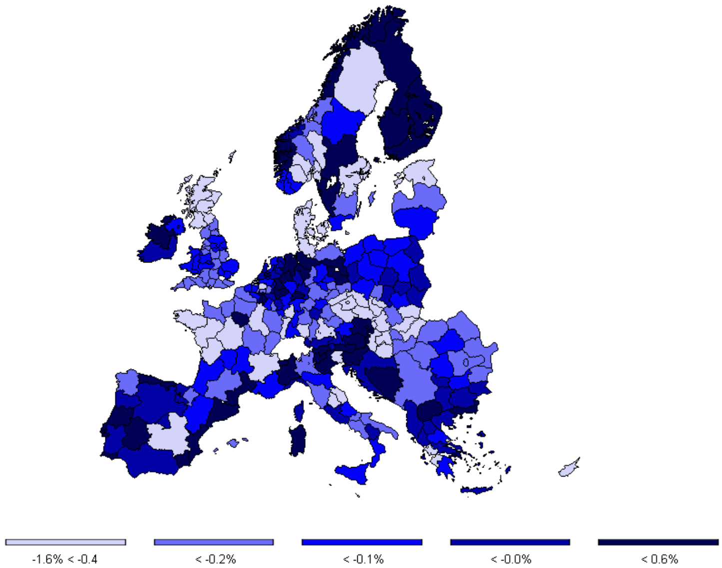
The overall positive effect of EU biofuel policies on area used for oilseeds is quite strong (+10%), especially in the New Member States and some northern French and German regions.

Figure 5.3. Changes in land use for cereals (left) and oilseeds (right) (in %)



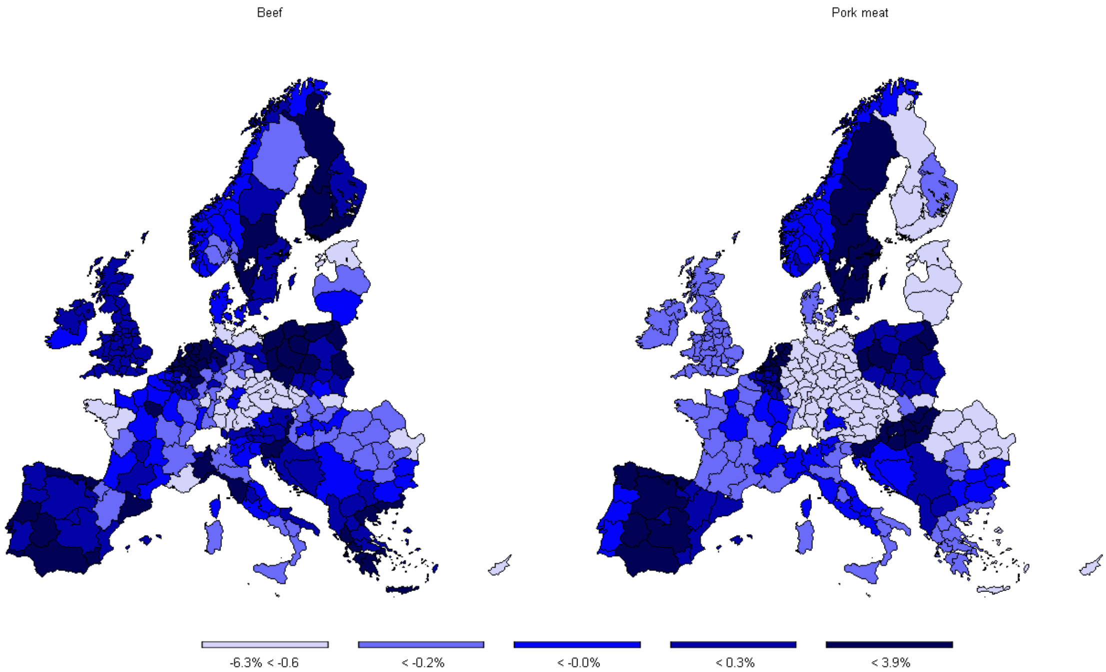
Area used for fodder production represents around 44% of total EU agricultural land, and is therefore also an important component of land use. In the baseline simulations, area used for fodder activities is lower by -0.2% for the EU27, this negative effect having to do with (a) the competition for land and (b) the higher cost of animal production (higher prices for cereals (+13% for soft wheat and +9% for maize), which has an indirect effect on livestock feed costs.

Figure 5.4. Changes in land use for fodder crops (in %)



The regional distribution of these effects is shown in Figure 5.4. Lower fodder production is most marked in regions with high shares of cereals (up to -1.6% in Poitou-Charentes). By contrast, the opposite effect is seen in regions with high shares of oilseeds (up to 0.6% higher in some German regions), where cereal production is lower and fodder prices do not change.

Figure 5.5. Changes in beef (left) and pork meat (right) production (in %)



Higher fodder costs are transmitted along the meat production chain so that, in general, meat prices are higher and EU meat demand is slightly lower. The regional effects on beef and pork meat supply are presented in Figure 5.5.

5.6. *Sensitivity analysis with CAPRI: Marginal impacts of increasing biodiesel and ethanol demand*

5.6.1. Rationale

In this section, we report an analysis of the effects of biofuel policies on trade and land use change *at the margin*. The effects of successive increments in demand are examined for ethanol and biodiesel feedstocks separately, with cereals and vegetable oil the main feedstocks considered. CAPRI was selected for this analysis because it allows for the endogenous representation of agricultural trade of cereals and vegetable oils, although biofuel trade is not allowed and all biofuels are assumed to be produced domestically.

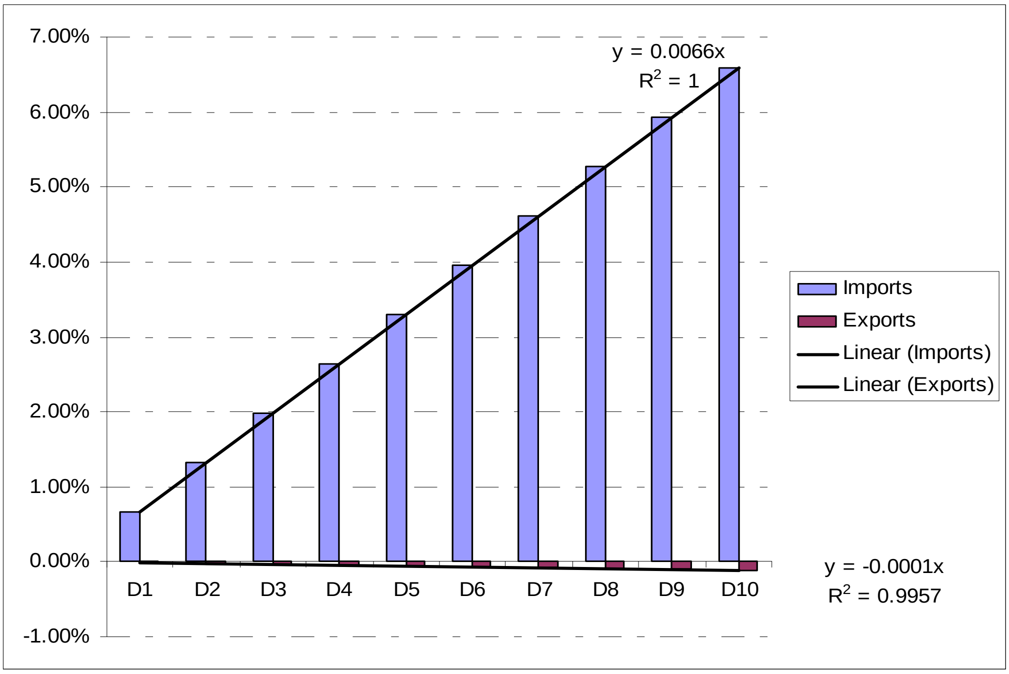
The effects of marginal increases in cereal demand (driven by ethanol processing demand) can be compared with the effects of marginal increases in oilseed/vegetable oil demand (for increasing biodiesel production). No geographical differences within EU27 are taken into account. All shocks are performed against a medium-term baseline (for the year 2020).

