FAPRI-UK Modelling of the UK Liquid Biofuels Sector

FAPRI-UK Project

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1. Introduction

The biofuels industry in the EU has expanded rapidly in recent years. The industry operates in a complex policy environment, with policies at the national and EU level impacting both production and consumption. The EU Biofuels Directive (2003), for example, encourages Member States to increase use of biofuels and other renewable fuels in transport to 5.75 per cent (calculated on the basis of energy content) by 2010. In response to the 2003 Biofuels Directive, the UK government introduced the Renewable Transport Fuel Obligation Order (RTFO Order, October 2007) which requires fossil fuel suppliers to increase the supply of biofuel to 5.25 per cent (calculated on the basis of volume) in the total road transport fuel they supplied by 2010.

Despite being viewed as a solution to the problems of climate change, energy security and as a new measure for rural development, some commentators have expressed concerns about the impact of increased biofuel production on global food prices (e.g. The World Bank report (Mitchell, 2008)) and the environment such as deforestation (e.g. The Gallagher Review (Renewable Fuels Agency, 2008)). In light of these growing concerns, the UK government has effectively slowed down the targets for increased biofuel supply; i.e., requiring fossil fuel suppliers to supply 5.25 per cent (volume basis) of biofuels in the total road transport fuel supply by 2013/14 rather than by 2010/11 (RTFO (Amendment) Order, April 2009). On the other hand, the EU has extended its commitment to biofuels use by requiring a minimum target of 10 per cent (energy content basis) renewable fuels in transport by 2020, conditional on the sustainability of the fuels (Renewable Energy Directive, 2009).

The expansion of biofuels production as a result of these policies will increase the impact of the biofuels sector on agricultural markets and this therefore necessitates its incorporation into agricultural market modelling frameworks. This paper describes the FAPRI-UK liquid biofuels model and its incorporation within the FAPRI-EU modelling system. Scenario results are presented on the likely impact of the increasing biofuels usage in road transport on the liquid biofuels and agricultural sectors in the UK.

The paper is organised as follows: in Section 2 the methodology underlying the analysis is discussed; this is followed by a description of the Baseline projections in Section 3; the details of the scenarios are discussed in Section 4; the impacts of the scenarios on the biofuels sector and agriculture sectors in the EU and UK are analysed in Section 5; and finally, some conclusions are drawn in Section 6.

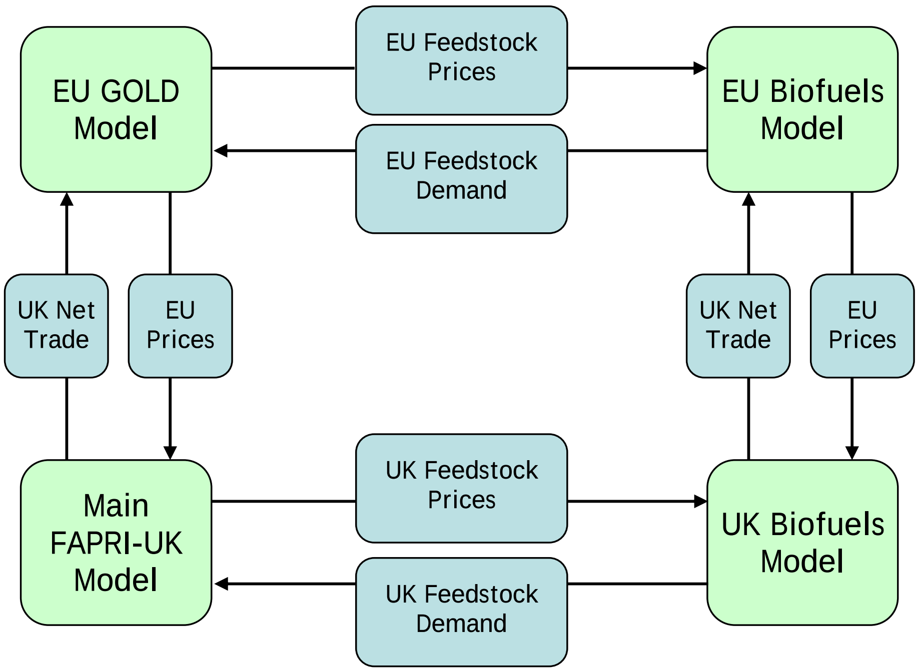
2. Methodology

The FAPRI-UK liquid biofuels model (i.e. biodiesel and bioethanol) is incorporated within the FAPRI-UK modelling system, as well as the EU liquid biofuels model which is in turn linked to the FAPRI-EU Grain, Oilseed, Livestock and Dairy (GOLD) model. As a consequence of these linkages, the liquid biofuels market and feedstock market for biofuels production in the UK are not determined in isolation but solve simultaneously with models representing the other EU countries' biofuels and feedstock markets.

Figure 1 illustrates the interactions between the UK biofuels sector model and the other models. The UK biofuel sub-model takes the feedstock prices used for biofuel production from the main FAPRI-UK model and the subsequent feedstock demands from the UK biofuels model are added to the main FAPRI-UK model, which in turn determines net trade and prices of agricultural products through linkages with the EU GOLD model. In addition, EU biofuel prices are solved at the EU level and determine the quantity of marketed biofuels and hence net trade of biofuels in the UK. Simultaneously, net trade of UK biofuels is added to the other EU countries' biofuels net trades in the EU biofuels model. Consequently, coupled with the interaction with EU GOLD model, aggregate EU level biofuel net trade solves for EU level biofuel prices by clearing the aggregate biofuel trades in the EU.

Interaction between the EU (Gold and biofuels model) and the rest of the world is captured by a reduced form rest of the world model. For the baseline, world prices are determined exogenously and come from the FAPRI global system. When the model is used to generate a policy scenario, reduced form equations that mimic behaviour of the global system (agricultural sector and biofuels sector model) are used to estimate the impact of changing EU biofuels trade on world prices.

Figure 1. Interaction between UK Biofuels Model and other Models



The current UK liquid biofuels model consists of domestic supply and demand for each type of the UK liquid biofuel (bioethanol and biodiesel) and feedstock demands for each domestic biofuel production. These are described in detail below. All parameters in the model are imposed except equations representing total UK fuel demand in road transport, UK petrol and diesel price and UK proportion of diesel and biodiesel in total road transport fuel due to data limitations. Actual model specifications including parameters and elasticities imposed in the equations are documented in Appendix 2.

i. Domestic Supply

Production of each type of liquid biofuel is estimated as the product of the industry capacity of biofuel plants and the capacity utilisation of these plants, reflecting long-run and short-run supply decision which in turn largely dependent on the net returns of the plants. In the case of biodiesel, the model obtains the net return of a representative biodiesel plant using the biodiesel price and the weighted vegetable oil prices based on the assumption that it is economically and technically feasible for a biodiesel plant to substitute feedstock (rape oil, soy oil, palm oil and oils from tallow and used cooking oils) in biodiesel production. In other words, the model operates as if there is only one large biodiesel plant that chooses various feedstocks based on prices and availability (Equation 1).

E1) Biodiesel net return (pound/litre) =
Biodiesel price + Glycerine price – Weighted vegetable oil price – Other biodiesel cost,

where glycerine price is included as a by-product of biodiesel production.

On the other hand, the model obtains total domestic bioethanol production by summing the wheat-based ethanol production and sugar beet-based ethanol production because, unlike biodiesel production, the model assumes that it is economically and/ or technically difficult (at least in the short and medium term) to convert a beet ethanol plant to a wheat ethanol plant and vice versa.

E2) Wheat-based bioethanol net return (pound/litre) =
Bioethanol price + Wheat DDGS price - Wheat price - Other ethanol cost,

where wheat DDGS price is included as a by-product of wheat-based bioethanol production.

E3) Beet-based bioethanol net return (pound/litre) =
Bioethanol price + Value of by-products of beet-based ethanol - Beet price – Other ethanol cost,

Co-products

A number of co-products are generated as part of the biofuels production process. In the process of biodiesel production, oilseed meals and glycerine are co-produced. Oilseed meals production is directly linked to the feed demand equations in the FAPRI-UK model. Increasing oilseed meal production as a by-product of increasing biodiesel production has important implications on the feed market and subsequently the livestock and dairy market. For example, in the baseline, UK rape meal production is projected to increase from 0.98 million tonnes in 2008 to 1.34 million tonnes in 2018 and subsequently rape meal domestic use is projected to increase from 1 million tonnes to 1.34 million tonnes over the same period. While oilseed meals are by-products of vegetable oil production, which is used both for human consumption and biodiesel production, glycerine is a co-product of biodiesel production in the transesterification process which converts vegetable oil or various fats into biodiesel. Glycerine is used for various purposes from food, industrial and pharmaceutical uses. However, unlike oilseed meals which have a knock-on impact on the agricultural market, glycerine has a limited, if any, knock-on impact and thus glycerine demand is not covered in the model.

Like biodiesel, co-products are also generated from bioethanol production for sugar-beet and wheat. For example, in the production process of beet-based bioethanol, pulp and lime are produced as a co-product. Although pulp is sold as animal feed and used as a substitute for UK feed wheat and lime is used as substitute for agricultural lime, the quantity of co-products from beet-based ethanol is quite small due to the limited beet-based ethanol production in the UK and thus demands for these co-products are not incorporated into the model.

Unlike co-products from beat-based bioethanol production, co-product of wheat-based bioethanol has important implications on the overall UK agricultural market due to the large scale of wheat-based bioethanol production. This can replace a considerable amount of cereal and soy meal in the feed concentrates. Dried distillers grains and solubles (DDGS) are co-produced with wheat-based ethanol and are used as animal feed, fuel or fertiliser. DDGS may be used to replace cereals and soy meal in the feed concentrates.

Within this study the quantities of DDGS used to replace specific feed in the concentrate and quantities of specific feed replaced by DDGS in the concentrate are obtained as follows.

Firstly, the model assumes that there is no trade of DDGS in the UK and the EU since internal EU data for DDGS is fragmented, so all DDGS produced in the UK and the EU is used domestically. Although DDGS trade is likely to be an important issue in the future[1], no trade assumption of DDGS in the UK and the EU is currently possible due to the complicated generically modified organism issues. Next, total DDGS production from UK wheat-based ethanol is used for animal feed replacing wheat, barley and soy meal in domestic feed use[2]. Thirdly, total DDGS is distributed to wheat, barley and soy meal feed use based on the share of each feed in the total feed use. Fourthly, the quantities of wheat, barley and soy meal replaced by DDGS is equal to the substitution ratio of cereal (soy meal) to DDGS[3] times DDGS used to replace wheat, barley and soy meal. Finally, wheat, barley and soy meal feed demand are reduced by the amount of DDGS replacement for each feed. As a consequence, the share of each feed to total feeds are changed simultaneously in the model.

DDGS production in the UK in 2018 is projected to increase to 1.3 million tonnes. In turn, 750, 340 and 210 thousand tonnes of DDGS are respectively projected to be used for wheat, barley and soy meal replacement in feed concentrates. Consequently, 290, 130 and 120 thousand tonnes of wheat, barley and soy meal are replaced by the DDGS, respectively in 2018. Two hundred and ninety and 130 thousand tonnes of wheat and barley replacement accounts for 4.5 per cent of wheat and barley feed use, while 120 thousand tonnes of soy meal replacement accounts for 6.8 per cent of soy meal feed use.

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[1] For example, the US Department for Agriculture has heightened the potential for US exports of DDGS to China.

[2] Although some proportion of DDGS would be used as fuel and/ or fertiliser at a discount rate.

