

Impact of Alternative Crude Oil Prices on the UK Liquid Biofuel and Agricultural Markets



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Executive Summary

The expansion of the EU biofuel sector in recent years has led to speculation that the linkages between the oil and agricultural markets has strengthened and resulted in increased transmission of price volatility. This study uses the FAPRI European modelling system, which includes a UK model, to explore the energy-biofuel-agricultural market linkages in the EU. The complete modelling system is a dynamic, partial equilibrium, multi-commodity model of the EU agriculture and liquid biofuel for transportation sectors. Within this modelling system the liquid biofuel market and feedstock market for biofuel production in the UK are not determined in isolation but solve simultaneously with models representing the other EU countries' biofuels and feedstock markets. A stochastic approach is used in which the modelling system is simulated 500 times under different paths of oil prices and world commodity prices. This stochastic approach provides a means to analyse the impact of alternative crude oil prices on the biofuel and agricultural sectors.

Simulating the model 500 times indicates that the crude oil price has a limited impact on EU biofuel consumption. The variation in EU biofuel consumption arising from changes in the competitiveness of biofuels relative to fossil fuels is small, with mandates largely driving consumption.

Within the UK, fuel suppliers are obliged to supply a certain percentage of renewable fuels each year under the Renewable Transport Fuel Obligation (RTFO). The model simulations indicate that fuel suppliers fulfil the RTFO target for the vast majority of simulations. However, under some simulations fuel suppliers have little incentive to meet the RTFO target and the mandate is not binding as the price difference between the biofuel price and the fossil fuel price is greater than the buy-out penalty. On the other hand, biofuels consumption increases significantly when biofuels are competitive relative to fossil fuels, but this is exceptional and only applies to a small proportion of the simulations.

The simulations indicate that there is a positive but modest relationship between crude oil prices and biofuel prices due to the role of mandates on the EU biofuel market. Projected UK bioethanol production is more responsive to variations in the crude oil price than UK biodiesel production due to differences in net returns. Net returns for biofuel production are not only affected by biofuel prices, but also by input costs, wheat and vegetable oil prices, which also vary to some extent with oil prices. Vegetable oil prices increase by more than the wheat price and hence biodiesel net returns are offset more by a higher oil price than bioethanol net returns.

It is projected that there is a positive relationship between the crude oil price and the price of crops, but the rapeseed price is more correlated to oil price changes than wheat and barley. This reflects the greater potential for substitution between grains for use as feedstocks, the fact that DDGS production as a by-product of bioethanol production can replace feed grains and to variation in the demand for animal feed due to higher/lower livestock numbers.

Volatility in crude oil prices exerts a moderate impact on the livestock sector. It is projected that cattle numbers and sheep numbers decline in response to higher crude oil prices due to higher input costs. The decline in livestock numbers has a knock-on negative impact on impact on greenhouse gas emissions from agriculture.

In general, the model simulations demonstrate the complex interactions between the different sectors. In order to determine the overall impact of oil price volatility on agricultural markets it is necessary not only to account for feedstock demand for biofuel production, but also for the production of by-products and for animal feed demands due to the impact of oil price volatility on input costs and hence animal numbers.

Impact of Alternative Crude Oil Prices on the UK Liquid Biofuel and Agricultural Markets

1. Introduction

The EU biofuel sector has expanded rapidly in recent years, largely in response to policy initiatives. The development of the biofuel sector has important implications for the agricultural sector due to the demand for feedstocks, but also potentially from the transmission of price volatility from energy markets to agricultural markets. Most observers agree that an increase in oil prices contributed (to varying degrees) to the surge in agricultural commodity prices during the 2007-08 "food crisis" due to the role of biofuels. However, this influence was downplayed by the European Commission due to the limited size of the biofuel sector, at least in the EU, during this period (European Commission, 2008). This study uses an EU partial equilibrium modelling system to examine the linkages between the energy, biofuel and agricultural sectors.