5.6.2. Marginal effects of biodiesel demand shocks

Effects on trade balances

Europe's position as a net importer of vegetable oils would become more dominant in order to satisfy the increase in demand for biodiesel. While supply is quite inelastic (production increases by 0.51% for a 10% demand increase), imports increase strongly (elasticity of 0.66).

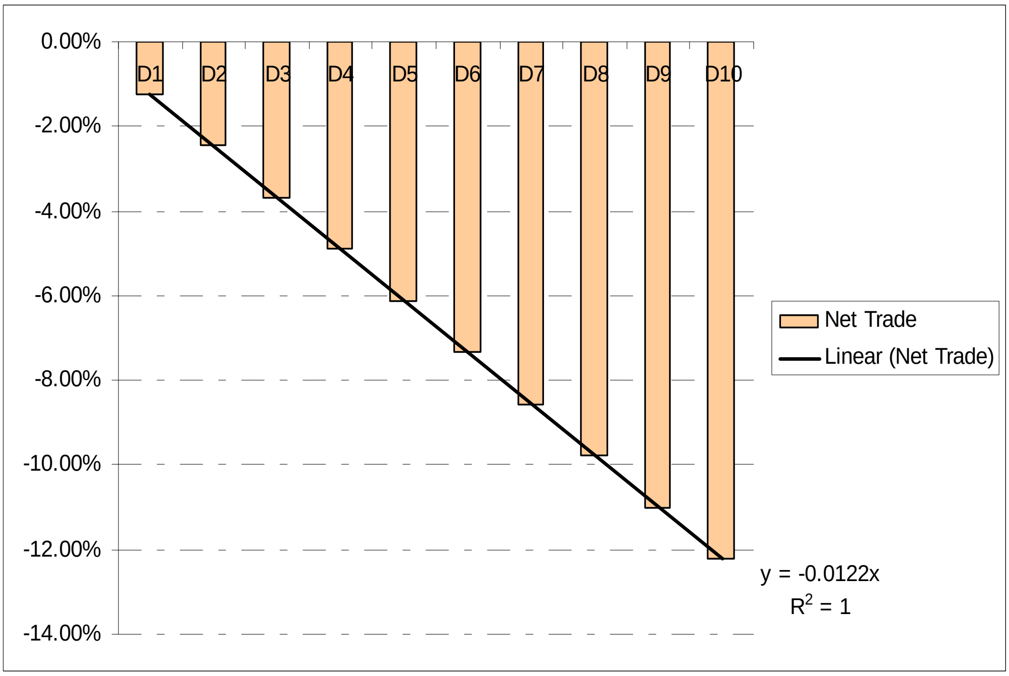
Figure 5.6. Marginal effects on EU vegetable oil trade flows due to incremental changes in biodiesel demand, 2020



Note: D1 to D10 correspond to increases in demand for biodiesel from 1% to 10%.

Figure 5.7 shows the marginal impact of increasing biodiesel demand on EU27's net trade position. A 1% increase in biodiesel demand increases net imports by 1.22%.

Figure 5.7. Marginal effects on EU27 net trade in vegetable oils due to incremental changes in biodiesel demand, 2020



Note: D1 to D10 correspond to increases in demand for biodiesel from 1% to 10%.

Effects on bilateral trade

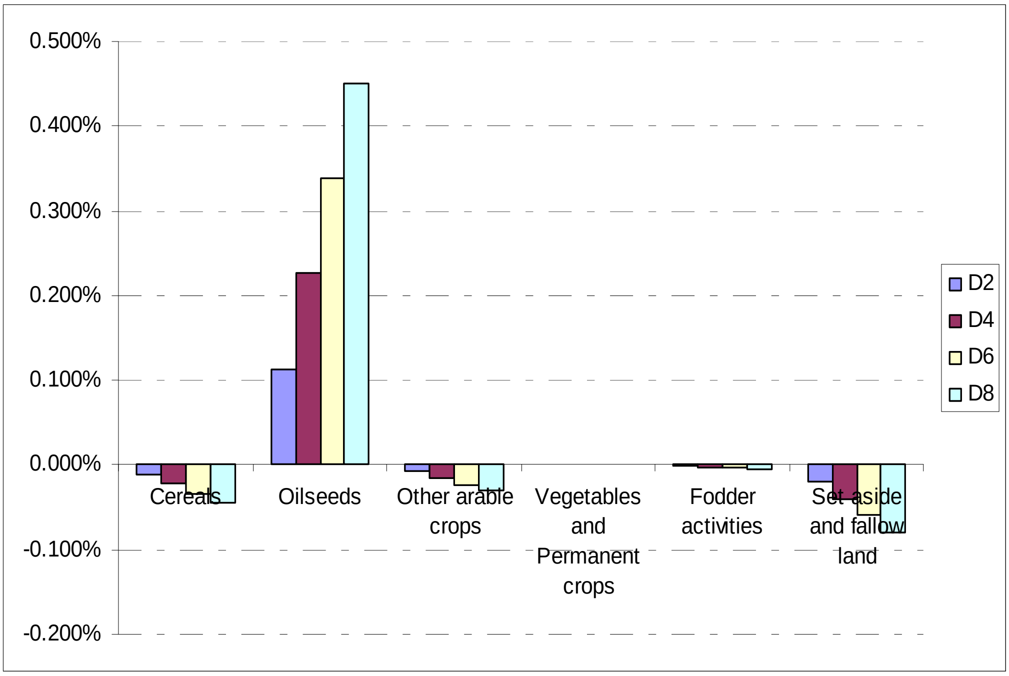
The main sources of imported rapeseed oil, in declining order of importance, are Norway, the USA, the rest of the Americas, the Western Balkans and Canada. The incremental effects of progressive demand increases for biodiesel (+2%, +4%, +6% and +8%) in EU 27 on these import flows are proportionate to the level of imports, such that the share of these source countries in total rapeseed oil imports remains more or less constant.

Effects on indirect land use change in the EU

Figure 5.8 shows the estimated land use changes from different-sized shocks to biodiesel demand in the EU. The effects are diverse: oilseed area increases because of increasing production of rapeseed, at a marginal rate of 0.056% per 1% increase in biodiesel demand. These marginal changes are accompanied by progressive falls in the area of cereals, other arable crops (such as potatoes and pulses) and fallow land.

Since the supply part of the model relies on quadratic functions, it is not surprising that the marginal effects described in this section follow a more or less linear trend. It is worth pointing out that, to the extent that non-linearity is observed for the land use changes, the incremental effects are slightly smaller at each progressive increase in demand.