[3] This study used exogenously determined substitution ratios (Warwick *et al.*, 2009). According to this report, wheat to wheat DDGS ratio is 0.386 and soy meal to wheat DDGS ratio is 0.594. We assume that the substitution ratio between barley and wheat DDGS is same as the ratio between wheat and wheat DDGS in this study.

ii. *Domestic Demand*

Retail consumer (vehicle owner) demand for biofuels at the pump is determined by the relative prices of each biofuel (bioethanol and biodiesel), taking into account energy contents of the corresponding fossil fuel and consumers' preferences toward biofuels. However, government policy on liquid biofuels in road transport use (i.e. RTFO order and biofuel tax incentive) focuses on the fuel suppliers rather than the final consumers. RTFO requires that biofuels comprise a certain percentage of total fuel (not per volume unit of fuel) supplied by obligated fossil fuel suppliers. Therefore, the demand component of the UK biofuels model is mainly determined by the obligated fuel suppliers' behaviour rather than consumers' choices.

The obligated fossil fuel supplier in the RTFO context is an agent who buys and/or imports biofuels from UK and/or foreign biofuels producers and supplies to the UK market (fuel retailers in UK). In some cases suppliers are also fuel retailers. They meet their share of biofuel supplies by redeeming Renewable Transport Fuel Certificates (RTFCs) to the Renewable Fuel Agency (RFA). RTFCs are issued by RFA for every litre of biofuel supplied to the market by obligated fossil fuel suppliers and voluntary biofuel producers who participate in the RTFO scheme. Obligated suppliers can also meet their obligation either by purchasing RTFCs from other suppliers or by paying the RTFO buy-out price for each obligated biofuel they should sell.

Biofuels Demand

Given this context, biofuels demand within the model is explained as a two-stage decision making process of obligated fossil fuel suppliers. Firstly, fossil fuel suppliers who are obligated to supply a certain percentage of biofuels from total fuel supply decide how much biofuels (i.e. the percentage of biofuels from total fuel supply) they will demand from biofuels producers and supply to the market. It is closely related to the decision as to whether they will meet the RTFO target. Clearly, obligated fossil fuel suppliers in aggregate have no incentive to meet the target if the profit from supplying fossil fuel instead of obligated biofuels is greater than the profit from supplying obligated biofuels instead of fossil fuel. Thus, the model estimates total biofuels demand by mandated RTFO target, fossil fuel price and biofuel price (Equation 4).

E4) Total biofuel demand (million litres) = f (mandated RTFO target, relative price of weighted biofuel price to weighted fossil fuel price).

Note that the buy-out price is not specifically incorporated into the biofuels demand equations. In theory, if the price difference between biofuel and fossil fuel taking into account fossil fuel tax, VAT and biofuel tax incentive is equal to or greater than the buy-out price, then obligatory fossil fuel suppliers have no incentive to meet the RTFO target. Otherwise, obligatory fossil fuel suppliers will at least demand the RTFO target. The question is then how much biofuels will be additionally demanded when obligatory fossil fuel suppliers, in aggregate, meet the RTFO target and how much biofuels will still be demanded when obligatory fossil fuel suppliers, in aggregate, have no incentive to meet the target. In addition, the different magnitude between bioethanol minus petrol price and biodiesel minus diesel price complicates matter further. Currently, the model assumes that obligatory fossil fuel suppliers, in aggregate, will meet the RTFO target over the projection years and additional demand is added as a function of relative price of weighted fossil fuel price to weighted biofuel price, where relative price of weighted fossil fuel price to weighted biofuel price =

> {Petrol price adjusted by tax * (Petrol consumption)/ (Petrol consumption + Diesel consumption) + Diesel price adjusted by tax * (Diesel consumption)/ (Petrol consumption + Diesel consumption)}/ {Ethanol price adjusted by tax * (Ethanol consumption)/ (Ethanol consumption + Biodiesel consumption) + Biodiesel price adjusted by tax * (Biodiesel consumption)/ (Ethanol consumption + Biodiesel consumption)}.

Next, fossil fuel suppliers decide the proportion of each biofuel (biodiesel and/ or bioethanol) from the total biofuels demand. In theory, the range could be zero to one. The model estimates the proportion of biodiesel as a function of relative price of ethanol to biodiesel, proportion of diesel and biodiesel in total road transport fuel use and proportion of ethanol production in total biofuel production (Equation 5). The first two variables have a positive effect on the dependent variable, while the last variable is designed to have a negative effect based on the assumption that fossil fuel suppliers are likely to favour domestic bioethanol when domestic bioethanol production is increased in the future.

> E5) Proportion of biodiesel in the total biofuel demand = f (relative price of bioethanol to biodiesel, proportion of diesel and biodiesel in total road transport fuel use, proportion of ethanol production in total biofuel production).

Biodiesel demand is determined by the total biofuel demand and the proportion of biodiesel in the total biofuel demand (Equation 6).

> E6) Biodiesel demand (million litres) = Total biofuel demand *Proportion of biodiesel in the total biofuel demand.

Bioethanol demand is total biofuel demand less biodiesel demand (Equation 7)[4].

> E7) Bioethanol demand (million litres) = Total biofuel demand – Biodiesel demand.

Each biofuel demand is converted to tonnes based on the corresponding density of fuel and then converted to tonnes of oil equivalent so that UK biofuels demand based on volume is incorporated into EU biofuel demand based on the energy content.

Total fuel demand by road transport

The UK government used both tax incentives and mandated incorporation rates to promote the use of biofuels in road transport. However, the 20 pence per litre fuel duty incentive for biofuel ended in April 2010 due to the concerns about indirect effects of biofuels and the focus shifted to the mandated biofuel use from April 2010 (Department for Transport, 2009). The combination of fuel duty incentive and

[4] Although categorising bioethanol demand as addictive, low-level blend and neat fuel as proposed by OECD (2008) would provide much enriched and accurate information, FAPRI-UK biofuels model did not divide bioethanol demand into three groups simply because there is no UK level bioethanol consumption data classifying total bioethanol consumption into sub-groups.

RTFO buy-out price until 2009/2010 was 35 pence per litre. From 2010/2011 fuel duty incentive ceased but the buy-out price has increased from 15 to 30 pence per litre (Department for Transport, 2009). As a result, it is necessary to project total fuel demand for road transport in order to properly project biofuels demand. The model derives total fuel use as a function of weighted fuel (petrol, diesel, bioethanol and biodiesel) prices and a real GDP (Equation 8).

E8) Total fuel demand for road transport (million litres) = f (weighted fuel prices, real GDP).

The model projects petrol and diesel prices as a function of oil price and a GDP deflator. Endogenised petrol and diesel prices provide a link between oil prices and the biofuel market and in turn the agricultural market (Equations 9 and 10).

E9) Petrol price (pound/ 1000 litres) = f (refiners' crude oil acquisition price, GDP deflator).

E10) Diesel price (pound/ 1000 litres) = f (refiners' crude oil acquisition price, GDP deflator).

In addition, the model projects petrol and diesel demand from total fuel use:

E11) Proportion of diesel and biodiesel in the total fuel demand = f (relative price of diesel to petrol, trend).

E12) Diesel and biodiesel demand (million litres) = Total fuel demand in the road transport * Proportion of diesel and biodiesel in the total fuel demand.

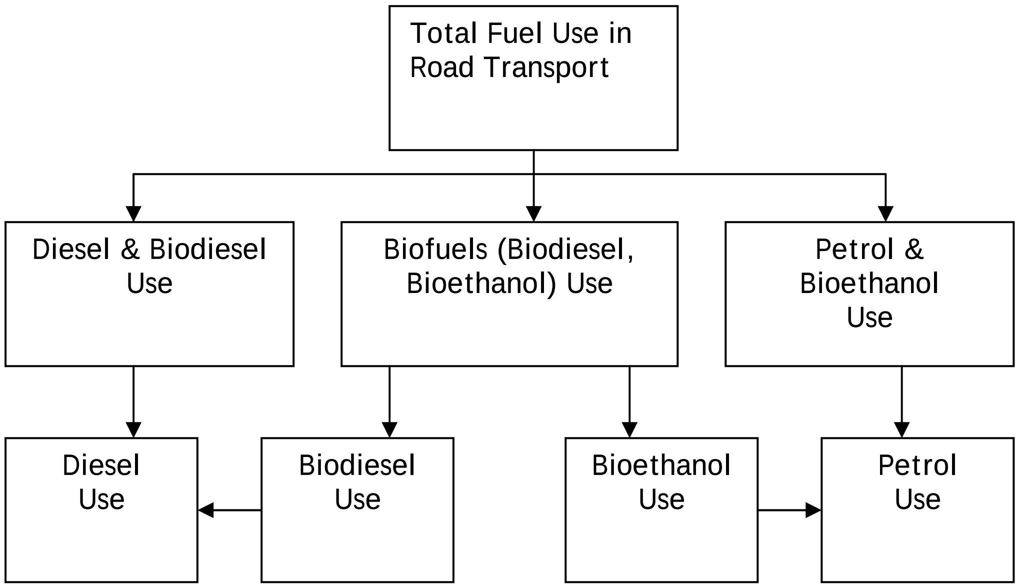
E13) Petrol and bioethanol demand (million litres) = Total fuel demand in the road transport - Diesel and biodiesel demand.

E14) Diesel Demand (million litres) = Diesel and biodiesel demand- Biodiesel Demand.

E15) Petrol Demand (million litres) = Petrol and bioethanol demand – Bioethanol demand.

Projected diesel and petrol demand in litres are converted to tonnes and tonnes of oil equivalent so that total fuel demand is expressed in terms of energy content and in turn incorporated within the EU biofuel model. Figure 2 describes the demand side of the UK liquid biofuels model building process.

Figure 2. Demand Component within the UK Liquid Biofuels Model



iii. Feedstock Demand [5]

UK biodiesel production is made from soy oil, rape oil and other oil (palm oil, tallow, used cooking oil and unknown). Soy and other oil share in biodiesel production is projected as a function of relative prices of soy oil and palm oil[6], respectively, while rape oil share is treated as a residual between soy plus other oil share and total oil share which is equal to one.

E16) Soy oil share (ratio) = f (relative soy oil price),

Where relative soy oil price = soy oil price / (rape oil price * rape oil share + palm oil price * other oil share).

E17) Other oil share (ratio) = f (relative palm oil price),

Where relative palm oil price = palm oil price / (soy oil price * soy oil share + rape oil price * rape oil share).

E18) Rape oil share (ratio) = 1 – Soy oil share – Other oil share.

[5] The Renewable Fuel Agency (RFA) reports accumulated monthly total biofuel quantities released for domestic consumption in each month of each RTFO year (e.g. RFA Monthly Report 20: 15 April 2009 - 14 December 2009). This domestic biofuel consumption is, in turn, categorised by country of origin (e.g. UK, US etc) and feedstock (e.g. soy, rape oil etc). However, the RTFO figures do not specifically state whether imports are finished product (biodiesel), intermediate product (soy oil) or raw materials (soy). Thus, it is not possible to identify by this data alone how much feedstocks are used for domestic biofuel production, especially biodiesel production. This study obtained oilseed and other oil share in domestic biodiesel production using RTFO figures, other information and informed assumptions.

[6] Other oil share is projected as a function of relative price of palm oil since there is no price data for tallow and used cooking oil.

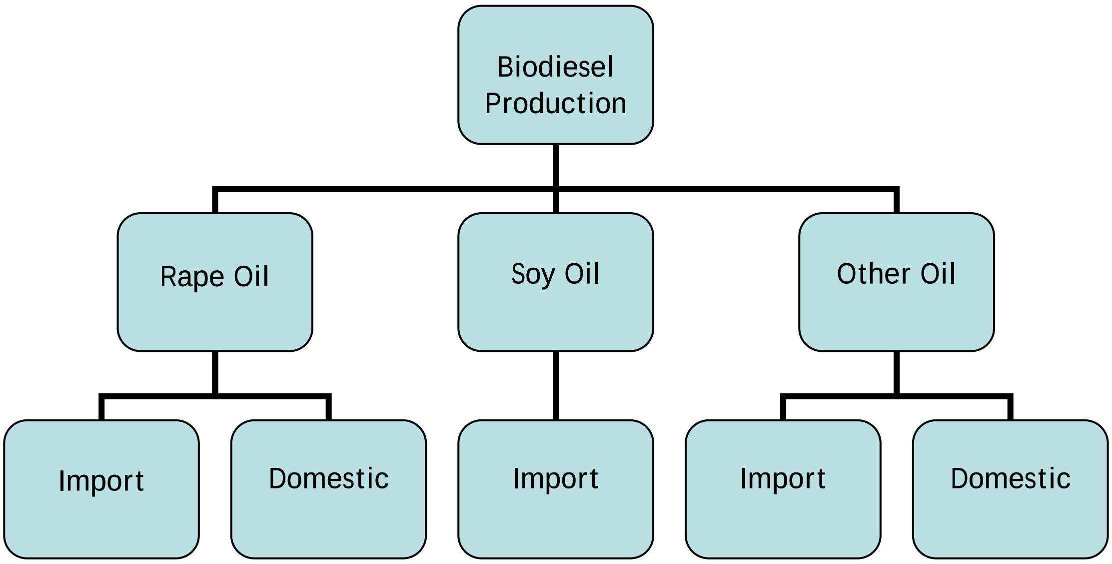
In the above equations, each oil share is determined simultaneously since relative price is a function of oil share and share is determined by relative price.