The oil market has always exerted an influence on the agricultural sector as an important determinant of input costs. A rise in the price of oil feeds through to the agricultural sector through higher costs of crop and livestock production, which leads to reductions in supply and hence, higher commodity prices. The expansion of the biofuel sector has potentially strengthened the linkages between the oil and agricultural markets. As a substitute to fossil fuel for transport (both petrol and diesel), the demand for biofuel is affected by the price of crude oil. In a freely operating market, a rise in the price of crude oil increases the price of petroleum based fuels and higher demand for biofuel. This exerts an upward impact on the price of biofuel and hence production. Increases in biofuel production leads to higher demand and hence prices for the feedstocks used in their production. In addition to this direct impact on the grain and vegetable oil sectors, variability in crude oil prices and consequently, crop prices, may affect the livestock sector through feed costs. However, thus far, biofuel in the EU have not been competitive with petroleum based products and consequently various policy initiatives have been introduced to promote the consumption of biofuel. Within the UK, under the Renewable Transport Fuel Obligation (RTFO), fuel suppliers are obliged to supply a certain percentage of renewable fuels each year (5 per cent by 2013/14). The various biofuel policy initiatives aim to reduce greenhouse gas emissions, improve energy security and support rural development. By altering the behaviour of the market for biofuel, the implementation of these policies impacts the linkages between the energy and biofuel sector.

While a large number of studies have examined the impact of a growing biofuel sector on the agricultural sector, relatively few studies have examined the interaction in the presence of volatile oil prices. This study uses the FAPRI European partial equilibrium modelling system, which includes a UK model, to analyse the energy-biofuel-agricultural linkages. A stochastic approach is used in which the modelling system is simulated 500

times under different paths of oil prices and world commodity prices. These 500 paths have been generated using FAPRI-Missouri's modelling system and therefore in each path the oil price and world prices are consistent. This provides a unique tool to obtain a better understanding of the impact of alternative crude oil prices on the biofuel and agricultural sectors.

2. Background

Following the surge in agricultural commodity prices in 2007-08 a number of studies in the US and, to a lesser extent, the EU have examined the interaction between oil prices, the biofuel sector and the agricultural sector. A range of approaches have been used to assess the impact of variability in the oil market on the biofuel and agricultural markets. One of the main approaches is cointegration analysis. By analysing the long-run relationships between oil, biofuel and agricultural commodity prices, cointegration analysis provides a means to examine the extent to which shocks to prices in one market are transmitted to other markets and thereby, assess the degree of integration between markets (Busse *et al.*, 2010). Various cointegration studies have shown that the linkage between the energy and agricultural sectors has grown in line with the development of the biofuel industry. Using different time periods, Harri *et al.* (2009) found evidence that the strength of the relationship between corn and oil has increased over time in the US. This is attributed to the growing use of corn for ethanol within the US and greater use of petroleum-based inputs in the corn market. In contrast, the authors found no evidence of a cointegrating relationship between oil and wheat in recent years, consistent with the limited use of wheat for ethanol production in the US.

Ciaian and Kanacs (2010) also demonstrated using cointegration analysis using world agricultural commodity prices and the world oil price that the influence of the energy market on the agricultural market has increased over time. The authors found limited evidence of cointegration pre-2004, but strong evidence of cointegration post-2004. Using impulse response functions the authors showed that the price transmission elasticity is higher for agricultural commodity goods that are also used for bioenergy purposes (sugar, soybeans, corn and wheat).

In an EU based cointegration study, Busse *et al.* (2010) found evidence of long-run relationships between crude oil and biodiesel and vegetable oil prices in Germany. However, the results suggest that the relationship between biodiesel and vegetable oil price weakened after 2007, in line with changes in the legal framework that affected biodiesel sales, import competition from the US and the sharp increase in agricultural prices during the food crisis.

Similar to the cointegration studies, Fabiosa (2008) showed that the correlation between crude oil and grain prices increased dramatically as the biofuel sector expanded in the US using a joint distribution approach. Moreover, the authors also demonstrated that the correlation between crude oil and feed ingredient prices showed a sharp increase in the latter part of the data period, suggesting that variability originating from the energy sector has knock-on effects on the livestock sector as well as the crop sector.

In addition to cointegration and joint distribution analyses, simulation models have been used to examine the impact of volatility in the oil market on the biofuel and agricultural sectors. Simulation models consist of behavioural equations that capture interrelationships among variables affecting supply and demand in specified markets. By incorporating linkages between oil, biofuel and agricultural markets, simulation models can be used to determine precisely how variations in the oil price influence agricultural markets. Tokgoz (2009) used a simulation framework to analyse the linkages between the EU ethanol, grain and dried distiller grains markets. The simulation analysis showed that higher oil prices leads to an increase in ethanol consumption, production and ultimately grain prices. At the same time, as a by-product of ethanol production, the price of DDGs decreases in response to increased ethanol production.