Figure 5.8. Marginal effects on EU27 land use from increments in biodiesel demand EU27 (2020)

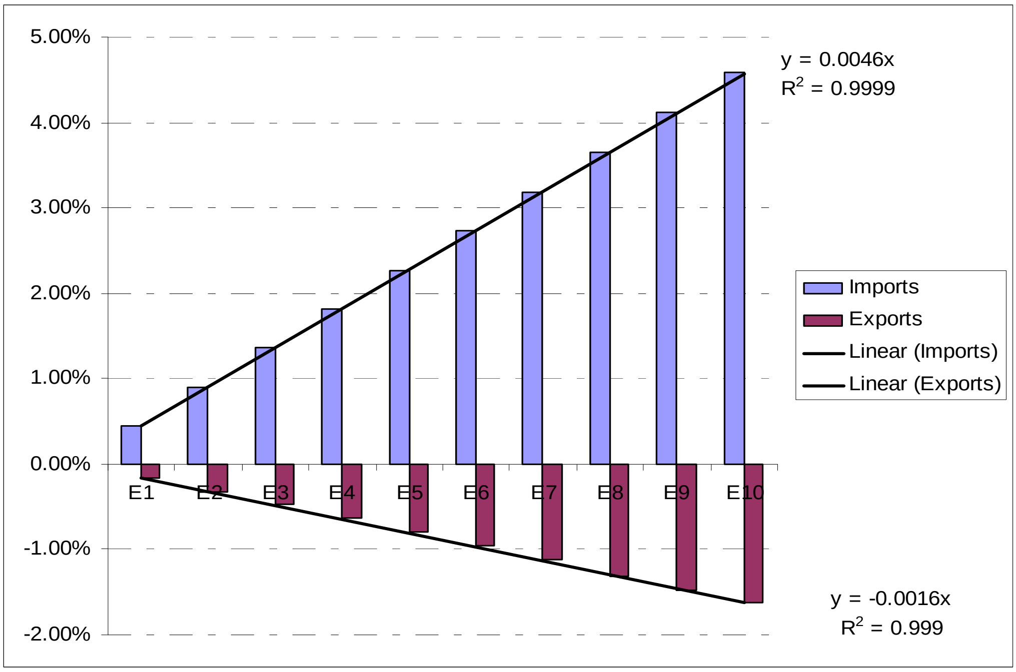


5.6.3. *Marginal effects of increased demand for cereals for ethanol*

Effects on trade balances

The story here is different from the biodiesel case, since cereals exports play an important role in the medium-term baseline. Europe would increase imports of cereals from the rest of the world in order to satisfy increasing demand for ethanol (marginal effect of 0.46%) and reduce its exports (marginal effect of -0.16%) (see Figure 5.9). Here too supply is quite inelastic, increasing by 0.02% for each demand increment of 1%. The resulting marginal changes in the net trade position of the EU27 for cereals are that net trade declines at the rate of -1.4% for each 1% increment in ethanol demand.

Figure 5.9. Marginal effects on cereals trade flows due to incremental changes in cereals demand, 2020



Note: E1 to E10 correspond to increases in demand for ethanol from 1% to 10%.

Effects on bilateral trade

Progressive increments in cereal demand for ethanol higher demand of ethanol do not produce any noteworthy changes in the composition by source of total EU cereals imports. The EU imports cereals from a large number of countries, and the simulation results show that the total incremental increase in imports is allocated more or less proportionally across all source countries. This has to do with the structure of the market model in CAPRI, which does not allow for expansion of zero import/export flows or big changes. Despite this, some non-linearity in cereal import increments can be observed. For shocks at higher demand levels, the marginal effects for Australia and New Zealand are slightly smaller, and slightly larger for USA, China, Canada, Turkey and Russia.

Effects on land use change

Table 5.7 shows the estimated land use change from different demand shocks on ethanol consumption in the EU. The main changes, corresponding to a 1% increase in cereals demand, can be summarised as:

- The 0.02% increase in cereal supply is broken down into a smaller proportional increase in cereals area (marginal rate varying between 0.007% and 0.009%) and some intensification of production (marginal yield increase of 0.006%).

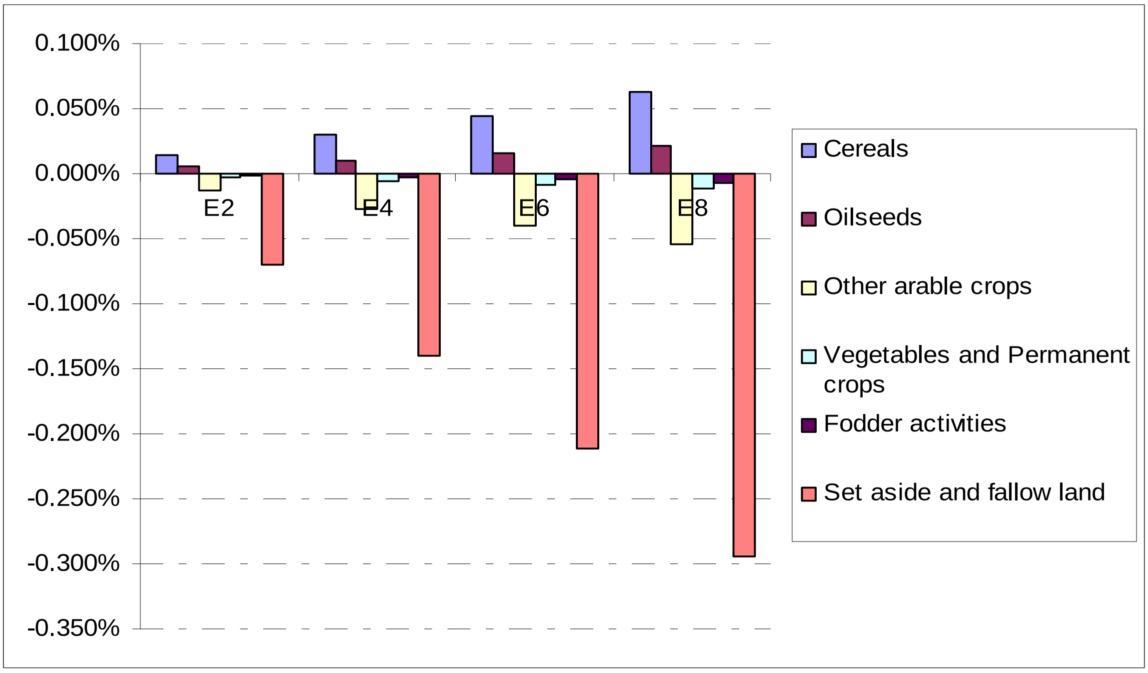
- The area of other arable crops (such as potatoes and pulses) and fallow land decreases.

Table 5.7. Effects (% changes) on EU27 land use from increases in cereal demand for ethanol, 2020

	E2	E4	E6	E8
Cereals	0.015	0.030	0.045	0.062
Oilseeds	0.005	0.011	0.016	0.021
Other arable crops	-0.013	-0.027	-0.040	-0.054
Vegetables	-0.003	-0.005	-0.008	-0.012
Fodder activities	-0.002	-0.003	-0.005	-0.007
Set aside and fallow land	-0.070	-0.141	-0.211	-0.294

Note: E2 to E8 correspond to increases in demand for ethanol from 2% to 8%.