Subsequently, each oil used for biodiesel production (i.e. feedstock demand for biodiesel production) is obtained by the product of each oil share and total oil used for biodiesel. Total oil used for biodiesel is obtained from the total biodiesel production by applying unit conversion rate oil to biodiesel. This study also obtains domestic rape oil share based on the relative world to EU biodiesel price and exchange rate of pound to euro (Equation 19). The former is chosen to reflect rape oil biodiesel import from non-EU countries while the latter variable accounts for rape oil biodiesel import within the EU. Both variables have positive effect on dependent variable in that relatively higher world biodiesel price to EU biodiesel price reduces imports from non-EU countries and appreciated euro raise competitiveness of domestic rape oil compared to rape oil from other EU. The magnitude of each coefficient is assigned to reflect that about 80 percent of rape oil biodiesel imports come from EU.

E19) Share of domestic rape oil in total rape oil used for biodiesel production = f(world biodiesel price/ EU biodiesel price, exchange rate of pound to euro)

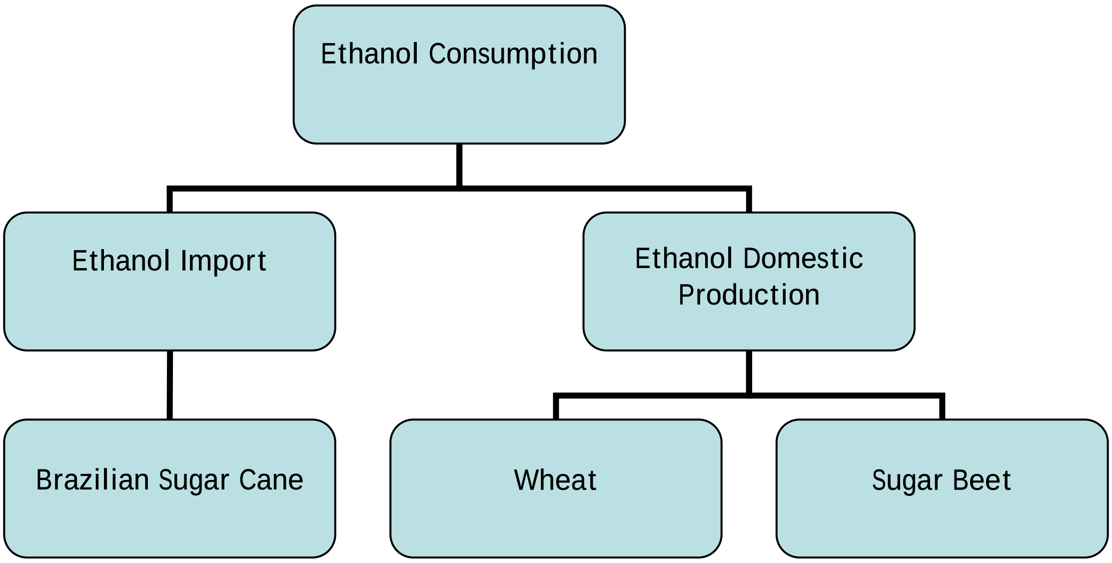
Based on this share equation, this study enables to estimate domestic rape oil use and domestic rapeseed production used to produce domestic biodiesel and in turn domestic rapeseed area harvested for domestic biodiesel production. Figure 3 summarises the feedstock demands for biodiesel production in the model.

Figure 3. Feedstock Demand for Biodiesel Production.



These feedstock demands for biodiesel production are directly and indirectly linked to the equations of area, yield, production, import, total domestic use and non-feed use in the oilseeds component and are also linked to the crush demand, meal production, oil production, oil imports and oil domestic supply. Wheat and sugar beet demand for bioethanol production follow a similar approach as that applied to biodiesel production. However, this is relatively simple compared to the oilseed equations. Figure 4 shows the modelling process for feedstock demand for bioethanol production.

Figure 4. Feedstock Demand for Bioethanol Production



3. Baseline Projections

The modelling system is first simulated to yield Baseline projections for a ten year period. The Baseline projections are used as a basis for comparison for the policy scenarios that vary the biofuels usage in road transport, in order to isolate the impact of the policy changes. While the Baseline projections are carefully reviewed to assess their robustness, they should not be interpreted as forecasts and used on a free standing basis. The Baseline projections are based on the continuation of existing policies (including trade rules for EU biofuels and other commodity markets), normal weather conditions and specific macro-economic and other exogenous assumptions. The world prices employed within the Baseline are based on projections from the Global FAPRI model generated for the World Outlook (FAPRI-Iowa State, 2010). Consequently, the Baseline projections within the EU modelling system, including the UK model, reflect biofuel policies outside the EU, including the US, Canada and Brazil.

EU projections

Within the Baseline, it is projected that the EU obtains less than the 10 per cent (on the basis of energy content) 2020 road transport target from first generation biofuels. By the end of the projection period (i.e. 2018), it is projected for the EU as a whole that first generation biofuels account for 5.7 per cent of total transport fuel use by energy content, while Capros *el al.* (European Commission 2008) projected the biofuels share in total transport fuel as 7.4 per cent in EU-27 in 2020. This shortfall partly reflects the fact that, under the EU renewable fuel target, it is not intended that first generation biofuels comprise all of the 10 per cent. Potentially second generation biofuels will contribute to the target as well as electric vehicles, but the technology for these products and therefore their future competitiveness is uncertain. The projected shortfall also reflects concerns within the Global Baseline that attempting to meet the EU targets would drive up vegetable oil prices.

In terms of the specific biofuel commodities, it is projected that EU biodiesel consumption increases from 8.4 million tonnes in 2008 to 15.2 million tonnes in 2018. Projected EU biodiesel production increases from 6.6 million tonnes to 13.6 million tonnes during the same period. Biodiesel capacity is projected to climb to around 30 million tonnes, which means that capacity utilization is 45 per cent. It is projected that the difference between EU biodiesel consumption and production (which is essentially imports) remains relatively constant (1.7 million tonnes in 2008 to 1.6 million tonnes in 2018)[7]. The majority of EU biodiesel is projected to come from rapeseed oil predominantly from the import and crush of rapeseed.

On the other hand, projected EU bioethanol consumption increases from 2.8 million tonnes in 2008 to 7.5 million tonnes in 2018. EU bioethanol production increases from 2.4 million tonnes to 7.2 million tonnes during the same period. In the ethanol industry, capacity utilisation rates have been higher at an EU level in recent years. Capacity is projected to increase to 9.3 million tonnes, with utilization rates of close to 80 percent. The difference between EU bioethanol consumption and production is projected to decline over the projection period (342 thousand tonnes in 2008 to 251 thousand tonnes in 2018).

UK projections

Total fuel use for road transport in the UK in 2008 amounted to 37.5 million tonnes of oil equivalent, which is about 12 per cent of total EU fuel use for road transport. The UK contributed 10 per cent of total EU biofuel use in the road transport in 2008. This contribution is projected to remain constant during the projection period. While the UK accounts for considerable amounts in both total fuel and biofuel use in the EU, the proportion of biofuel production in the EU is relatively small. This accounted for approximately 5 per cent of total EU biofuel production in 2008. This proportion is projected to increase to 9 per cent due to the large planned investment in wheat-based ethanol production in the UK over the projection period.

Within the Baseline it is projected that biofuels account for 6 per cent of the total road transport of fuel on the basis of volume in terms of litres (6.4 per cent in terms of tonnes; 5 per cent on the basis of energy content) by the end of projection period[8]. Thus, the UK fulfils the amended RTFO 2013/14 target, but does not exceed this target by a significant margin during the rest of the projection period.

This translates to an increase in projected UK biodiesel consumption from 905 thousand tonnes in 2008 to 1.24 million tonnes in 2018. Projected UK biodiesel production increases from 424 thousand tonnes to 755 thousand tonnes during the same period. The projected increase in production is based on the biodiesel capacity increasing from 731 thousand tonnes to 1.17 million tonnes, which implies that capacity utilization increases from 58 per cent to about 65 per cent during the

[7] Note net trade is difficult to determine as regulations regarding trade are complicated by technical specifications and complex trade barriers.
[8] While Capros *el al.* (European Commission 2008) projected that the biofuels share (on the basis of energy content) in total transport fuel equals 6.8 per cent in UK in 2020.

same period. About half of biodiesel production is projected to be sourced from rape oil and most of the rape oil for biodiesel production is dependent on foreign grown rapeseed. It is projected only 14 per cent of total rape oil used for UK biodiesel production is sourced from domestic rapeseed. The difference between UK biodiesel consumption and production is projected to remain constant (481 thousand tonnes in 2008 to 492 thousand tonnes in 2018).

On the other hand, projected UK bioethanol consumption increases from 174 thousand tonnes in 2008 to 1.24 million tonnes in 2018. Projected UK bioethanol production increases from 29 thousand tonnes to 1.18 million tonnes during the same period. This significant bioethanol production increase is based on the planned investment of wheat ethanol in the UK. Almost all bioethanol in the UK is projected to come from wheat-based ethanol (i.e. 97 per cent in the total production in 2018). This study projects 1.57 million tonnes bioethanol production capacity with 75 per cent utilisation in 2018. This leads to a slight decrease in the difference between UK bioethanol consumption and production (145 thousand tonnes in 2008 to 61 thousand tonnes in 2018).

As shown in above discussion, there are distinctive differences in biofuel consumption and production patterns between the overall EU and the UK. In the overall EU, the majority of biofuel consumption and production is sourced from biodiesel, while in the UK half of biofuel consumption is sourced from bioethanol and about 60 per cent domestic biofuel production is dependent on bioethanol rather than biodiesel. More specifically, in the EU the proportion of biodiesel in the total biofuel consumption and production is respectively 67 and 65 per cent at the end of projection period, while in the UK they are 50 and 39 per cent, respectively. Furthermore, the proportion of biodiesel consumption in the UK in terms of litres rather than tonnes is projected to be only 47 per cent in 2018.

These differences are due to a significant increase in projected wheat-based ethanol production in the UK compared to the other EU Member States. The wheat-ethanol production in the UK is lower than the planned wheat-based ethanol plants capacity. For example, according to Clarke *et al.* (October, 2008), proposed wheat-based bioethanol production capacity in the UK at September 2008 was already 1.83 million tonnes while this study projects only 1.57 million tonnes at 2018. However, many of the proposed investments have not yet materialised due to the current economic difficulties. The projection figures are thus based on the assumption that many of planned wheat-based ethanol plants will eventually materialise over the projection period but not all the proposed capacity will be realised.

The other important difference between the EU and the UK is the import dependency on biodiesel consumption. In the EU the self-sufficiency of biodiesel consumption is about 90 per cent, while in the UK it is about 60 per cent in 2018. This implies that in the simulations the percentage increase in biodiesel production is likely to be greater in the UK than in the overall EU, in response to the increase in biodiesel consumption.