Simulation models have also been used to explore how biofuel policy affects the interaction between the agricultural and energy markets. Thompson *et al.* (2009) identified links between the oil, ethanol and corn markets in the US using the FAPRI-MU US multi-commodity partial equilibrium model. The partial equilibrium modelling system was simulated stochastically (see Section 3 for more information about stochastic simulations) to determine how variations in the oil price lead to variations in ethanol use, ethanol price and corn price. The authors estimated the magnitude of these links with and without biofuel mandates introduced in the US, which set minimum quantities of biofuel use. The simulations demonstrated that the mandates weaken the links between ethanol and oil prices under some circumstances. When oil prices are sufficiently high the mandates are not binding and consequently, corn prices are not affected by the mandate. However, when oil prices are lower the mandates are binding. In this situation, use of biofuels that meet the mandate cannot be reduced, which in turn acts to support both the ethanol price and production. Since corn is the main feedstock for ethanol production in the US, ethanol production influences the demand for corn. As a consequence, when oil prices are low, projected corn prices are higher with the mandates compared to without. Similarly, using a partial equilibrium model Yano *et al.* (2010) showed that due to the effect of mandates on ethanol use the impact of variability in the oil price on US corn prices is large without mandates, but low when mandates are binding.

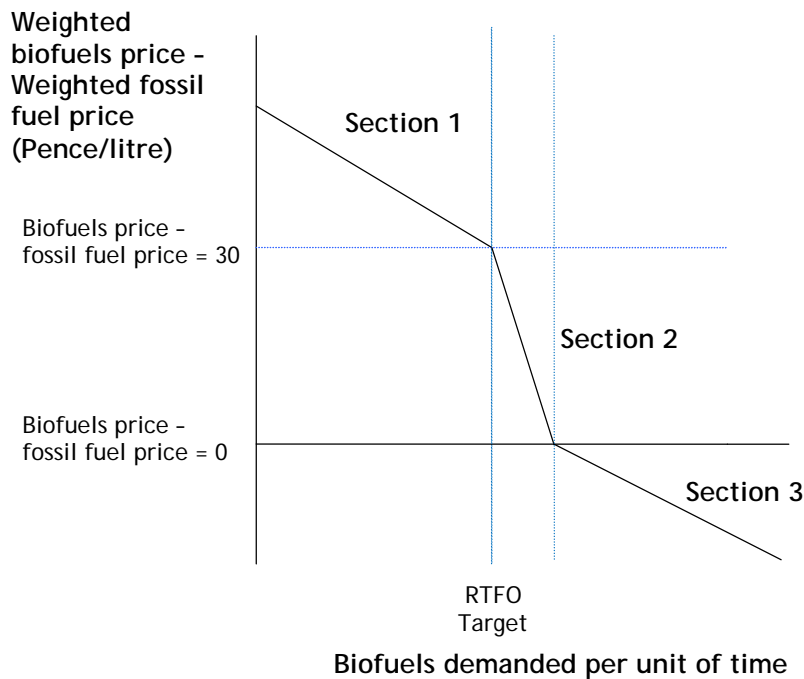
3. Methodology

Within this study the FAPRI-UK modelling system, which includes liquid biofuels and agricultural commodities, is linked to the EU GOLD model. The complete modelling system is a dynamic, partial equilibrium, multi-commodity model of the EU agriculture and liquid biofuel for transportation sectors. Within this modelling system the liquid biofuel market and feedstock market for biofuel production in the UK are not determined in isolation but solve simultaneously with models representing the other EU countries' biofuels and feedstock markets. The liquid biofuel component is separated into the UK, France, Germany, Italy and a rest of Europe sector¹. The model solely incorporates first generation liquid biofuel. Changes in the demand for the raw materials for biofuel production impact their respective commodity markets. An increase in the demand for cereal exerts an upward impact on cereal prices, increasing the cost to livestock markets. By-product markets are also modelled. For example, increasing ethanol production results in by-product for the feed industry, reducing cereal prices. Total transport use is modelled through projections of fuel prices based on exogenous forecasts of oil prices by IHS Global Insight. Fuel use is broken into ethanol/gasoline and biodiesel/diesel.