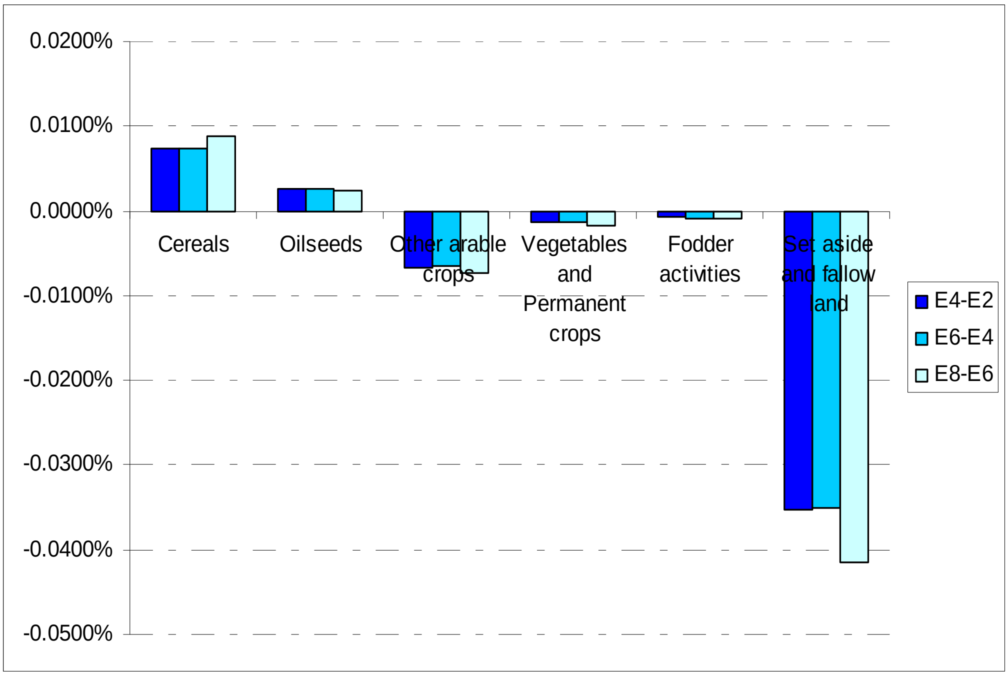
Figure 5.10. EU27 land use change from different marginal shocks on cereals demand (% changes)



E2 to E8 correspond to increases in demand for ethanol from 2% to 8%.

Figure 5.10 shows the marginal land use change different-sized demand shocks. There are some non-linearities, especially for cereals and fallow land area, where a 2% increase in demand has a larger incremental impact at higher levels of cereals demand, with a reciprocal non-linearity in oilseeds area.

Figure 5.11. Non-linearities in land use changes from a marginal shocks on ethanol at different commitment levels for the EU27 – in % changes



5.7. Conclusions

At EU level, the main impacts of EU biofuel policies are

- Impact on land use: Cereals and oilseeds areas are higher by 0.05% and 10.5%, respectively, at the expense of fodder activities and fallow land (0.2% and 5.6% lower, respectively).
- Impact on farming practices: Cereals and oilseeds yields are 1.4% and 1.6% higher, respectively, thanks to the use of higher-yielding varieties and intensification.
- Effects on production and market balances: Output of cereals and oilseeds higher by 1.4% and 12.3%, respectively, whereas demand for cereals and oilseeds is higher by 6.9% and 0.3%, respectively.
- Effects on prices and farm income: producer prices for cereals and oilseeds are higher by 10.2% and 19.5%, respectively, and farm income is 3.5% higher.

- Environmental effects: a general tendency towards greater intensification in arable cropping, and higher nitrogen surpluses.
- EU imports of vegetable oils increase and the EU's net export position in cereals declines.

Within the EU, there are marked differences in the distribution of crop outputs, with higher cereal production in southern and south-western Europe, and more oilseed production in north-eastern Europe.

The effects of marginal increases in demand for biodiesel and ethanol feedstocks are not negligible. However, the orders of magnitude here must be treated with caution, since this experiment reveals above all the pervasive linearity of the CAPRI model in percentage changes, due to its wide use of isoelastic functional forms. Similarly, the unchanging structure of import flows following these incremental demand increases is more revealing of the properties of the model than of likely real-world effects.

The simulation exercise shows significant impacts of EU biofuel policies on land use and agricultural markets. Results from this simulation exercise should, however, be taken as preliminary. Once the CAPRI baseline is fully synchronised with those of AGLINK and ESIM, and the endogenous biofuel module is operational, the CAPRI model will be able to provide further insights into the regional impacts of these policies.

6. Further considerations

The models used in this study have certain limitations that need to be borne in mind when interpreting the results. This section first discusses features common to all three models used, followed by some model-specific issues and a brief comparison of the three models.

6.1. Limitations of current models

6.1.1. Absence of energy markets

Because energy is not an agricultural product, partial equilibrium agricultural sector models do not model the supply and demand for energy, and thus treat energy market outcomes as exogenous. Energy demand and supply depend on the long-term evolution and short-run changes in various structural factors and macroeconomic variables, as well as cyclical factors. Crude oil prices are determined in the global energy market. Demand for transport fuel depends on the crude oil price, and other factors affecting businesses and households.

The biofuel market is currently too small to have much impact on crude oil price, which could therefore be treated as exogenous. However, if the average price of transport fuel rises because of the targeted share of (more costly) biofuel, this *will* reduce the total amount of transport fuel demanded. The extent of this effect is determined by the elasticity of demand for transport fuel and the price differential between the two fuels. Despite an exogenous oil price, this differential depends on the price of the biomass feedstock, which is determined endogenously in the agricultural sector. The consequence of these inter-linkages is that *biofuel consumption in quantity terms* is not fixed exogenously (even though it is expressed as a *fixed share* of the total transport fuel consumed), but instead depends on developments in the agricultural sector itself. Ideally, this requires linked simulation of the two markets.

Failure to account for this endogeneity means that the total biofuel satisfying the EU's targeted share may be overstated in our baseline simulation, and the simulated land use implications are larger than they would be.

Aside from the issue of endogeneity of transport fuel consumption, the markets for crude oil and biofuel feedstocks are likely to be related, either directly or because they are subject to common influences from other factors. Tyner and Taheripour (2008) showed that, although the correlation between the prices of energy and agricultural commodities has been historically low, the situation is rapidly changing. They analysed price relationships in the US under various biofuel policy options, showing that crude oil and maize prices move together.

Since ethanol is a near perfect substitute for petrol, higher petrol price increases demand for ethanol and induces investment in ethanol plants. More ethanol production boosts demand for corn, which, in turn, means higher corn prices. The reverse occurs when petrol price falls. It follows that, if the projections of energy demands generated by other models and used as exogenous input into partial equilibrium models are based on different macroeconomic assumptions from those used in the PE model simulations, inconsistencies can be introduced. Furthermore, there is no guarantee that the exogenous crude oil price assumed in the PE simulations is either compatible with the endogenous bio-feedstock prices generated by this model, or with the crude oil price that was simultaneously generated along with the projected fuel demand by the model from which this exogenous figure is taken.

6.1.2. Technological and productivity developments

The ease with which biofuel targets can be met and the cost of meeting them in the coming years depends on technological developments and productivity trends. The most important of these concern the development of second-generation biofuels, and productivity trends both in crop production and in the conversion of feedstocks to biofuel.

Supply and demand for second-generation biofuels are not included in most available models. A wide range of potential biomass feedstocks is still being evaluated. Moreover, the cost conditions for commercialised versions of these products are not known, nor the timing of their introduction. Nonetheless, it is possible that second-generation biofuels will be on the market within the next 10 years[46]. Their price and the timing of their market entry will depend partly on the prices of first-generation feedstocks and energy prices.

Msangi *et al*. (2007) performed simulations, using the IMPACT model, which show that if second-generation biofuels become available in 2015 and displace some consumption of first-generation fuel, the price increases for the major crops world wide due to biofuels policy would be 35-45% lower. These reductions are greater if, in addition, yield growth and other productivity improvements can be stimulated in the crop sector. Land use decisions are also affected by these lower prices. The alternative AGLINK-COSIMO scenarios with different rates of exogenous yield growth, which are reported in Chapter 3, give some idea of the sensitivity of the conclusions to yield-growth assumptions.