Finally, in the EU it is projected that there is a large divergence between biodiesel industry capacity compared to projected biodiesel consumption in the Baseline. In contrast, in the UK, projected biodiesel capacity and biodiesel consumption are similar. This implies that in the simulations, increased production in the other EU Member States is likely sourced from increased utilisation with a relatively constant capacity level, while in the UK the increased production is likely sourced from a significant increase in industry capacity coupled with a relatively small increase in the utilisation rate.

4. Scenarios[9]

The following scenarios are simulated within the modelling framework:

1 Increase only UK biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018;
2 Increase biofuel consumption for other EU Member States (i.e. all Member States except the UK) to 10 per cent of total transport fuel use in energy content until 2018; and
3 Increase UK and EU biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.

Note under Scenario 1 biofuel consumption in the other EU Member States is not fixed but adjusts to the policy changes in the UK in response to price movements. Similarly, under Scenario 2 biofuel consumption in the UK responds to price movements resulting from the change in policy in the other Member States. The scenarios should not be interpreted as determining the impact of the EU's 10 per cent target since the Commission expects a contribution from other sources of renewable energy[10]. Rather the scenarios quantify the impact of different levels of production of first generation fuel. In other words, the scenario is not "what would happen if the EU's 10 percent target is imposed" rather "what would happen if the EU's 10 percent target was met solely by first generation fuels."

5. Results[11]

The results for each of the scenarios are discussed below and should be read in conjunction with the summary tables at the EU-27 level and the UK level provided in the Appendix 1. Due to the complexity of the models, the simulations generate a wealth of information. The key results of interest within the biofuels sector are projected consumption, prices, production and the difference between consumption and production for both biodiesel and bioethanol. Within the agricultural sector the main interest is in how increased biodiesel and bioethanol production affects the rape oil, rape meal, grain and livestock markets.

Scenario 1: *UK only increases the share of biofuel in total transport fuel use to 10 per cent (energy content) until 2018*

Biofuels Sector

The modelling system is simulated to increase UK biofuel consumption by a constant rate to reach 10 per cent of total transport fuel use at the end of the projection period (2018) under Scenario 1. This translates to an increase in the

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[9] Scenarios do not represent any policy proposals, they proposed only to test the model.

[10] Incorporating other sources of renewable energy into the model is beyond the limit of this study.

[11] The current report only presents UK results because there is no country level (England, Wales, Scotland and Northern Ireland) data for the biofuels sector. Hence, the biofuels model is not disaggregated by country.

proportion of biofuels in total transport fuel use from 6.4 per cent (5 per cent in energy) to 12.6 per cent (10 per cent in energy) in 2018 which is equal to a 98 per cent increase (100 per cent increase in energy content), as shown in Table 2, under Scenario 1 compared to the Baseline in 2018.

While the change in UK biofuels consumption is simulated exogenously in Scenario 1, the proportion of biodiesel in the total UK biofuels is determined endogenously by the model. The 98 per cent increase in UK biofuels share leads to a 3 per cent increase in UK biodiesel share in total UK biofuel consumption (increase from 0.47 to 0.49). As noted in Section 2, biodiesel consumption share is positively related to the relative price of ethanol to biodiesel and the proportion of diesel and biodiesel in total road transport fuel use, but is negatively related to the share of ethanol production in total biofuel production in the model. Under this scenario, the first two variables remain reasonably constant (0.1 per cent and 0 per cent increase, respectively), while the share of ethanol production in total biofuel production falls from 0.61 to 0.52 (a 14 per cent decrease). The capacity and utilisation of the biodiesel industry and hence the production level of biodiesel in UK in 2018 is much smaller than bioethanol (the import dependency of biodiesel consumption is much larger than bioethanol consumption in the baseline) so there is a greater potential for expansion in biodiesel than bioethanol. As a result, other things being equal, in meeting 10 per cent target obligated fossil fuel suppliers in the UK are likely to increase the biodiesel share.

The increase in both biofuel and biodiesel shares leads to higher UK biodiesel and bioethanol consumption, amounting to 104 per cent and 92 per cent, respectively. Subsequently, these increases result in a 9 per cent increase in EU biodiesel consumption and 15 per cent increase in EU bioethanol consumption in 2018 under Scenario 1 compared to the Baseline (Table 1). Although the biodiesel consumption increase is relatively greater than bioethanol consumption increase in the UK, the biodiesel consumption increase is relatively smaller than that of bioethanol in the overall EU. This discrepancy between the UK and the overall EU is expected since biodiesel consumption is much larger than bioethanol consumption in the overall EU Baseline.

EU biodiesel and bioethanol prices both rise by 4 per cent compared to the Baseline in response to the increases in consumption (Table 1). These price increases exert an upward impact on net returns for UK biofuels plants. The increases in net return for each type of UK biofuel are higher than the biofuel price increases since the biofuel price increases are higher than the input cost (i.e. vegetable oil and wheat price) increases[12].

Consequently, the projected increase in net return for the biofuel plants raises both the capacity and utilisation of plant and in turn production. UK biodiesel production increases from 755 thousand tonnes to 1844 thousand tonnes in 2018; i.e. an increase of 144 per cent compared to Baseline (Figure 5 and Table 2).

While UK bioethanol production increases from 1182 thousand tonnes to 2013 thousand tonnes in 2018; i.e. an increase of 70 per cent compared to the Baseline (Figure 6 and Table 2). These significant increases in UK biofuel production under Scenario 1 are only partially explained by the relatively small increases in biofuel

[12] Price changes in the crop sector are shown in Tables 3 and 4.

prices[13] and net returns for the biofuel plants. It is assumed that domestic biofuel producers increase their capacity in line with UK government's policy change.

Figure 5: Projected UK Biodiesel Production under the Baseline and Scenarios 1 to 3

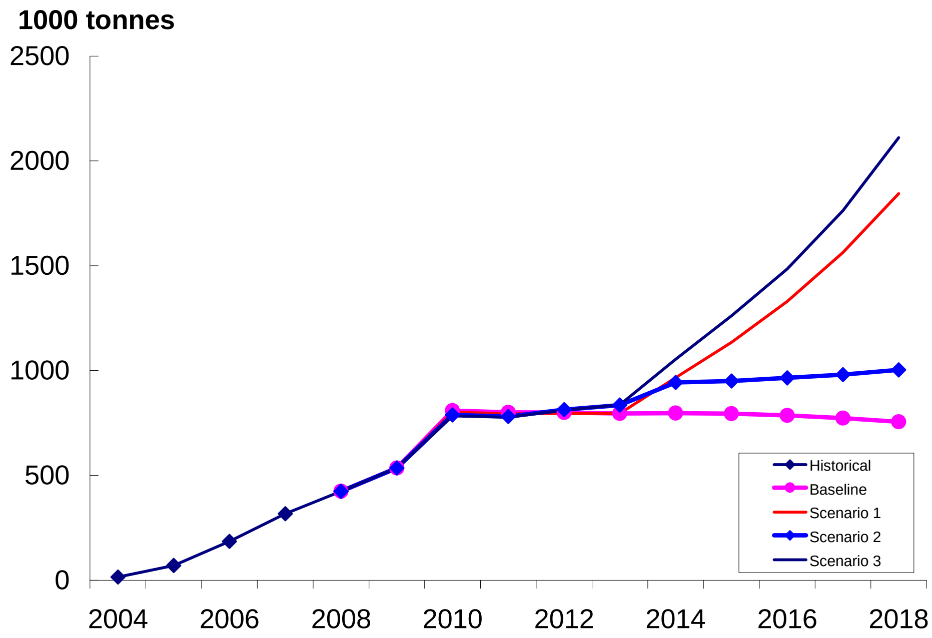
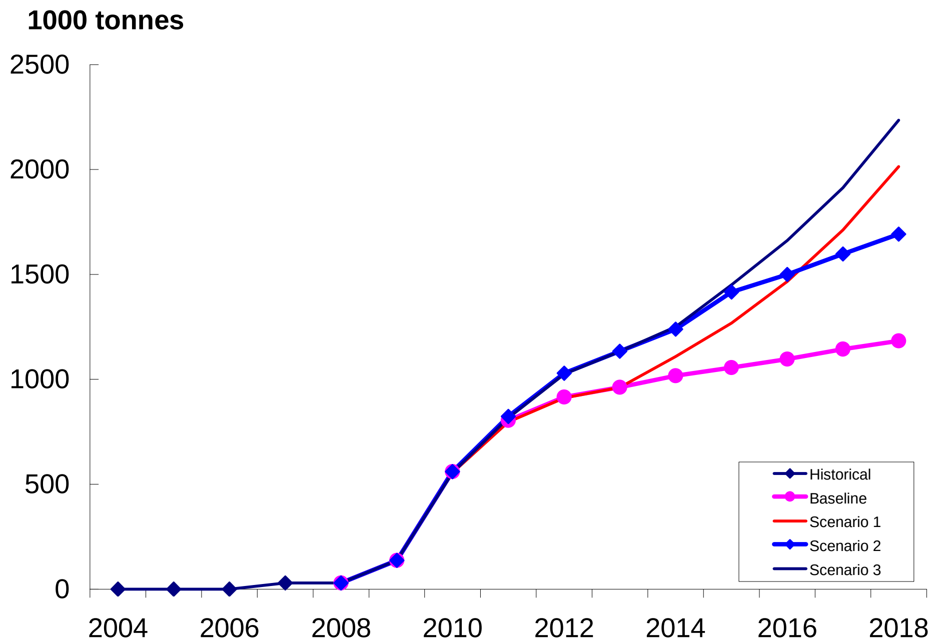


Figure 6: Projected UK Bioethanol Production under the Baseline and Scenarios 1 to 3



13 Biofuel prices in the model are determined at the EU level and thus a 100 per cent increase in the UK biofuel share in total UK fuel use has a small impact on EU biofuel prices.

Although UK biofuel production increases in response to the higher biofuel prices, it does not fulfil the entire increase in biofuel demand and thus it is projected that imports increase. The projected difference in UK biodiesel consumption and production increases by 43 per cent (from 492 to 706 thousand tonnes), while the difference between UK bioethanol consumption and production increases by 510 per cent (from 61 to 377 thousand tonnes) under Scenario 1 compared to the Baseline in 2018 (Table 2).

At the EU level, it is projected that the policy change in the UK triggers a modest increase in other EU Member States biofuel production due to the slight increase in EU biofuel prices. Projected EU biodiesel production increases from 13600 to 14853 thousand tonnes (9 per cent) (Figure 7 and Table 1), while EU bioethanol production increases from 7257 to 8276 thousand tonnes (14 per cent) compared to the Baseline in 2018 (Figure 8 and Table 1). The EU Biofuel price increases also lead to higher biofuel imports compared to the Baseline. It is projected that the difference between EU biodiesel consumption and production increases by 5 per cent (1.67 to 1.76 million tonnes), while the difference between EU bioethanol consumption and production increases by 37 per cent (0.25 to 0.35 million tonnes).