Within this study the UK total biofuel consumption function has been modified to account for a wide range of oil prices and the possibility that the RTFO target may not be met under certain conditions. Under the RTFO fuel suppliers must supply renewable fuel transport certificates each year to verify that they have fulfilled the RTFO target. Suppliers that do not have sufficient certificates can purchase these from other companies or pay a fine. This fine is known as the buy-out penalty and from April 15th 2010 equals 30 pence per litre of non-supplied biofuel. In theory, if the price difference between biofuel and fossil fuel (taking into account fossil fuel tax, VAT and biofuel tax incentives) is equal to or greater than the buy-out penalty, then obligatory fossil fuel suppliers have little incentive to meet the RTFO target. To account for the possibility that the aggregate RTFO target may not be filled the total UK biofuel consumption function is segmented into three regions. As shown in Figure 1, when the price difference between the weighted biofuel price and the weighted fossil fuel price is greater than the buy-out penalty, the mandate is not binding and demand is relatively elastic compared to when mandate is binding (Section 1). When the price difference is between the buy-out penalty (30 pence per litre) and zero, the mandate is binding and demand is relatively inelastic (Section 2). Finally, when the price difference is less than zero (i.e. when biofuel is competitive compared to fossil fuel), demand is very elastic (Section 3).

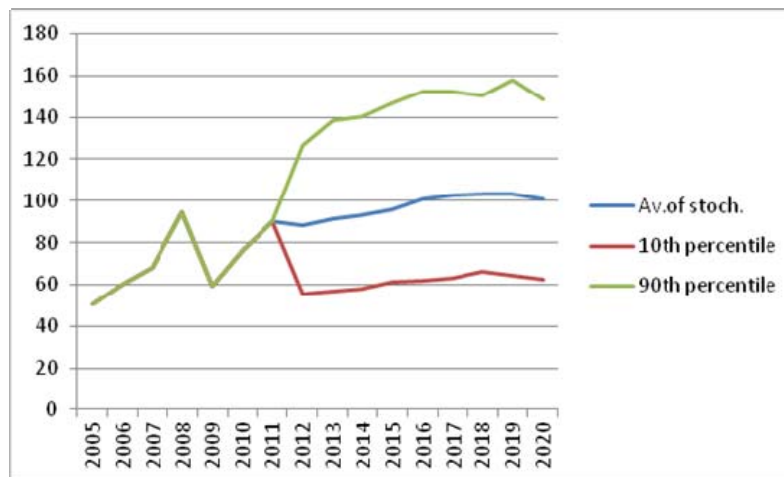
¹ See Kim *et al.* (2010) for documentation of the UK model and Binfield *et al.* (2008) for a description of the complete EU modelling system.

Figure 1: Kinked UK Total Biofuel Consumption Function



Within this study the modelling system is simulated stochastically to determine the impact of variable world prices on the biofuel and agricultural sectors. Under the stochastic approach assumptions about certain exogenous variables may be varied by taking random draws from distributions based on past variations. In this case, variable crude oil and world prices are obtained from the FAPRI-Missouri stochastic modelling system [see Meyer *et al.* (2010) for further details of the Missouri stochastic approach]. The EU modelling system is then simulated using 500 sets of variable crude oil and world prices, generating 500 sets of market outcomes [see Moss *et al.* (2011) for further details of this partial stochastic approach]. Note, in the case of the crude oil price some persistence is imposed through a lagged dependant variable. The mean of the distribution is chosen to reflect the IHS Global Insight forecast, with the distribution chosen to reflect recent volatility and judgement of future volatility. If the distribution were purely based on historical prices and volatility the mean and range would be much lower. This is a good example of how the FAPRI stochastic process blends data with analyst judgement in order to produce analysis that is rigorous but reflects current market conditions. The stochastic crude oil price used for this analysis is shown in Figure 2.

Figure 2: Stochastic World Oil Price (\$/barrel)



Within the main analysis the baseline modelling system is simulated 500 times using stochastic crude oil and world prices. In addition, a number of sensitivity analyses are undertaken with different assumptions about the elasticities of the UK total biofuel consumption function and the overall level of EU biofuel demand.

4. Baseline Liquid Biofuel Projections

The purpose of the Baseline is not to produce a forecast, but rather to develop a yardstick against which policy simulations can be compared. As such it is usual in the FAPRI-EU model to take world prices and macroeconomic variables as exogenous. It is also usual to take policy that is in force at the time of the simulation, with any changes to policy in the projection years that have been agreed as incorporated. The Baseline therefore includes the phasing in of payments for new members, but does not try to anticipate changes under the WTO. In the case of biofuel, however, it has been necessary to take a cautious approach to EU policy.