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[46] In this study, the AGLINK baseline assumes that second-generation biofuels enter the EU market in 2016, and increase to meet a separate 1.5% target share. This production is assumed absent in the 'no policy' AGLINK scenario. No second-generation biofuel is assumed for the ESIM baseline, since the ESIM simulations evaluate only the 7% target for first-generation biofuels by 2020.

It should be noted that the conversion coefficients used in AGLINK-COSIMO (see Table A3.1) for feedstock to biofuel and feedstock to by-product assume some technological progress in the efficiency of these processes. However, the rate of this progress is projected forward, based on past trends, and is subject to considerable uncertainty.

6.1.3. Changes in total agricultural land use

One can distinguish two categories of land use change that are triggered by biofuel policies: direct and indirect. A *direct land use change* occurs when a producer allocates more of his land to growing crops to be used as feedstock for biofuels, at the expense of the previous use of the reallocated land. Direct land use changes thus alter the supplies of other outputs, which may affect relative prices across a wide range of commodities, thereby causing a further round of land use changes, so-called *indirect land use changes*.

In the case of biofuel policies, an additional new demand on agricultural resources has been added to those already present, making agricultural resources in general scarcer in relation to demand. Thus, the associated indirect land use changes are not in response simply to changes in relative prices to meet a fixed aggregate demand. Rather, they are the combined effect of changed relative prices (in favour of energy crops) *and* an overall increase in the prices of agricultural (land-using) outputs generally stimulated by higher aggregate demand.

The general rise in commodity prices may have various effects on land use. First, it may slow down the rate of land abandonment in areas where this process is underway. Second, it may cause land remaining in agricultural use to be used more intensively (for example, by adopting higher-yielding varieties and techniques). A result of switching lower-grade land to more demanding land uses is that production becomes less sustainable in the longer term. Increases in intensity of land use are modelled to the extent that yields are allowed to be price-sensitive.

Third, there may also be land use changes at the so-called 'extensive margin'. Because of the extra pressure generated by higher prices on the total land area in commercial use, there are strong incentives for land that was previously not used for agriculture (commercial forest, rainforest, peat land, rangeland, savannah) to be cleared and switched to agricultural use. This very often involves reducing the carbon-storage role played by the land that is switched, resulting in a loss of sequestered carbon that will take many years to cancel out by the use of bioenergy. Moreover, this previously virgin land often performed other important ecological functions as well, such as providing unique habitat for wildlife and helping to regulate complex climate patterns.

In the studies by Hertel *et al*. (2008) and Taheripour *et al*. (2008) reviewed in Chapter 2, substitution between agricultural land and commercial forestry *is* allowed for, but not the clearing of virgin land for commercial use. Given the active debate surrounding this particular unintended consequence of biofuel policy, land use change is still a major shortcoming of the current generation of models.

The LEITAP model (Banse *et al*, 2008b), tries to solve the problem by incorporating land supply functions that are driven by land prices, whilst acknowledging that this solution presents calibration problems for countries where land price data are lacking. In their study, Banse *et al* (2008b) found that global agricultural area is 17-19% higher in 2020, relative to 2001, with the EU biofuels target and high oil prices[47], but that without the target and the higher oil price, the increase would still be about 16% due to demographic and macroeconomic changes alone. Nonetheless, in their conclusions, Banse *et al*. (2008b) stress the importance of land supply endogeneity, and relative degrees of land scarcity in different countries and regions, for their results.

6.1.4. Impact on agriculture's GHG emissions

Direct and indirect land use changes potentially alter the greenhouse gases emitted by agriculture, because of changes in the type of vegetation covering the land and/or changes in the degree of intensity of cultivation of an existing crop. Where land is switched from permanent pasture to arable use, net carbon emissions result. However, if the fall in pastureland is accompanied by a reduction in the ruminant population, emissions of methane will be lower. As mentioned already, switching land from dense non-commercial vegetation to cropping causes high carbon losses.

In a context where GHG emission targets are likely to become more binding, the impact of *any* policy change on a sector's GHG emissions is policy-relevant, particularly when the sector, like agriculture, is a major contributor to total GHG emissions. This is even more relevant for the analysis of biofuel policy, for which part of its rationale is to reduce GHG emissions caused by transport fuel use. CAPRI is the only one of the three models that currently calculates changes in GHG emissions for cropping activities.

6.1.5. *Other environmental effects*

A further category of unintended effects of biofuel policies includes other environmental effects. Just as for changes in GHG emissions, these other environmental effects also are the consequence of changes in land use and in the intensity of land use when these changes are due to policy-induced increases in feedstock production. They include higher rates of nitrate and phosphate leaching into surface and ground water, pesticide contamination, soil degradation, loss of biodiversity and deterioration of landscape amenity. Greater demands on water resources made by higher cropping intensity are of particular concern in some areas. To an extent, these effects could be inferred in general qualitative terms from changes in output and land use, where both are simulated. However, these inferences may be misleading unless the model contains biophysical constraints that control the consistency and feasibility of area and aggregate output changes. Accuracy in the simulation of some of these impacts becomes more feasible the more spatially disaggregated the sector model is. However, as models become more disaggregated, data availability and reliability may become a problem, results may become more difficult to interpret.

Environmental impacts are usually not modelled in simulation models constructed with the aim of analysing market, price and trade impacts of policies. In theory, linking such models to purpose-built environmental models looks like a promising approach. In practice, the challenges of achieving technical compatibility and full operational functioning when linking models can be daunting. This is because many of the unintended environmental changes due to changes in land use and intensity of land use are site-specific and crop-specific. It is quite difficult to include them in a market simulation model because of its higher level of spatial aggregation. However, for effects such as biodiversity loss and landscape deterioration, the phenomena are complex, data are unavailable for model construction and validation, target variables are difficult to measure and/or causal pathways are not well understood. Moreover, the construction of a reliable no-policy counterfactual against which to measure these effects is equally problematic. Therefore, the quantification of these potential environmental effects is likely to remain beyond the reach of sectoral simulation models indefinitely. They can only be analysed or predicted on a more piecemeal basis using smaller-scale studies where generality is lost but in exchange for empirical validity and scientific rigour.

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[47] A 10% biofuel share is imposed for 2020 and the crude oil price is assumed to be 70 % above that of the reference scenario.

6.2. Model-specific features

This section begins with a detailed discussion of some of the key features of AGLINK-COSIMO that should be borne in mind when interpreting the results, and then compares the three models used in the study in terms of these, and other, features.

6.2.1. AGLINK-COSIMO

Country representation and policy coverage

EU-27 is disaggregated into just two blocks (representing the old and the new Member States) and the biofuel market is modelled at the aggregate EU-27 level only. This means that differences in national biofuel policies have been "averaged" in order to apply at a more aggregate level. Since the incidence of production and consumption of biofuels varies considerably between EU member states (partly as a result of policy differences), the treatment of the EU as just two blocks introduces a degree of imprecision.

In addition, biofuel production is modelled in only a relatively small number of countries. Moreover, for a relatively new product like biofuels, there is insufficient historic information available to calibrate market behaviour accurately. Therefore, it is necessary to scrutinise closely the results and the driving assumptions.

Trade

Each country's trade is modelled as "net trade", calculated as the difference between national supply and demand. Although import and export flows are identified separately, one of the two is generally calculated residually. This means that any errors will be concentrated in this residual term, which could distort the trade situation reported. This approach to modelling trade also means that bilateral trade flows are not captured, making it impossible to identify which countries are the source of a particular country's imports or the destination for its exports. Thus, when AGLINK simulations show that EU imports of a given commodity increase whilst the exports of that commodity from a third country also increase, it cannot be inferred that the EU imports originate directly from that third country. All that can be inferred is that the participation of both the EU and the third country in the world market has increased.