Figure 7: Projected EU Biodiesel Production under the Baseline and Scenarios 1 to 3

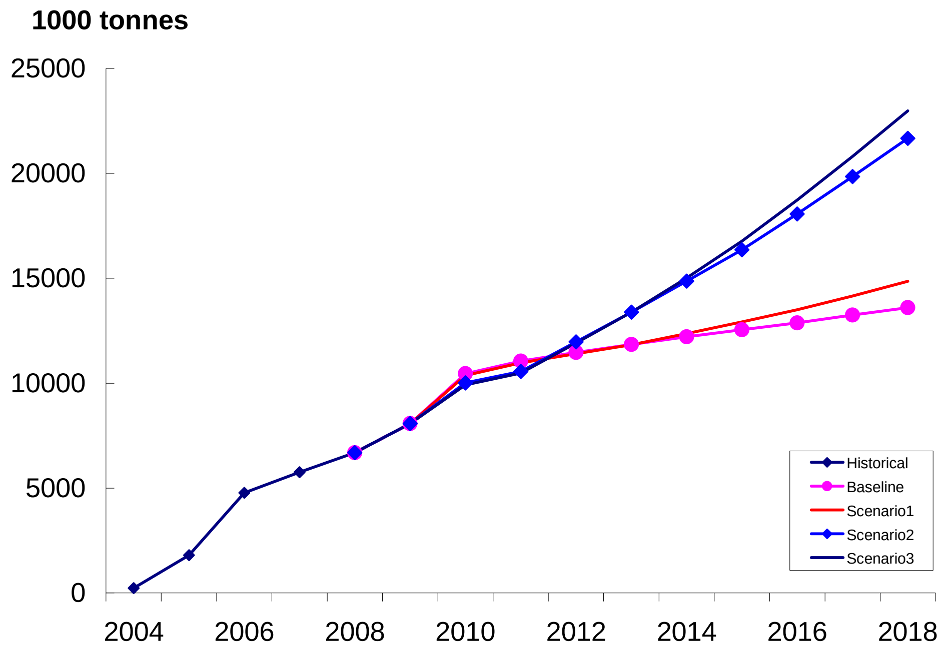
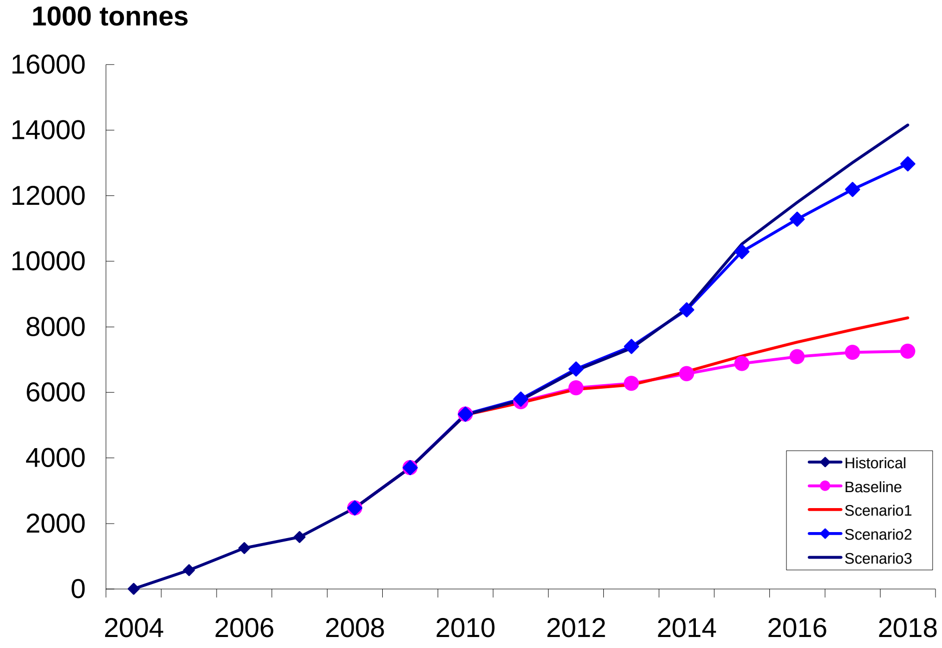


Figure 8: Projected EU Bioethanol Production under the Baseline and Scenarios 1 to 3



Agricultural Sector

The projected increase in biodiesel production leads to increased demand for rape oil. In the UK projected rape oil demand increases by 61 per cent under Scenario 1 compared to the Baseline in 2018 (Table 4), which results in an increase in EU rape oil domestic use of 6 per cent (Table 3). As a consequence, the projected EU rape oil price increases 4 per cent under Scenario 1 compared to the Baseline. Projected UK rape oil production increases by 21 per cent in response to the projected price increase. As a consequence of the changes in demand and supply UK net trade (exports minus imports) decreases by 224 per cent.

Increasing rape oil production also raises rape meal production (21 per cent in the UK and 3 per cent in the EU). Within the modelling system, the projected increase in rape meal production is used internally. Increasing domestic rape meal use, thus, decreases domestic soy meal use in both the UK and the EU (Tables 3 and 4). Projected soy meal use also declines in response to the projected increase in DDGS use within feed concentrates arising from increased bioethanol production (see below).

The projected increase in rape oil production impacts rapeseed domestic use, production and net trade. As shown in Table 4, the increased production of rape oil in the UK is mostly sourced from changes in net trade of rapeseed rather than production of rapeseed. Rapeseed production increases by 2 per cent, while net trade of rapeseed decreases by 164 per cent under Scenario 1 compared to the Baseline in 2018. These changes in the UK impact the EU market for rapeseed, resulting in a 6 per cent increase in price (Table 3).

While biodiesel production mainly affects the markets for vegetable oil and oilseeds, bioethanol production predominantly affects the grain market, especially wheat. As shown in Table 4, a 70 per cent increase in bioethanol production in the

UK leads to a 14 per cent increase in wheat use in the UK under Scenario 1 compared to the Baseline in 2018. This translates to a slight increase in domestic use of wheat in the EU (i.e. 1 per cent), as shown in Table 3. The projected increase in wheat-based bioethanol production requires extra wheat demand and hence exerts an upward impact on the price of wheat. However, it also increases DDGS (a by-product of bioethanol production) replacement of feed wheat, which exerts a downward impact on domestic wheat use and hence the price of wheat. Overall, the projected wheat price increases by 2 per cent. The projected price increase in turn decreases wheat feed use in the UK and EU by 5 and 1 per cent, respectively.

Within the modelling system the relationship between grain production and price is relatively inelastic within both the UK and the EU, but the world grain market is relatively elastic. In general there are good reasons to assume that the world grain market is more elastic than the EU. The EU tends to already have pretty high yields and there is limited potential to exploit additional land, although it is very uncertain how the new member states such as Romania and Hungary where there may be more potential for additional land and investment will react. Consequently, increases in EU grain demand due to the extra EU ethanol production are mostly obtained from changes in net trade rather than EU domestic production increases. Thus, as shown in Tables 3 and 4, projected wheat area and production in both the UK and the EU remain constant, while projected net trade changes substantially (100 per cent decrease in the UK and 15 per cent decrease in the EU). The barley sector in both the UK and the EU is relatively unaffected by the policy change.

The small projected impact of meeting the 10 per cent biofuel share in total fuel use in the UK alone on grain and oilseed meal prices has a marginal knock-on impact on the livestock sectors (Tables 5 and 6). As a consequence, it is projected that the change in UK agricultural market receipts under Scenario 1 compared to the Baseline is insignificant (Table 7)

<u>Scenario 2</u>: *All Member States (except the UK) increase the share of biofuel in total transport fuel use to 10 per cent (energy content) until 2018*

Biofuels Sector

The modelling system is simulated to increase biofuel consumption in all Member States (except the UK) by a constant rate to reach 10 per cent of total transport fuel use at the end of the projection period (2018). This is equal to an increase of 75 per cent in the proportion of biofuels in total transport fuel use (from 5.7 per cent to 10 per cent) in the overall EU (except the UK)[14].

The 75 per cent increase in the proportion of biofuels in total transport fuel use in the EU-26 increases overall EU biodiesel and bioethanol consumption to 60 per cent (from 15272 to 24417 thousand tonnes) and 84 per cent (from 7508 to 13776 thousand tonnes), respectively, in 2018 under Scenario 2 compared to the Baseline (Table 1). Subsequently, EU biodiesel and bioethanol prices respectively increase by 32 per cent and 27 per cent compared to Baseline in response to the increases

[14] It is difficult to project the proportion of biodiesel (bioethanol) consumption in the total biofuels consumption in meeting the 10 per cent target at each member state level due to differences in policies and market situations. Unlike the UK model, it is assumed that both biodiesel and ethanol shares are equal to 10 per cent to respective fossil fuel (i.e. diesel and petrol). This means that EU biodiesel consumption is about double that of ethanol under Scenario 2.

in consumptions (Table 1). These significant biofuel price increases discourage obligatory fossil fuel suppliers in the UK to supply biofuel to the UK market (1 per cent decrease in biofuel consumption in the UK)[15] and marginally reduces total UK tansport fuel use (0.2 per cent reduction). As a result, the proportion of biofuels in total fuel use in the UK decreases by 1 per cent under Scenario 2 compared to the Baseline in 2018 (Table 2). The proportion of biodiesel also decreases by 1 per cent compared to the Baseline (Table 2) due to the slight decrease in the relative price of ethanol to biodiesel (3 per cent decrease) and slight increase in the proportion of bioethanol production in total biofuel production (3 per cent increase). Reductions in both the proportion of biofuels (1 per cent) and the proportion of biodiesel (1 per cent) leads to a decrease of 2 per cent in UK biodiesel consumption and 0.4 per cent decrease in bioethanol consumption compared to the Baseline (Table 2).

While the price rises have a downward impact on UK biofuels consumption, it increases production levels in both the EU and UK[16]. As shown in Table 1 and Figures 7 and 8, overall EU biodiesel production increases from 13600 to 21674 thousand tonnes (60 percent increase), while EU bioethanol production increases from 7257 to 12972 thousand tonnes (79 per cent increase) compared to the Baseline in 2018. UK biodiesel and bioethanol production also increases by 33 per cent (from 755 to 1003 thousand tonnes) and 43 per cent (from 1182 to 1691 thousand tonnes), respectively, compared to the Baseline in 2018 (Table 2 and Figures 5 and 6).

Although the projected biodiesel price increase is slightly bigger than that of bioethanol, it is projected that bioethanol production in the UK increases by a greater amount than biodiesel. This reflects the relatively large decrease in biodiesel consumption compared to that of bioethanol in the UK, which means that the increase in biodiesel production capacity is relatively smaller than that of bioethanol (15 per cent and 28 per cent, respectively) and subsequently production levels.

At the overall EU level, the projected increase in production is insufficient to meet the 10 percent target and imports of biodiesel and bioethanol increase. As a result, it is projected that the difference between EU biodiesel consumption and production increases by 64 per cent, while the difference between EU bioethanol consumption and production increases by 222 per cent compared to the Baseline in 2018 (Table 1).

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[15] It is important to note that under Scenario 2, obligatory fossil fuel suppliers in the UK are not required to supply biofuels beyond the RTFO target level (i.e. 5.25 per cent by volume) and hence their decision to supply biofuels beyond the RTFO target are only subject to relative price of weighted biofuels price to weighted fossil fuel price in the model, unlike Scenario 1 where UK biofuels consumption level is determined exogenously.

[16] In the EU, the supply side of biodiesel is complicated by the fact that (in the baseline and in reality) large excess capacity of biodiesel has already been constructed in anticipation of aggressive biodiesel targets. In this case the model is adjusted so that capacity does not increase by much more than the baseline as shown in Table 1 (i.e. 1 per cent increase). For the overall EU biodiesel industry, the excess capacity that is present in the baseline means that the increase in demand for biodiesel from reaching the 10 percent target is met mostly from an increase in the utilization rate (i.e. 58 per cent increase) as shown in Table 1.

Agricultural Sector

The significant increase in projected EU biodiesel production (59 per cent under Scenario 2 compared to the Baseline in 2018) has a marked impact on the rape oil market. At the EU-level, it is projected that rape oil domestic use and production increases by 37 (13.5 to 18.5 million tonnes) and 18 per cent (12 to 14.1 million tonnes) respectively, while rape oil net trade (exports minus imports) decreases by 187 per cent (-1.6 to -4.5 million tonnes). The projected EU rape oil price increases by 26 per cent under Scenario 2 compared to the Baseline (In contrast, the projected EU rape oil price increased by just 6 per cent under the previous scenario.).

The projected expansion in rape oil production leads to large increases in the production and use of EU rape meal (19 per cent). In response it is projected that EU soy meal use declines by 17 per cent since it is assumed that all the rapeseed meal is consumed internally. The projected expansion in rape oil production also increases EU rapeseed crushing use and hence overall rapeseed domestic use (18 per cent). This, in turn, exerts a significant upward impact on the EU rapeseed price. In addition, increased rapeseed prices are not diminished much by the significant increase in rapeseed production due to the increase in cereal prices (see below), which increases the competition for land. Overall, the projected EU rapeseed price increases by 38 per cent under Scenario 2 compared to the Baseline (Table 3). It is projected that rapeseed area in the EU grows by around 11 per cent, mostly at the expense of barley. Yields of crops decline slightly (1 per cent) as the upward impact of price on yield is offset by land expansion, which has a negative impact as more marginal land is brought into production. Consequently, projected EU rapeseed production increases by 10 per cent. Despite this large increase, more rapeseed must be imported and projected net trade of EU rapeseed decreases by 52 per cent.