EU Projections

At present it is the EU policy for renewable energy to comprise at least 10 percent of total transport energy in 2020, but the FAPRI-EU projections for liquid biofuel use have always been well below this for a number of reasons:

- i) It is envisioned by policy makers that second generation fuels will contribute by 2020. In the model only first generation fuels, ethanol from grain and sugar and biodiesel from vegetable oils are considered
- ii) The EU Commission also anticipates that electricity from renewable sources will contribute.

- iii) The Global FAPRI models could be simulated imposing the 10 percent target would be met but in practice this would lead to very high prices, especially for vegetable oils. It might be anticipated that under these circumstances countries would back off from their targets.

A summary of the EU-27 projections for the key variables in the baseline is presented in Table 1.

Table 1: Average of stochastic simulations for key variables in the baseline for the EU-27.

	2010	2020	Abs. change	% change
Biodiesel		000 tonne		
Capacity	22255	24576	2321	10%
Production	9540	13030	3490	37%
Consumption	12048	15666	3618	30%
Net trade	-2508	-2636	-128	5%
Price index	100	125		25%
Ethanol		000 tonne		
Capacity	5311	6117	806	15%
Production	3930	4833	903	23%
Consumption	4588	6218	1630	36%
Net trade	-658	-1385	-727	110%
Price index	100	97		-3%
Use as % trans.	4.6%	5.6%		
EU feedstock prices		euro/tonne		
Wheat	222	177	-45	-20%
Rapeseed oil	1036	863	-173	-17%

In the baseline consumption of first generation biofuels is assumed to rise only to 5.6 percent of total transport use. In the sensitivity analysis presented below a higher proportion of transport fuel is assumed to come from first generation fuels. In the baseline total transport fuel use is growing, largely on the basis of an expansion in fuel use in the new member states as for the large EU-15 countries growth in fuel use has largely stagnated in recent years.

Biodiesel capacity in Europe is well above production levels and there is therefore projected to be little increase in capacity over the production period. Consumption grows

by 3.4 million tonnes and most of this comes from domestic production. The issue of sustainability requirements is key and here imports of fuel are much less elastic than for ethanol given the sustainability concerns which apply to most imported biodiesel.

Ethanol capacity utilisation is much higher than for biodiesel and an increase in demand of 1.5 million tonnes requires a larger proportional expansion in capacity than for biodiesel. Production of ethanol rises by 21 per cent despite imports nearly doubling. Feedstock prices for both cereals and vegetable oils are expected to drop from their peaks in 2010 although remain at a high level relative to history.

UK projections

Total fuel use for road transport in the UK in 2010 amounted to 37.4 million tonnes of oil equivalent, which is about 12 per cent of total EU fuel use for road transport. Within the Baseline this contribution is projected to increase to 13 percent at the end of projection period. The total biofuel use in road transport in the UK in 2010 amounted to 1.1 million tonnes of oil equivalent, which is about 8 per cent of total EU biofuel use for road transport. While the UK contribution of total EU fuel use for road transport is projected to remain relatively constant, the UK contribution of total biofuel use is projected to moderately increase to 12 per cent.

Although the UK accounts for considerable amounts in both total fuel and biofuel use in the EU, the proportion of biofuel production is relatively small. The UK accounted for approximately 3 per cent of total EU biofuel production in 2010. This proportion is projected to increase to 6 per cent due to the planned investment in wheat-based ethanol production in the UK over the projection period.

Within the Baseline it is projected that biofuel accounts for 5 per cent of the total road transport fuel on the basis of volume in terms of litres by the end of projection period. This projected biofuel share is equal to the UK amended RTFO target but significantly less than EU Renewable Energy Directive target (10 per cent of the total transport fuel use on the basis of energy content).

The projected total biofuel consumption translates to an increase in projected UK biodiesel consumption of 40 per cent between 2010 and 2020. Projected UK biodiesel production increases by 65 per cent over the same period. The projected increase in production is based on the biodiesel capacity utilization increasing from 33 per cent in 2010 to approximately 50 per cent in 2020. The majority (60 per cent) of biodiesel production in the UK in 2010 was sourced from the "other" oil, which includes palm oil,

used cooking oil, tallow and “unknown” oil, but it is projected to decrease to 35 per cent at the end of the projection period. Soy and rape oil are respectively projected to account for 30 and 35 per cent of total biodiesel production in 2020. The net import of biodiesel is projected to increase over the projection period.