By-products

AGLINK includes corn gluten feed, oil meals and DDG as variables. However, corn gluten feed is not a biofuel by-product: it is a by-product of the high fructose corn syrup industry, and does not depend on ethanol production. Therefore, we ignore it in this report. Oil meals are a by-product of oilseed crushing, and AGLINK does not disaggregate them according to whether or not the oil obtained is destined for biofuel. When comparing the with-policy and without-policy scenarios, it could be misleading to interpret the difference in oil meals produced solely in terms of a by-product of biofuels. If, due to relative price changes triggered by EU biofuel policy, more – or less – oilseeds are crushed for other purposes also, this will also contribute to changes in oil meal production.

Land use

Land use is not modelled for every country whose market is individually represented in AGLINK, including some countries whose land use may be more than marginally impacted by EU biofuel policies (such as Malaysia and Indonesia).

Agricultural land available is given exogenously in AGLINK. Area allocation to particular crops depends on crop returns. There is no mechanism that forces land reallocation to be pursued to the point where crop returns are equal at the margin. Therefore, considerable differences in crop profitability can exist in each period, which is completely realistic for an annual dynamic model. For EU-15, there is no substitution between cropland and pasture, whereas although in EU-12 cropped area is assumed to respond to returns to pasture, the coefficients are small. This means that the model allows very little substitution between these two major land uses. It can be argued that this may impose restrictions on the outcomes when rather large policy changes are being simulated, as is the case here.

Although the AGLINK simulations allow for commercially available second-generation biofuels at an arbitrarily chosen date near the end of the simulation period, they appear with their own 2020 target (1.5% of the transport fuel market) and are not allowed to substitute for first-generation fuels. At this stage, the information necessary to allow an accurate depiction of the supply conditions of these biofuels, and of their land use consequences, is unknown.

Since AGLINK-COSIMO does not consider multi-cropping, some other relevant crops (not modelled) may have seen their area decrease (which may compensate for the land expansion of the crops simulated in the model). Furthermore, production changes on the scale simulated may induce stronger technological progress and investment than assumed in the present structure of the model, which is normally used for more incremental policy changes. An idea of the relevance of the latter has been given in the sensitivity analysis involving yields.

6.2.2. Comparison of the three models

Table 6.1 compares the specification of the three models used in this study.

Table 6.1: Comparison of the three models used in this study

	AGLINK-COSIMO	**ESIM**	**CAPRI**
Basic specification			
Type/structure	PE, dynamic recursive	PE, comparative static	PE, comparative static
Countries/regions	52 countries or regions	MS of EU-27; HR, WB, TR, US modelled separately, RoW	MS of EU-27 + 33 non-EU countries/regions
Product coverage	39 individual primary and processed products	43 individual primary and processed products	47 individual primary and processed products
Level of EU disaggregation	EU-15 + EU 12 For biofuels: EU-27	Individual EU Member States	NUTS 2 regions
Trade flows	Net trade for each country	Net trade for each country	Bilateral trade between pairs of countries
Year of calibration	Up to 2008	2004-5 (average)	2001-03 (average)
Land use change modelled?	For selected countries only	At Member State level	At NUTS 2 level within EU; not modelled outside EU
Total agricultural area in each country	Given exogenously	Endogenous at country level, subject to an upper limit	Given exogenously
Features of specific interest for biofuel modelling			
Biofuel market specified	Yes	Yes	No
Level of relevant product disaggregation	Oilseeds not disaggregated	Three individual oilseeds	Two individual oilseeds
Biofuel by-products	DDG (corn gluten feed **not** treated as an ethanol by-product)	Gluten feed + 3 oil meals	Gluten feed + 2 oilcakes
Trade in biofuels?	Yes	Yes	No (in feedstocks, yes)
Technical change in biofuel production?	Yes, conversion coefficients evolve over time	Yes, efficiency trend with fixed conversion coefficients	No, fixed conversion coefficients
Relevant features of this application			
Baseline	From AGLINK-COSIMO (version 2009), extended to 2020 by IPTS, with updated macro-economic assumptions as of May 2009	From "Prospects for Agricultural Markets and Income in the EU 2008-15" (DG AGRI), with updated macro-economic assumptions of May 2009	Does not include reforms of dairy and sugar regimes, or Health Check reforms
Second-generation biofuels	Included from 2017, but no interaction with first-generation biofuel production or target	Not included	Not included
Aggregate EU demand for biofuels in 2020	Taken from PRIMES 2007	Taken from PRIMES 2007	Not relevant
EU production of biofuels in 2020	Endogenous (determined by the model)	Endogenous (determined by the model)	Taken from AGLINK results

The three models whose results are given in this report share some of the most important characteristics for analysing the policy question addressed, such as the inclusion of biofuel by-products and land use by particular crops. It is important to bear in mind when comparing the model results that, whilst the baselines used for ESIM and AGLINK incorporate the same assumptions[48], the CAPRI simulations use a different baseline that does not recognise the reform of the CAP dairy and sugar policy regimes, or the CAP Health Check reform of 2008[49]. Beyond this difference, each model has its own relative strengths and weaknesses in the context of this study.

The advantages of AGLINK-COSIMO are that it presents the most detailed picture of production in non-EU countries and of world trade, includes a rich representation of policy measures and uses a baseline agreed by OECD member countries. Its dynamic properties allow adjustment lags to be taken into account. Among its relative weaknesses are that EU-27 is disaggregated into just two blocks (representing the old and the new Member States) and that the biofuel market is modelled at the aggregate EU-27 level only. In addition, biofuel production is modelled in only a relatively small number of countries. Although AGLINK includes corn gluten feed and DDG as variables, corn gluten feed is not a biofuel by-product: in this model corn gluten feed is a by-product of the high fructose corn syrup industry, and does not depend on ethanol production.

The relative strengths of ESIM are that each EU Member State is separately modelled, EU policies are specified in depth, and total land use (up to an effective limit) is endogenised. It has a more detailed specification of the relevant energy crops and by-products, and can handle Member-State-specific biofuel policies. Its relative weaknesses are its comparative static nature, and its more condensed treatment of activity outside the EU.

CAPRI's most important relative strengths are, first, its lower level of spatial disaggregation (NUTS 2), which permits a far richer and more informative picture of land use changes and hence greater possibilities for drawing qualitative conclusions about the incidence of environmental effects within the EU, and second, its more detailed representation of agricultural production technologies and environmentally relevant activities. A weakness of CAPRI for this study is the absence of an explicit biofuel market (represented by supply and

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[48] Those of the 2008 OECD-FAO Outlook exercise, plus macroeconomic assumptions provided by DG AGRI to reflect information available up to June 2009.

[49] A different baseline incorporating recent policy developments was used for the simulations in Section 5.6.

demand equations), which makes it impossible to represent certain aspects of biofuel policy (notably tax exemptions). Instead, the quantities of each biofuel implied by the 2020 target (taken as those given by the AGLINK-COSIMO model) are translated into demands for agricultural feedstocks. The results with and without this extra commodity demand are then compared, and the differences are interpreted as the effects of the biofuel policies. No trade in biofuels is considered in this model.

Given these model differences, it is not surprising that the three models do not give identical results. However, if the differences between the models' specification are borne in mind when comparing their results, this can provide a deeper understanding of the underlying responsiveness of the agricultural market outcomes to the policies examined.