As in the rest of the EU, it is projected that the prices for rape oil and rapeseed in the UK increase by 26 and 38 per cent respectively. The projected increase in prices exert a positive impact on rape oil production (4 per cent increase) and rapeseed production (11 percent increase) (Table 4). Although it is projected that UK rape meal use increases (4 per cent), projected UK soy meal use also increases slightly (2 per cent) due to the relatively large price decline in soy meal (9 per cent) (Tables 3 and 4).

Within the EU as a whole, bioethanol production from grain is mainly sourced from maize, barley and wheat. The projected increase in bioethanol production of 79 per cent under Scenario 2 leads to increases in EU domestic use of wheat (6 per cent), barley (1 per cent) and maize (4 per cent). Projected EU grain prices rise in response to the increase in demand (wheat increases by 12 per cent, barley by 7 per cent and maize by 15 per cent). While the increases in grain prices are significant, they are lower than that for rapeseed due to the large increase in biodiesel demand in the EU. The projected increase in grain prices reduces the feed use for wheat and maize.[17]

The projected increase in grain use for bioethanol production comes mostly through reduced exports of wheat and barley and increase in imports of maize. In contrast, projected production levels remain relatively constant. It is projected

[17] Feed use for barley remains constant due to the relatively small increase in price and DDGS replacement.

that EU net trade (exports minus imports) of wheat, barley and maize decrease by 81, 49 and 50 per cent, respectively. Projected wheat and maize areas rise slightly as a result of relative price changes, with a switch from barley to maize and wheat.

In the UK, projected wheat domestic use increases by 7 per cent in response to the 43 per cent increase in bioethanol production under Scenario 2. This relatively large increase in wheat demand reflects the high proportion of wheat used in bioethanol production in the UK. Similar to the EU as a whole, the increase in demand in the UK is mostly sourced from changes in trade rather than production.

The shifts in land use within the EU and UK are small (Tables 3 and 4). This is partly due to the fact that the elasticities with regard to overall crop area are small. This is supported by the experience of the last couple of years, where much larger swings in prices have not led to huge swings in total cropped land in the EU or the UK. Also, since all of the modelled crops prices are rising, substitution effects are small.

Despite the increase in grain prices, projected animal numbers in both the EU as a whole and the UK remain relatively constant under Scenario 2 compared to the Baseline (Tables 5 and 6). The limited impact of the grain price rises on the livestock sector reflects the increase of rape meal use and DDGS use and the decrease of grain feed use. Finally, total UK agricultural market receipts increase by 5 per cent largely due to the increase in grain prices (Table 7).

Scenario 3*:* Both UK and other EU Member States (i.e. EU-26) increase biofuel consumption to 10 per cent of total transport fuel use in energy content by 2018

Biofuels Sector

Under Scenario 3, both the UK model and the models for the other Member States are simultaneously simulated to increase biofuel consumption by a constant rate to reach 10 per cent of total transport fuel use at the end of the projection period (2018). This leads to an increase in the proportion of biofuels in total transport fuel use in the EU as a whole and the UK by 75 per cent and 98 per cent, respectively, compared to the Baseline in 2018.

Subsequently, a 75 per cent increase in the proportion of biofuels in total transport fuel use in EU-27 increases EU biodiesel and bioethanol consumption to 69 per cent and 100 per cent, respectively, in 2018 under Scenario 3 compared to Baseline (Table 1). While a 98 per cent increase in the proportion of biofuels in total transport fuel use in the UK increases UK biodiesel and bioethanol consumption to 103 per cent and 91 per cent, respectively in 2018 under Scenario 3 compared to the Baseline (Table 2). As expected, under Scenario 3 increases in consumption levels compared to the Baseline are greater than those of Scenario 2 at the EU level (i.e. 9 per cent increase in biodiesel consumption and 16 per cent increase in bioethanol consumption compared to the Scenario 2), while UK consumption levels are almost the same as Scenario 1.

As a result of the projected increases in biofuel consumption, biodiesel and bioethanol prices increase by 35 and 31 per cent respectively compared to the Baseline in 2018. The projected prices are approximately 4 per cent higher under Scenario 3 compared to Scenario 2.

The projected increases in biofuel prices have a production stimulating impact in both the EU and UK. As shown in Table 1 and Figures 7 and 8, overall projected EU biodiesel production increases by 69 per cent, while EU bioethanol production increases by 95 per cent compared to the Baseline. Thus, the projected increases in EU biodiesel and bioethanol are slightly greater under Scenario 3 relative to Scenario 2. Similarly, in the UK projected biodiesel and bioethanol increases by a greater amount under Scenario 3 compared to the other scenarios in response to the price impact. It is projected that UK biodiesel and bioethanol production increases by 180 per cent and 89 per cent, respectively, compared to the Baseline in 2018 (Table 2 and Figures 5 and 6).

Finally, similar to Scenario 2, imports increase to meet the 10 per cent target and it is projected that the difference between EU biodiesel consumption and production increases by 71 per cent, while the difference between EU bioethanol consumption and production increases by 245 per cent under Scenario 3 compared to the Baseline in 2018. In contrast, in the UK biodiesel imports decrease due to the large expansion in biodiesel production. However, similar to the EU, UK bioethanol imports increase.

Agricultural Sector

The projected increase in EU biodiesel production of 69 per cent under Scenario 3 compared to the Baseline leads to a 43 per cent increase in EU rape oil domestic use (Table 3). It is projected that the EU rape oil price increases by 30 per cent, which stimulates an increase of EU rape oil domestic production of 20 per cent. As a consequence, net trade of EU rape oil declines 220 per cent.

It is projected that EU rape meal and rapeseed use increase in response to the projected rise in rape oil production. Consequently, rape meal use replaces soy meal use in feed use. The projected increase in EU rapeseed use (20 per cent use) is sourced from an increase in rapeseed production (plus 11 per cent) and increased imports (EU rapeseed net trade declines by 61 per cent). It is projected that rapeseed prices throughout the EU increase by 44 per cent.

Within the UK, the projected increase in rapeseed price has a positive impact on rapeseed area and yield. It is projected that rapeseed yield increases slightly, while rapeseed area increases by 10 per cent at the expense of wheat and barley. Although the projected UK rapeseed area increases by a 10 per cent, total crop area only increases by 1 per cent due to the small proportion of rapeseed in total crop area. As a result of the projected increase in area and yield, UK rapeseed production increases by 12 per cent (Table 4). In conjunction with the production increase, projected UK rapeseed net trade significantly decreases (minus 126 per cent) in order to fulfil the increase in rapeseed domestic use under Scenario 3.

The increase in EU bioethanol production of 95 per cent under Scenario 3 leads to higher domestic uses of grain. In particular, projected wheat demand increases by 7 per cent, which in turn, exerts upward pressure on wheat prices. Although it is projected that there are considerable EU cereal prices increases, projected EU cereal production remains relatively constant (Table 3). These moderate cereal supply responses in the EU are partly explained by the fact that within the EU the price of oilseeds rises more rapidly than the price of cereals (due to the increase in

EU biodiesel demand) and given the inelastic total area response there is a shift out of cereals and into rapeseed.

As mentioned before, the EU cereal demand increases are mostly sourced from the net trade changes rather than domestic production increases. Consequently, increased cereal demand in EU for extra ethanol production is mostly met by a reduction in EU exports since the EU is competitive with rest of world in cereal market and net exporter in the baseline (e.g. EU wheat net trade declines by 99 per cent, Table 3). This significant reduction of EU cereal exports in the world market raises world cereal prices. It is projected that the world wheat, barley and maize prices increase by 6.5, 5.7 and 1.4 per cent, respectively (Table 8). These relatively moderate world cereal price increases compared to the EU cereal price increases (Table 3) reflects the larger volume of world cereal trade compared to the volume of EU cereal trade as well as relatively elastic world cereal supply response compared to the EU, which implies land use changes in the rest of world as a result of EU biofuels demand increase[18].

In the UK, projected wheat domestic use increases by 16 per cent in response to the 89 per cent increase in bioethanol production under Scenario 3. As in the EU, the increase in demand is mostly sourced from a decline in net trade (Table 4). It is very difficult to predict whether the increased demand for wheat in the UK bioethanol sector is met through domestic production or imports (from within the EU and/ or outside the EU) because there is no historical data. There was no wheat demand for UK ethanol production in 2008/ 2009 and most ethanol used in the UK in 2008/ 2009 was sourced from Brazilian sugar cane or UK sugar beet. This study assumes that the obligatory fossil fuel supplier would prefer bioethanol to biodiesel because a significant proportion of bioethanol can be produced domestically and subsequently save transportation cost compared to the imported biodiesel. However, it does not necessarily mean that UK bioethanol manufacturers are likely to favour domestic wheat to imported wheat. UK bioethanol manufacturers will choose imported wheat as long as it is cheaper than domestically produced wheat and UK fossil fuel suppliers are not likely to be concerned if domestically produced ethanol is made from domestic wheat or imported wheat as long as there is no quality difference[19].

In terms of the knock-on impact on the livestock sector it is projected that animal numbers in the EU and the UK decrease marginally or remain unchanged under Scenario 3 compared to the Baseline (Tables 5 and 6)[20]. Finally, projected total UK agricultural market receipts increase slightly compared to Scenario 2 due to the slight increase in grain prices (Table 7).

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[18] Although it is argued that the world grain market is relatively elastic, it is important to note that the EU model does not model global land use, yield and supply response explicitly but rather implicitly incorporated into world price equations (i.e. reduced form representation of the FAPRI global model that attempt to mimic changes in world price and hence EU trade if the EU model and FAPRI global system were linked and solved simultaneously).

[19] With further time series data from the renewable fuel agency it should be possible in the future to more accurately determuine the UK bioethanol manufacturers' choice regarding wheat demand.

[20] Even though there are some different responses between the EU and the UK in the livestock sectors with respect to increased biofuel production, the magnitudes of difference are very small. Consequently, it is inappropriate to read too much into these differences.

Conclusions

The biofuels industry in both the UK and the EU as a whole has expanded rapidly in recent years in response to policy initiatives. Further expansion of biofuel production will increase the impact of the biofuels sector on the agricultural sector. Through the incorporation of a liquid biofuels model within the FAPRI agricultural policy modelling system this study examines the potential impact of increased levels of biofuel production on agricultural markets within the EU and specifically the UK. Three scenarios are simulated within the modelling framework:

Scenario 1 - UK only increases the share of biofuel in total transport fuel use to 10 per cent;
Scenario 2 - All Member States (except the UK) increase the share of biofuel in total transport fuel use to 10 per cent; and
Scenario 3 - Both UK and other EU Member States increase the share of biofuel in total transport fuel use to 10 per cent.

It is important to note that it is not the intention of the EU Commission that first generation biofuels will comprise all of the 10 per cent target, as other sources of renewable energy, including second generation biofuels and electric cars, are expected to contribute. However, there is great deal of uncertainty concerning the extent to which alternative technologies can be developed. This study examines the implications of meeting the target solely from first generation biofuels consumption.

The projected impact of the model simulations on the biofuel and agricultural sectors is most marked when both the UK and the other EU Member States increase their share of biofuels in total transport fuel use (Scenario 3). Increasing the share of biofuels in total transport fuel use increases the demand for biofuels, resulting in significant price rises for biodiesel and bioethanol. The increased demand for biofuels also pushes up the demand for the feedstocks used to produce them. In response it is projected that there is a marked increase in EU rapeseed production. Despite this large increase, more rapeseed also has to be imported into the EU. In contrast, it is projected that EU grain production remains relatively unchanged and the increased demand for grains is met through significantly reduced exports of wheat and barley and increased imports of maize.