In addition, UK bioethanol consumption is projected to increase by 70 per cent between 2010 and 2020. Projected UK bioethanol production increases significantly over the same period (154 per cent). Projected bioethanol capacity utilization equals 57 per cent in 2020. Projected consumption and production leads to an increase in bioethanol net imports over the projection period. About 90 per cent of domestic bioethanol production is projected to come from wheat-based bioethanol. In response to increase of wheat-based bioethanol production, wheat demand for bioethanol production is projected to increase between 2010 and 2020.

5. Results

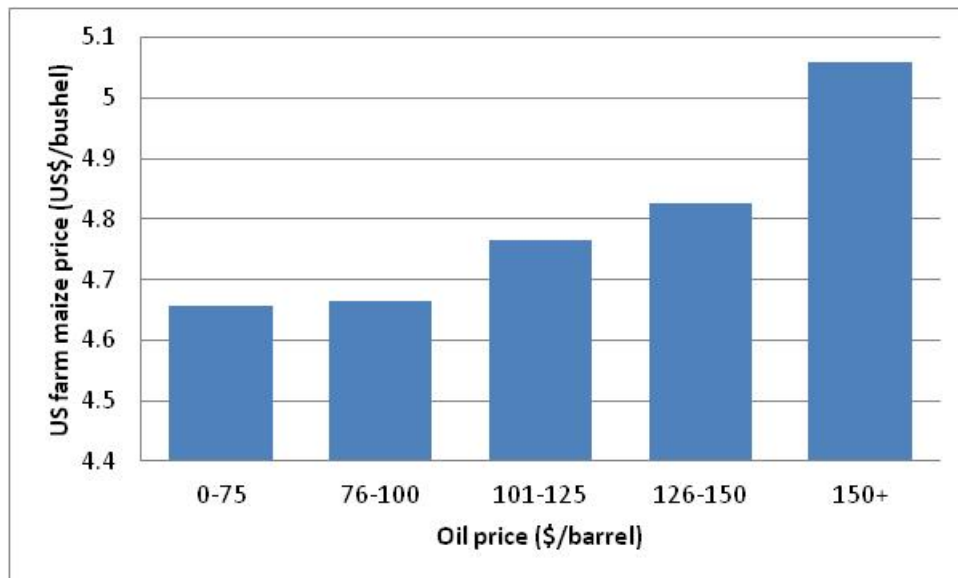
5.1. Main Analysis

EU and World Results

The expansion of the biofuels industry in the US mirrors that seen in the EU. In the US, however, it is ethanol that accounts for the majority of biofuels consumed and this is almost all produced from maize. In the US now as much maize goes into ethanol as goes into feed, and this has increased the link between developments in oil markets and agricultural markets. The exact link between these two markets is determined through policy, however and is not straightforward. To simplify there are three different ranges where the interaction differs. If oil prices are low relative to maize prices, then the mandates will bind and changes in oil prices will not result in changes in the demand for maize. As oil prices rise ethanol can become competitive with gasoline in low level blends, and this can pull use above the mandates and therefore oil price changes will influence use.

However, use in low level blends is constrained by technical restrictions. In order for ethanol use to exceed the blend wall, ethanol prices must reflect their energy disadvantage with gasoline. Once the stock of flex-fuel vehicles is large enough, and oil prices are high enough (or maize prices low enough) transmission of oil prices to maize prices is very high. The relationship between oil prices and maize prices for the US is shown in Figure 3. Increasing oil prices initially has no impact on maize prices, but over higher oil price ranges ethanol from maize becomes competitive with different blend-types of gasoline.

Figure 3: Projected Stochastic Relationship between Oil Price and US Maize Prices (average of 2012-2020).



The 500 projections of world prices that are generated for this analysis come from the stochastic simulation of the US model in the generation of the 2011 outlook. For example, each of the US maize prices that are shown in Figure 3 is converted into the fob equivalents that are used in the EU model. In order to do that it is necessary to adjust for transportation costs and these are strongly linked the oil price (which is different in each case too) and this effect strengthens the link between oil prices and commodity prices in the EU relative to the US. The world price appears in the EU model through the determination of the level of trade and therefore gets transmitted through to EU markets, although the EU price can move independently to the world price under some circumstances and this transmission varies by commodity.