Moreover, the literature review confirms that no other model exists that simultaneously succeeds in overcoming all the particular relative weaknesses of the models used in this study. The comparative modelling exercise presented here assembles a composite picture of the impacts of EU biofuels policy that could not be achieved by relying on just one model. Divergences in the results may serve as a source of additional information.

7. Summary of results and conclusions

This report has presented an analysis of the impact of EU biofuel policies based on three different partial equilibrium agricultural sector models. The core of each model depicts a set of interlinked markets for a large set of agricultural commodities, including trade flows. Each model has been extended in order to depict the use of certain agricultural commodities as feedstock for biofuel production.

The models differ from each other in their degree of product and country disaggregation, and the detail with which they depict world market interactions and the activities of third countries. Moreover, different approaches have been taken in each model to incorporate biofuel supply and demand, biofuel policies and the by-products of biofuel production. In addition, the models differ in the extent to which they reflect the spatial distribution of their impacts on land use and third countries.

The impact of EU biofuel policy is simulated by each model according to the same procedure. In each case, two standardised scenarios are run over the period to 2020. The first, the 'baseline', assumes current EU biofuel policies remain in place; the second, the 'counterfactual', assumes the absence of all EU biofuel policies apart from trade measures. The consequences of EU biofuel policies are measured by comparing the baseline against the counterfactual[50].

The presentation of the results in each model chapter follows the same sequence. First, an overview is given of the economic impacts of the EU biofuel policies, as they relate to production, prices and trade flows. Particular attention is given to the two biofuel commodities (ethanol and biodiesel) and the agricultural commodities they use as feedstock. Modellers and policy makers are experienced in assessing this kind of model output in relation to real-world developments, and have well-formed prior expectations about what is plausible and acceptable in this context. Thus, this output performs an important role in allowing users to assess the overall credibility of the simulations, and acts as a quality control for the study. Furthermore, comparing this output, which is common to all three models, across the models allows the user to assess the degree of consensus reached by the three

[50] It is important to bear in mind that all results are given in the form of the impact due to the policies, relative to the hypothetical no-policy scenario, and *not* the impact that would occur, relative to the status quo, if biofuel policies were removed.

models, and contains information about whether and how their differences regarding general specification and treatment of the biofuel sector might have influenced the simulated effects.

Second, for each model, additional results that are more directly related to the specific research question are presented. Typically, these results are based on developments or features that are available in at most two, or only one, of the models, so that comparison of these results across the three models is not possible. Thus, for example, only AGLINK-COSIMO can provide details on production and land use effects outside the EU, and CAPRI is the only model that can simulate land use changes within the EU at NUTS 2 level.

The following concluding remarks consider what can be learnt from both of these sets of results, beginning with the core economic results on market outcomes.

Table 7.1 summarises the effects on some of the key market outcomes as simulated for 2020. Further details can be found in each of the individual model chapters. A number of conclusions can be drawn regarding the impacts of EU biofuel policies. First, domestic production of both biofuels is much higher in 2020 than it would be without the policies. Domestic production of the crops used as feedstock for biodiesel is also higher. The models are not unanimous regarding which cereals crop(s) will serve as the major source of EU-produced ethanol feedstock. AGLINK-COSIMO and ESIM both take the target biofuel share as given (by the Directive), as well as the total transport fuel volume (taken from PRIMES 2007). However, each model determines endogenously to what extent the overall volume target will be met by domestically produced or imported biofuel, and the shares of ethanol and biodiesel in total demand and production. According to AGLINK, the shares of ethanol and biodiesel in EU biofuel production will be about 43% and 57%, respectively, whereas ESIM indicates that that EU production will be divided more or less equally between the two fuels.

Second, regarding external trade, AGLINK-COSIMO indicates that the EU will have to import both biofuels in order to meet the 2020 target, whereas ESIM results suggest that the EU will import ethanol, but export biodiesel (although at a lower rate than under the counterfactual). It is not easy to gauge from these summary results to what extent the EU's energy independence is improved by its biofuel policies, particularly when reliance on imported feedstocks is taken into account. A more detailed focus on this issue, with these models, could provide more guidance. However, the models agree that the EU remains a net exporter of wheat, although wheat exports are lower with EU biofuel policies.

Table 7.1: Summary of impacts of biofuel policies across the three models, 2020

	AGLINK	ESIM	CAPRI
EU			
Production Fuels			
Ethanol	↑↑	↑↑↑↑	↑↑(by assumption)
Biodiesel	↑↑↑	↑	↑↑(by assumption)
Production Feedstocks			
Wheat	↑	↑	↑
Coarse grains/maize	↑(< 1 m t)	↑	↑ (small)
Oilseeds	↑	↑	↑↑
Production livestock products	negligible	↑ (small, pork and poultry only)	cattle numbers slightly ↓
Net trade Fuels			
Ethanol	imports ↑↑↑	imports ↑	
Biodiesel	imports ↑↑↑	exports ↓	
Net trade Feedstocks			
Wheat	exports ↓	exports ↓	imports ↑
Coarse grains/maize	from exporter to small importer	imports ↑	imports ↑
Oilseeds	imports ↓	imports ↑ (small)	imports ↓
Vegetable oils	imports ↑↑	imports ↑	imports ↑↑
Land use: EU	+ 1.44 mn ha (arable) - 1.13 mn ha (pasture)	+ 0.700 mn ha (agricultural area)	arable ↑ fallow ↓ [1] pasture ↓
World Market			
Prices Fuels			
Ethanol	↑ (small)	↑	
Biodiesel	↑↑	↑↑	
Prices Feedstocks			
Ethanol feedstocks	ca. zero	↑ (wheat),↑↑ (maize)	↑ (cereals)
Biodiesel feedstocks	ca. zero (oilseeds) ↑ (oils)	↑ ↑ ↑ (oils)	↑ (oilseeds) ↑ (oils)
Global land use (cereals, oilseeds, sugar)	+ 5.2 mn ha (+ 0.7%)		

1. Total agricultural area fixed by assumption

Third, there is close agreement regarding the order of magnitude of the impact of EU policies on EU agricultural area. AGLINK-COSIMO results allow the net difference to be separated into the effect on the relevant arable area and the effect on land used for pasture (temporary and permanent). In this context it is worth pointing out that, following the 2003 CAP reform, Member States must ensure that the share of permanent pasture in total area utilised for agriculture does not fall more than 10% below its national reference share in 2003. This share is, for the EU as a whole, about 26%, implying an average fall would be constrained to about

2.6 percentage points of this ratio, which translates roughly into a maximum reduction of about 4.8 million hectares of permanent pasture for the EU as a whole. Although the AGLINK-COSIMO results show that, with the biofuel policies, total pastureland is over 1 million hectares lower in 2020 than without the policies, the simulation also shows that land used for pasture with the policies in place is significantly above its 2008 level. This suggests that the policy constraint on pasture preservation is very unlikely to be breached. When interpreting these land use results, it is useful to recall the differences in the way total land supply and total land used for agriculture is treated in these models.

Fourth, both AGLINK-COSIMO and ESIM indicate upward effects on world market prices for both biofuels in 2020, relative to the no-policy scenario. However, the relative size of these effects differs between the two models, with AGLINK-COSIMO showing a larger impact on biodiesel price than on ethanol price, and the reverse for ESIM. This difference between the two models' simulated price differences is clearly not independent of the differences in the net trade flows reported for the two biofuels. Both models indicate minimum disruption to world market prices of agricultural commodities that are used as ethanol feedstocks, whilst showing that world market prices for biodiesel feedstocks are, by contrast, sensitive to the EU's biofuel policies. This is easily explained by the fact that ethanol production is a relatively small component of total demand for those commodities used as ethanol feedstocks and, moreover, that this study assesses the impact of EU biofuel policies alone, assuming that all other countries' biofuels policies remain in place[51]. Thus, in the absence of EU biofuel policies, the decrease in demand for these ethanol feedstocks would be relatively small in world market terms. On the other hand, demand for oilseeds and vegetable oils for biodiesel is, under the with-policy scenario, a much larger component of total world demand for biodiesel feedstocks, and hence the absence of EU biofuel policy has greater consequences for these prices. This suggests that any direct pressure on global food markets due to EU biofuel policies will concern vegetable oils rather than grains or sugar.