Similarly in the UK it is projected that there is a significant expansion in rapeseed production, while wheat production remains unchanged. The increased demand for wheat in the UK is mostly met through increased imports. It is projected that the prices for wheat and barley in the UK increase significantly (15 and 9 per cent respectively), but the price rise is even greater for rapeseed (44 per cent) due to the greater dependence on biodiesel rather than bioethanol in the EU as a whole.

The knock-on impact on the livestock sector is minimal. Despite the projected increase in grain prices, it is projected that rape meal and DDGS replace grain feed use because of the increased supply and relatively lower prices of these by-products.

Overall the results demonstrate the complexity of the biofuels sector and its interactions with the agricultural sector. The projected impact on the crop sector is significant and highlights the importance of including a biofuels sub-model in the FAPRI-UK modelling system.

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Appendix 1: Summary Tables

Table 1: EU-27 Biofuels Sector Results
(Percentage difference in 2018 compared to Baseline)

	S1	S2	S3
Biodiesel			
Production	9.2%	59.4%	69.0%
Capacity	5.6%	1.1%	6.2%
Utilisation rate	3.4%	57.6%	59.2%
Consumption	8.8%	59.9%	69.2%
Consumption minus production	5.2%	64.0%	71.1%
Biodiesel price	3.7%	31.7%	35.5%
Bioethanol			
Production	14.0%	78.8%	95.1%
Capacity	12.8%	63.0%	76.4%
Utilisation rate	1.1%	9.7%	10.6%
Consumption	14.8%	83.5%	100.1%
Consumption minus production	37.4%	220.0%	245.1%
Bioethanol price	3.9%	27.4%	31.4%

S1: Increase only UK biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.
S2: Increase biofuel consumption for other EU Member States (i.e. all Member States except the UK) to 10 per cent of total transport fuel use in energy content until 2018.
S3: Increase UK and EU biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.

Table 2: UK Biofuels Sector Results
(Percentage difference in 2018 compared to Baseline)

	S1	S2	S3
Road Transport Fuel Consumption			
Proportion of Biofuels	98.2%	-1.2%	98.1%
Proportion of Biodiesel	3.2%	-1.1%	3.1%
Biodiesel			
Production	144.2%	32.9%	179.5%
Capacity	139.6%	14.5%	138.6%
Utilisation	1.9%	16.0%	17.2%
Consumption	104.4%	-2.4%	103.5%
Consumption minus production	43.4%	-56.3%	-13.1%
Price	3.7%	31.7%	35.5%
Net return	9.1%	82.7%	89.2%
Bioethanol			
Production	70.3%	43.0%	89.0%
Capacity	67.0%	27.6%	66.6%
Utilisation	2.0%	12.1%	13.4%
Consumption	92.2%	-0.4%	91.8%
Consumption minus production	510.5%	-829.9%	144.8%
Price	3.9%	27.4%	31.4%
Wheat-based net return	7.8%	61.3%	68.6%

S1: Increase only UK biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.
S2: Increase biofuel consumption for other EU Member States (i.e. all Member States except the UK) to 10 per cent of total transport fuel use in energy content until 2018.
S3: Increase UK and EU biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.

Table 3: EU Crop Sector Results
(Percentage difference in 2018 compared to Baseline)

	S1	S2	S3
Area			
Wheat	0.2%	1.1%	1.2%
Barley	-0.4%	-2.9%	-3.3%
Maize	0.3%	2.0%	2.4%
Rapeseed	1.4%	10.7%	12.0%
Yield			
Wheat	0.0%	0.2%	0.2%
Barley	0.0%	0.3%	0.3%
Maize	0.0%	0.3%	0.3%
Rapeseed	-0.1%	-0.8%	-0.8%
Wheat			
Production	0.2%	1.3%	1.5%
Domestic use	1.0%	5.6%	6.9%
Feed use	-0.9%	-4.8%	-5.7%
Net trade*	-15.1%	-81.0%	-98.9%
Barley			
Production	-0.4%	-2.6%	-3.0%
Domestic use	0.3%	1.1%	1.6%
Feed use	0.1%	0.1%	0.4%
Net trade*	-8.5%	-49.4%	-60.1%
Maize			
Production	0.3%	2.3%	2.7%
Domestic use	0.7%	4.1%	4.7%
Feed use	-1.3%	-7.2%	-9.0%
Net trade*	-10.5%	-50.1%	-52.8%
Rape oil			
Production	2.5%	17.8%	20.4%
Domestic use	5.8%	37.3%	43.3%
Net trade*	-31.1%	-186.9%	-219.4%
Rapeseed			
Production	1.3%	9.8%	11.1%
Domestic use	2.5%	17.7%	20.2%
Net trade*	-7.5%	-52.2%	-60.6%
Oilseed Meal			
Rapemeal use	2.6%	18.8%	21.6%
Soymeal use	-2.2%	-17.0%	-19.4%
Prices			
Wheat	2.2%	12.0%	14.7%
Barley	1.2%	7.1%	8.6%
Maize	2.8%	15.3%	19.1%
Rapeseed	5.9%	37.9%	44.3%
Rape oil	3.9%	25.5%	29.7%
Soy meal	-1.4%	-9.2%	-10.7%

*Net trade is equal to exports minus imports

S1: Increase only UK biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.
S2: Increase biofuel consumption for other EU Member States (i.e. all Member States except the UK) to 10 per cent of total transport fuel use in energy content until 2018.
S3: Increase UK and EU biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.

Table 4: UK Crop Sector Results
(Percentage difference in 2018 compared to Baseline)

	S1	S2	S3
Area			
Total crop	0.2%	1.1%	1.3%
Wheat	-0.1%	-0.4%	-0.2%
Barley	-0.2%	-0.9%	-0.9%
Rapeseed	1.5%	9.0%	9.9%
Yield			
Wheat	0.1%	0.6%	0.7%
Barley	0.1%	0.4%	0.4%
Rapeseed	0.2%	1.4%	1.6%
Rape oil			
Production	20.7%	4.3%	25.0%
Domestic use	61.2%	12.9%	74.3%
Net trade*	-224.3%	-47.8%	-273.5%
Rape meal			
Production	20.7%	4.3%	25.0%
Domestic use	20.7%	4.3%	25.0%
Soy meal			
Domestic use	-13.1%	2.0%	-9.4%
Rapeseed			
Production	1.7%	10.5%	11.7%
Domestic use	19.2%	4.8%	24.0%
Net trade*	-163.7%	42.3%	-125.5%
Wheat			
Production	0.0%	0.1%	0.4%
Domestic use	14.1%	6.5%	15.6%
Feed use	-4.8%	-8.9%	-12.7%
Net trade*	-100.1%	-45.6%	-107.9%
Barley			
Production	-0.1%	-0.5%	-0.5%
Domestic use	-1.9%	-1.1%	-2.4%
Feed use	-3.4%	-1.7%	-4.0%
Net trade*	32.2%	13.8%	39.8%
Prices			
Wheat	2.2%	12.0%	14.7%
Barley	1.2%	7.1%	8.6%
Rapeseed	5.9%	37.9%	44.3%

*Net trade is equal to exports minus imports

S1: Increase only UK biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.

S2: Increase biofuel consumption for other EU Member States (i.e. all Member States except the UK) to 10 per cent of total transport fuel use in energy content until 2018.

S3: Increase UK and EU biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.

Table 5: EU Livestock Sector Results
(Percentage difference in 2018 compared to Baseline)

	S1	S2	S3
Dairy cows number	0.0%	-0.4%	-0.5%
Suckler cows number	-0.1%	-1.1%	-1.3%
Sows number	-0.1%	-0.4%	-0.5%
Ewes number	-0.1%	-0.3%	-0.4%
Poultry production	-0.1%	-0.7%	-0.8%

Table 6: UK Livestock Sector Results
(Percentage difference in 2018 compared to Baseline)

	S1	S2	S3
Dairy cows number	-0.2%	-1.4%	-1.7%
Suckler cows number	0.0%	0.3%	0.3%
Sows number	0.0%	0.1%	0.1%
Ewes number	0.0%	0.2%	0.2%
Chicken production	0.0%	0.3%	0.3%

Table 7: UK Market Receipts Results
(Percentage difference in 2018 compared to Baseline)

	S1	S2	S3
Market receipts			
Wheat	3.9%	21.9%	27.3%
Barley	2.5%	14.9%	18.5%
Rapeseed	6.4%	42.9%	50.1%
Total Crops	4.0%	24.6%	29.9%
Cattle	0.2%	1.3%	1.5%
Pig	0.5%	2.8%	3.5%
Sheep	0.1%	1.1%	1.3%
Poultry	0.7%	6.2%	7.1%
Total Livestock	0.4%	2.8%	3.3%
Milk	-0.1%	-0.7%	-0.8%
Total Market Receipts	0.8%	5.2%	6.3%

S1: Increase only UK biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.
S2: Increase biofuel consumption for other EU Member States (i.e. all Member States except the UK) to 10 per cent of total transport fuel use in energy content until 2018.
S3: Increase UK and EU biofuel consumption to 10 per cent of total transport fuel use in energy content until 2018.

Table 8: World Price Results
(Percentage difference in 2018 compared to Baseline)

	S1	S2	S3
Crop Sector			
HRW wheat, U.S. Gulf	1.0%	5.4%	6.5%
Barley, U.S. Portland	0.8%	4.8%	5.7%
Maize, U.S. Gulf	0.2%	1.3%	1.4%
Rapeseed, Hamburg	5.9%	37.7%	44.3%
Rape meal, Hamburg	0.4%	2.4%	2.9%
Rape oil, Hamburg	3.9%	25.4%	29.7%
Soy meal, Rotterdam	-1.4%	-9.2%	-10.7%
Livestock Sector			
Steers, Nebraska	0.0%	-0.2%	-0.2%
Hogs, U.S. 51-52% lean	-0.2%	-2.2%	-2.5%
Broilers, U.S. 12-city	-0.2%	-1.4%	-1.6%

Appendix 2: Specifications of the FAPRI-UK Liquid Biofuels Model [21]

Endogenous Variable	Explanatory Variables	Units	Coefficient	Elasticity
UK Petrol price, w/o taxes		£/1000 lt		
(Estimated)	Intercept		91	
	Refiners' crude oil acquisition price	£/1000 lt	0.91	0.68
	Dummy (1990=1, 1996-2004=1, 2008=1)		-27.5	
	UK GDP Deflator	2003=1	11.8	0.04
UK diesel price, w/o taxes		£/1000 lt		
(Estimated)	Intercept		55.74	
	Refiners' crude oil acquisition price	£/1000 lt	1.15	0.75
	UK GDP Deflator	2003=1	21.75	0.07
UK total road transport fuel consumption		million lt		
(Estimated)	Intercept		45814	
	UK weighted road fuel price	£/1000 lt	-6.34	-0.12
	UK Real GDP	million £	0.01	0.17
UK weighted road fuel price		£/1000 lt		
(Identity)	Intercept		0.00	
	[Petrol /(Petrol+Diesel+Ethanol+Biodiesel)] Consumption* Petrol Price	£/1000 lt	1.00	
	[Diesel /(Petrol+Diesel+Ethanol+Biodiesel)] Consumption * Diesel Price	£/1000 lt	1.00	
	[Ethanol /(Petrol+Diesel+Ethanol+Biodiesel)] Consumption* Ethanol Price	£/1000 lt	1.00	
	[Biodiesel /(Petrol+Diesel+Ethanol+Biodiesel)] Consumption*Biodiesel Price	£/1000 lt	1.00	
UK proportion of diesel and biodiesel in total road transport use		ratio		
(Estimated)	Intercept		1.04	
	(Diesel/Petrol) price ratio	ratio	-0.70	-1.47
	Diesel consumption trend		0.02	0.36
UK Diesel and biodiesel consumption		million lt		
(Identity)	Intercept		0.00	
	Total fuel consumption*Diesel & biodiesel proportion in the total consumption	million lt	1.00	

[21] Reported model specifications (estimated/ imposed parameter values and elasticities) are based on the 2008/2009 Renewable Fuel Agency data and situations in 2008/2009. Given the infant stage of the industry and rapidly changing policy environments, frequent changes in the assumed parameter values and elasticities are inevitable. Model specifications and baseline results therefore should be interpreted on the situations in 2008/2009.