As has been noted above there is a significant range where there is a strong link between petroleum prices and maize prices when ethanol is competitive with petrol. Biodiesel is rarely competitive with diesel in the US however and this market is largely mandate driven. The EU model functions in practice in a similar way to the US biodiesel market with mandates driving consumption to the most part, with only a small variation in consumption resulting from changes in the relative competitiveness of the fuels. Figures 4a and 4b show ethanol and biodiesel consumption for the EU as a whole. Note that although the relative fuel prices do not have a large impact on consumption, oil prices do determine the level of total fuel consumed and since mandates are mostly based on a percentage of fuel this feeds through to consumption of biofuels. This contrasts to the US situation where mandates are set on volumes of biofuel. For the EU-27, the variation in fuel consumption in tonnes for both biodiesel and ethanol are approximately the same, but due to lower consumption of petrol than diesel the variation is higher proportionally

for ethanol. This reflects a smaller spread between the petrol and ethanol price as compared with biodiesel and diesel.

Figure 4a: Biodeisel Consumption in the EU-27 ('000 tonnes)

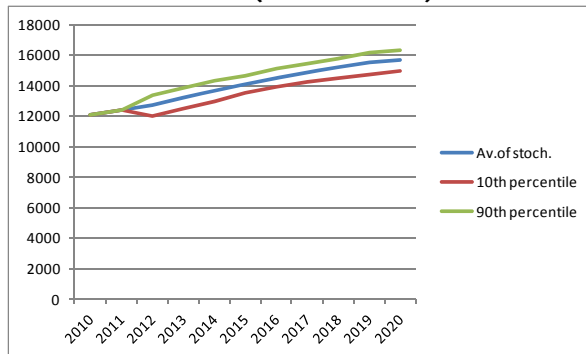
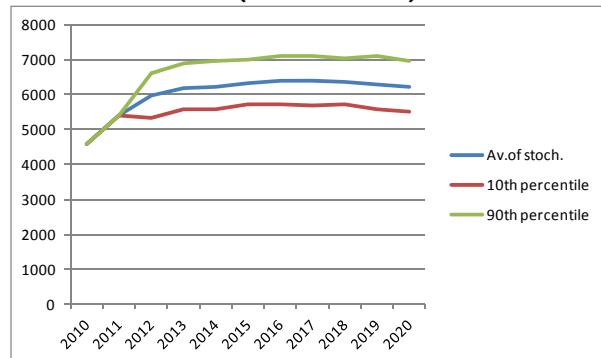


Figure 4b: Ethanol Consumption in the EU-27 ('000 tonnes)



Factors on the supply side also impact the transmission of prices through markets. It has been noted above how the US maize price is linked to oil prices. Although the US biodiesel mandate is almost always binding oil prices can still influence soybean prices through their competition for land and this means that the world prices for the oilseed complex are still correlated to some degree with oil prices. The same applies to the EU market, which is mainly mandate driven. The extent to which these feedstock prices influence biofuels markets is dependent on the characteristics of the market concerned. Figure 5a and 5b show the relationship between the most popular feedstock and its corresponding biofuel price.

Figure 5a: Projected Stochastic Relationship between Wheat Price and Ethanol Price (2020)

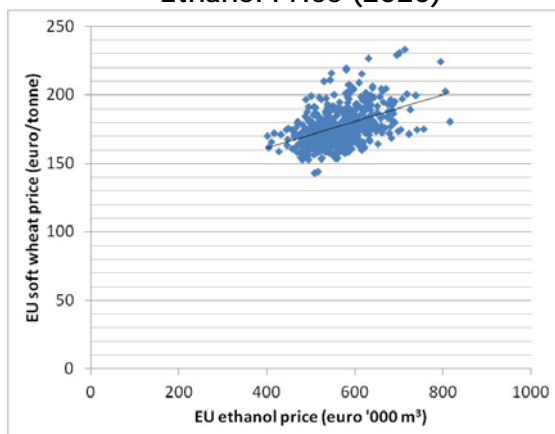
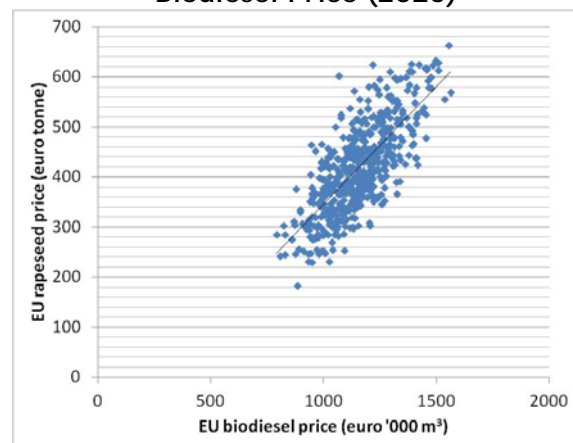