Fifth, not surprisingly, given the higher levels of world market prices for both ethanol and biodiesel due to the EU directive, production of these two fuels is higher elsewhere in the world. According to AGLINK-COSIMO, the US and Brazil produce 5% and 3.5% more ethanol, respectively. However, the reactions of these two major players are quite different

[51] This should be borne in mind when comparing the results with studies (e.g. OECD, 2008) that assume the removal of *all* biofuel policies globally.

regarding biodiesel production: US production is nearly 50% higher, whereas that of Brazil is lower by almost two-thirds.

Turning to the second (non-core) set of results produced by this exercise, we focus on land use changes, productivity and production intensity (yields), and the role of biofuel by-products, which are among the issues specific to biofuel policy that were itemised earlier in this report. Here, an attempt is made to draw together or highlight some results of this study relating to these three issues. It must be borne in mind that none of these issues can be analysed by all three models, and that where results are available from more than one model, the way in which the particular issue is treated and the amount of detail incorporated may vary greatly. Therefore, it is not attempted here to compare or seek consensus across models, but simply to summarise the main thrust of the results where they exist.

Within the EU, the CAPRI simulations show that there are significant implications for changes in cropping patterns at NUTS 2 level. In some parts of the Union, biofuel policies create incentives to replace oilseeds with cereals, or vice versa. In other areas, there appears to be an overall increase in land used for both types of crop, at the expense of other types of field crop (including fodder), fallow and/or pasture[52]. In particular, there is a shift of cereals away from Central and Central-Eastern Europe, towards the North-Eastern, North-Western and Southern periphery[53]. At the same time, oilseed production is much higher in Eastern, Northern and Central Western Europe[54]. Clearly, such large shifts have implications for resource use and the siting of downstream processing facilities. Outside the EU, the picture is somewhat incomplete as AGLINK-COSIMO cannot identify land use changes associated with all relevant feedstocks or all affected countries. Thus, the extra global net usage of land for arable crops of about 5.2 million hectares implied by Table 3.16 probably understates the true picture. For example, it does not include any land use implications of the large increases in vegetable oil production in Indonesia and Malaysia[55].

The question of whether, and if so how, second-generation biofuels might modify land use changes due to biofuel policies cannot be treated at present in our models. Whether, and how

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[52] Total agricultural land area is assumed fixed in CAPRI.
[53] In particular, cereals production increases by more than 3% in Scotland, Central Sweden, the Po Valley and South-eastern Italy, Western Greece, and Central and Southern Spain.
[54] Increases of more than 3% occur in Finland, Southern Sweden, the Baltic States, Scotland and Ireland, Poland, Romania and Bulgaria, Northern France, Southern Italy and around the Mediterranean coast of Spain.
[55] The current area of mature palm oil plantation in Malaysia and Indonesia amounts to about 9 million ha with immature plantations at about 2.5 million ha.

strongly, future commercially viable second-generation biofuel feedstocks would compete with agricultural commodities for agricultural land, or would use land currently not suitable for agriculture, or would come from non-land-using sources, is currently unknown. Although the AGLINK-COSIMO baseline simulation assumes the entry of second-generation biofuels onto the market in the later years of the simulation period, they appear with their own separate target of 1.5% of total transport fuel demand (hence the 7% target for first-generation biofuels remains unaffected) and the model does not allow them to compete with agricultural crops for land. Therefore, none of the effects simulated by AGLINK-COSIMO in relation to the EU's 7% blending target for 2020 is in any way affected by the inclusion of second generation fuels in the model. Hence, the consequences of second-generation biofuels, in general and for land use in particular, remain an open question, and further model development would be needed in order to run realistic hypothetical scenarios involving second-generation biofuels.

On the issue of yields, all three models include long-term yield trends together with some flexibility around these trends that depends on output price. The simulations show that the price increases for energy crops raise yields above what they would be without the policies. For example, CAPRI results show that, in 2020 EU producer prices are 10.2% and 19.6% higher, for cereals and oilseeds respectively, than they would be without EU biofuel policies, and the respective crop yields are 1.4% and 1.6% higher as a consequence.

In the comparisons between the baseline and the counterfactual, the same rate of autonomous yield growth has been maintained. However, if the prospect of long-term sustained higher prices for these crops induces the development of higher-yielding varieties or other types of productivity-enhancing investment, whether upstream or at farm level, this could have the effect of giving an upward tweak to exogenous yield trends that would be relevant in the case of the with-biofuel-policy scenario[56]. Furthermore, no assumptions about worsening productivity due to water scarcity or other climate change effects have been incorporated into either scenario for this exercise.

Regarding the land use implications of by-products, the models indicate that biofuel by-products do indeed have potential for reducing pressure on crop supplies from the higher demand for biofuel feedstocks. For example, AGLINK-COSIMO indicates that the EU feed sector's use of DDG is about 6 million tonnes higher in 2020 with the EU biofuel policies, which compensates for an equivalent amount of cereals diverted into biofuel production.

ESIM simulations suggest that although world market prices for oilseeds (especially rape and sunflower seed) are significantly higher due to EU biofuel policies in 2020, the fall in EU prices of the corresponding meals is far greater (in terms of euros per ton).

Table 7.2: Effect of EU biofuel policies on availability of by-products within the EU (% difference relative to the counterfactual)

	AGLINK	ESIM	CAPRI
EU Production			
Gluten feed	-	857	160
Oil meals/cake	-	12	28
DDG	211	-	-
Net trade			
Gluten feed	-	imports↑	-
Oil meals/cake		imports↑	exports↑
EU price			
Gluten feed	-	-84	-41
Oil meals/cake	-8	-38 (rape)	-31
DDG	-6	-	-

The main changes indicated in the availability (volume and price) of those by-products that are recognised by the three models are shown in Figure 6.2. Again, the differences between the models in their treatment of by-products should be recalled.

Finally, it is worth reiterating that, since none of the models whose results are reported in the study includes *all* the features that could be considered desirable for the particular research question, and each model has its own particular strengths and weaknesses, the results of the three models taken together give a composite, multi-layered picture, albeit one that requires sensitive interpretation.

[56] An additional scenario, assuming faster autonomous yield growth, is reported in Section 3.6.

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Abstract

The Renewable Energy Directive (2009/28/EC) requires that 20% of the EU's energy needs should come from renewable sources by 2020, and includes a target for the transport sector of 10% from biofuels. This report analyses and discusses the global impacts of this biofuel target on agricultural production, markets and land use, as simulated by three agricultural sector models, AGLINK-COSIMO, ESIM and CAPRI. The impacts identified include higher EU production of ethanol and biodiesel, and of the crops used to produce them, as well as more imports of both biofuels. Trade flows of biofuel feedstocks also change to reflect greater EU demand, including a significant increase in vegetable oil imports. However, as the extra demand is small in world market terms, the impact on world market prices is limited.
With the EU biofuel target, global use of land for crop cultivation is higher by 5.2 million hectares. About one quarter is area within the EU, some of which would otherwise have left agriculture.

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