Endogenous Variable	Explanatory Variables	Units	Coefficient	Elasticity
UK Petrol and Ethanol consumption		million lt		
(Identity)	Intercept		0.00	
	Total fuel consumption - Diesel & biodiesel consumption	million lt	1.00	
UK Biofuels consumption		million lt		
(Synthetic)	Intercept		0.00	
	UK RTFO target*Total fuel consumption	million lt	1.00	
	(Petrol+Diesel)/(Ethanol+ Biodiesel) price ratio	ratio	167.38	0.50
UK proportion of biodiesel in total biofuel consumption				
(Synthetic)	Intercept		0.2	
	(Ethanol/Biodiesel) price ratio	ratio	0.10	0.10
	(Diesel and biodiesel/ Total fuel) consumption ratio	ratio	0.14	0.10
	(Ethanol/ Total biofuel) production ratio	ratio	-0.17	-0.15
UK biodiesel consumption for road tansport		million lt		
(Identity)	Intercept		0.00	
	Total biofuel consumption *Share of biodiesel in the total biofuel consumption	million lt	1.00	
UK ethanol Consumption for road transport		million lt		
(Identity)	Intercept		0.00	
	(Total biofuel - Biodiesel) consumption	million lt	1.00	
UK biodiesel consumption for road tansport		1000 tonnes		
(Identity)	Intercept		0.00	
	Biodiesel consumption	million lt	0.88	
UK ethanol consumption for road tansport		1000 tonnes		
(Identity)	Intercept		0.00	
	Ethanol consumption	million lt	0.79	
UK biodiesel consumption for road tansport		1000 tonnes of oil equivalent		
(Identity)	Intercept		0.00	
	Biodiesel consumption	1000 tonnes	0.89	

Endogenous Variable	Explanatory Variables	Units	Coefficient	Elasticity
UK ethanol consumption for road tansport		1000 tonnes of oil equivalent		
(Identity)	Intercept		0.00	
	Ethanol consumption	1000 tonnes	0.66	
UK petrol consumption for road transport		million lt		
(Identity)	Intercept		0.00	
	Petrol & ethanol consumption - Ethanol consumption	million lt	1.00	
UK diesel consumption for road transport		million lt		
(Identity)	Intercept		0.00	
	Diesel & biodiesel consumption - Biodiesel consumption	million lt	1.00	
UK biodiesel net return		£/ lt		
(Identity)	Intercept		0.00	
	UK biodiesel price/1000	£/1000 lt	1.00	
	UK Glycerin price	£/ lt	1.00	
	UK weighted oilseed oil price *0.88/1000	£/ tonne	-1.00	
	Other biodiesel cost	£/ lt	-1.00	
UK weighted oilseed oil price		£/tonne		
(Identity)	Intercept		0.00	
	Rape oil price*Rape oil share in biodiesel production	£/tonne	1.00	
	Soy oil price*Soy oil share in biodiesel production	£/tonne	1.00	
	Palm oil price* Other oil share in biodiesel production	£/tonne	1.00	
UK wheat-based ethanol net return		£/lt		
(Identity)	Intercept		0.00	
	Ethanol price /1000	£/1000 lt	1.00	
	Wheat DDG price	£/lt	1.00	
	Wheat price*(1/370)	£/ tonne	-1.00	
	Other ethanol cost	£/lt	-1.00	
UK beet-based ethanol net return		£/lt		
(Identity)	Intercept		0.00	
	Ethanol price /1000	£/1000 lt	1.00	
	Beet ethanol by-product return	£/lt	1.00	
	Beet price*(1/95)	£/ tonne	-1.00	
	Other ethanol cost	£/lt	-1.00	

Endogenous Variable	Explanatory Variables	Units	Coefficient	Elasticity
UK biodiesel production capacity		1000 tonnes		
(Synthetic, max(sum of first two variables, sum of all variables))	Intercept		0.00	
	lag(Biodiesel production capacity)	1000 tonnes	1.00	0.98
	lag10(Biodiesel production capacity)	1000 tonnes	-0.05	-0.03
	Biodiesel net return/ GDP deflator	£/lt	200	0.01
	lag(Biodiesel net return/ GDP deflator)	£/lt	400	0.03
	lag2(Biodiesel net return/ GDPdeflator)	£/lt	1600	0.10
	lag3(Biodiesel net return/ GDP deflator)	£/lt	800	0.05
UK biodiesel capacity utilization rate		Per cent		
(Synthetic, Logit function)	Intercept		0.00	
	Biodiesel net return/ GDP deflator	£/lt	5.24	1.00
UK biodiesel production		1000 tonnes		
(Identity)	Intercept		0.00	
	Biodiesel (capacity*utilisation rate)	1000 tonnes	1.00	
UK beet-based ethanol production capacity		1000 tonnes		
Assume fixed capacity	Intercept		0.00	
	55.00	1000 tonnes	1.00	
UK beet-based ethanol capacity utilisation rate		per cent		
(Synthetic, Logit function)	Intercept		0.00	
	beet-based ethanol net return/ GDP deflator	£/lt	5.09	1.00
UK Beet-based ethanol production		1000 tonnes		
(Identity)	Intercept		0.00	
	Beet ethanol (capacity* utilisation rate)	1000 tonnes	1.00	

Endogenous Variable	Explanatory Variables	Units	Coefficient	Elasticity
UK wheat-based ethanol production capacity		1000 tonnes		
(Synthetic, max(sum of first two variables, sum of all variables))	Intercept		0.00	
	lag(Wheat ethanol production capacity)	1000 tonnes	1.00	0.96
	lag10(Wheat ethanol production capacity)	1000 tonnes	-0.05	-0.01
	Wheat ethanol net return/ GDP deflator	£/lt	50	0.003
	lag(Wheat ethanol net return/ GDP deflator)	£/lt	100	0.005
	lag2(Wheat ethanol net return/ GDP deflator)	£/lt	400	0.023
	lag3(Wheat ethanol net return/ GDP deflator)	£/lt	200	0.013
UK wheat-based ethanol capacity utilisation rate		Per cent		
(Synthetic, Logit function)	Intercept		0.00	
	Wheat ethanol net return/ GDP deflator	£/lt	8.52	1.00
UK wheat-based ethanol production		1000 tonnes		
(Identity)	Intercept		0.00	
	Wheat ethanol (capacity* utilisation rate)	1000 tonnes	1.00	
UK Ethanol production		1000 tonnes		
(Identity)	Intercept		0.00	
	(Beet ethanol+ Wheat ethanol) production	1000 tonnes	1.00	
UK Ethanol production Capacity		1000 tonnes		
(Identity)	Intercept		0.00	
	(Beet ethanol+ Wheat ethanol) production capacity		1.00	
UK Ethanol utilization rate		Per cent		
(Identity)	Intercept		0.00	
	Ethanol (production/capacity)		1.00	

Endogenous Variable	Explanatory Variables	Units	Coefficient	Elasticity
UK Total Biofuel production		1000 tonnes		
(Identity)	Intercept		0.00	
	(Biodiesel+Ethanol) production	1000 tonnes	1.00	
UK proportion of ethanol production in total biofuel productioon		RATIO		
(Identity)	Intercept		0.00	
	(Ethanol/ Biofuel) production		1.00	
UK Ethanol Net Trade (net export)		1000 tonnes		
(Identity)	Intercept		0.00	
	Ethanol (production-consumption)	1000 tonnes	1.00	
UK Biodiesel Net Trade (net export)		1000 tonnes		
(Identity)	Intercept		0.00	
	Biodiesel (production-consumption)	1000 tonnes	1.00	
Total oilseed & other oil used for biodiesel production		1000 tonnes		
(Identity)	Intercept		0.00	
	Biodiesel production	1000 tonnes	1.00	
Soy oil share of biodiesel production		Ratio		
(synthetic)	Intercept		0.27	
	Relative soy oil price	£/tonne	-0.10	-0.50
Other oil and fat share of biodiesel production		Ratio		
(synthetic)	Intercept		0.20	
	Relative palm oil price	£/tonne	-0.10	-0.50
Rape oil share of biodiesel production				
(Identity)	Intercept		0.00	
	1-Soy oil share-Other oil share		1.00	
Rape oil used for biodiesel production		1000 tonnes		
(Identity)	Intercept		0.00	
	Total oil used for biodiesel*Rape oil share	1000 tonnes	1.00	

Endogenous Variable	Explanatory Variables	Units	Coefficient	Elasticity
Soy oil used for biodiesel production		1000 tonnes		
(Identity)	Intercept		0.00	
	Total oil used for biodiesel*Soy oil share	1000 tonnes	1.00	
Other oil used for biodiesel production		1000 tonnes		
(Identity)	Intercept		0.00	
	Total oil used for biodiesel*Other oil share	1000 tonnes	1.00	
Wheat used for ethanol production		1000 tonnes		
(Identity)	Intercept		0.00	
	Wheat ethanol production*(1/0.292)		1.00	
Beet used for bio ethanol production		1000 tonnes		
(Identity)	Intercept		0.00	
	Beet ethanol*(1/0.0752)		1.00	
Share of UK grown rape oil in total rape oil used for biodiesel prod.		Ratio		
(synthetic)	Intercept		0.00	
	(World /EU) biodiesel price	Ratio	0.02	0.15
	(£/euro) exchange rate	Ratio	0.08	0.56
Rape oil, from UK grown rapeseed, used for biodiesel production		1000 tonnes		
(Identity)	Intercept		0.00	
	Rape oil used for biodiesel production*domestic share	1000 tonnes	1.00	
DDGS Production		1000 tonnes		
(Identity)	Intercept		0	
	Wheat used for ethanol	1000 tonnes	0.33	
DDGS Feed use		1000 tonnes		
(Identity)	Intercept		0	
	DDGS production	1000 tonnes	1	

Endogenous Variable	Explanatory Variables	Units	Coefficient	Elasticity
DDGS used for wheat replacement		1000 tonnes		
(Identity)	Intercept		0	
	DDGS feed use* (wheat/ wheat+barley+soymeal) feed use	1000 tonnes	1	
DDGS used for barley replacement		1000 tonnes		
(Identity)	Intercept		0	
	DDGS feed use* (barley/ wheat+barley+soymeal) feed use	1000 tonnes	1	
DDGS used for soymeal replacement		1000 tonnes		
(Identity)	Intercept		0	
	DDGS feed use* (soymeal/ wheat+barley+soymeal) feed use	1000 tonnes	1	
Wheat replaced by DDGS		1000 tonnes		
(Identity)	Intercept		0	
	DDGS used for wheat replacement	1000 tonnes	0.386	
Barley replaced by DDGS		1000 tonnes		
(Identity)	Intercept		0	
	DDGS used for barley replacement	1000 tonnes	0.386	
Soymeal replaced by DDGS		1000 tonnes		
(Identity)	Intercept		0	
	DDGS used for soymeal replacement	1000 tonnes	0.594	
Wheat replacement rate by DDGS		rate		
(Identity)	Intercept		0	
	Wheat replaced by DDGS/ (Wheat feed use + wheat replaced by DDGS)	rate	1	
Barley replacement rate by DDGS		rate		
(Identity)	Intercept		0	
	Barley replaced by DDGS/ (Barley feed use + Barley replaced by DDGS)	rate	1	

Endogenous Variable	Explanatory Variables	Units	Coefficient	Elasticity
Soymeal replacement rate by DDGS		rate		
(Identity)	Intercept		0	
	Soymeal replaced by DDGS/ (Soymeal use + Soymeal replaced by DDGS)	rate	1	