Figure 5b: Projected Stochastic Relationship between Rapeseed Price and Biodiesel Price (2020)



It can be seen in Figure 5a and Figure 5b that the rapeseed price and biodiesel price follow each other more closely than the wheat and ethanol price, although both have a strong positive relationship as would be expected. There are a number of factors that are

important in the determination of this relationship. One is the number of substitutes that are available for feedstocks. In the case of ethanol there are a greater variety of feedstocks in use at the moment including wheat, barley, maize and some other cereals, wine and sugar. In the model biodiesel is allocated between rapeseed and soybeans, with an “other” category that includes other fats and oils, so there is more substitution in feedstocks with ethanol.

The structure of the industry itself is also important. EU biofuels policy spurred a massive expansion in biodiesel capacity in the EU, while ethanol capacity has not seen the same explosive growth. Ethanol capacity utilisation runs at about 80 percent on average for the EU-27 as a whole over the projection period, whereas for biodiesel capacity utilisation starts at 43 percent and climbs to just over 50 percent by 2020 on average. In general, lower levels of capacity utilisation result in a higher pass through of changes in feedstock prices to final biofuel prices as higher returns to production are quickly bid away by increased output.

Another important influence on the transmission of feedstock prices (and hence oil prices) on to agricultural markets is trade. The issue of trade is very important in determining the reaction of the sector to changes in energy prices or feedstock prices. For ethanol, with production near capacity, for large changes in consumption prices must rise enough to prompt investment in new capacity, but this will not happen if import supply is very elastic. For biodiesel there is ample capacity, but with rapeseed taking up a high share of domestic production, EU producers could find themselves at a competitive disadvantage if relative prices of feedstocks change, and domestic users were free to source their products from overseas. However, existing tariffs restrict imports, and the implementation of sustainability requirements will hamper imports. In the EU model at present the issue is simplified, trade is determined by relative domestic and international prices adjusted for tariffs currently in place, but a higher elasticity is assumed for ethanol than for biodiesel as it is assumed that imported (sugar based) ethanol more easily achieves the sustainability requirements than (soybean or palm based) biodiesel (shown in Figure 6a and 6b).

Figure 6a: Bioethanol Net Trade in the EU-27 (1000 tonnes, 2020)

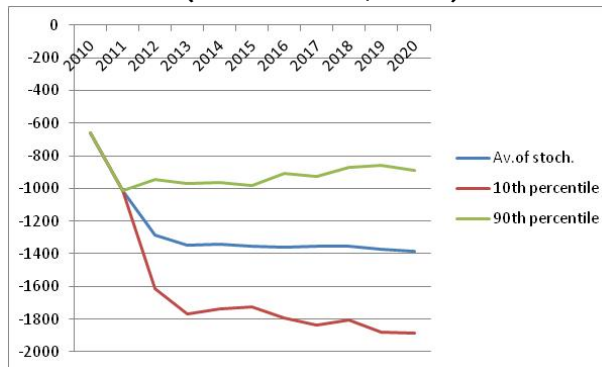
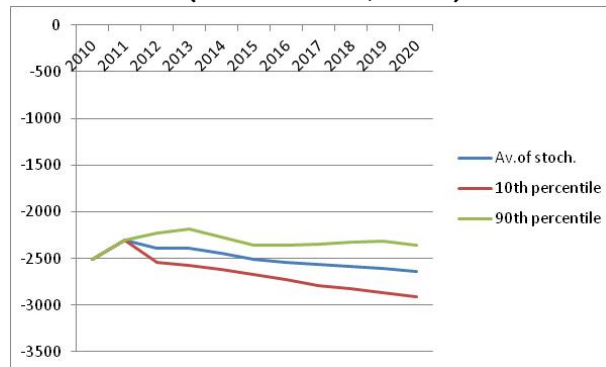


Figure 6b: Biodiesel Net Trade in the EU-27 (1000 tonnes, 2020)



The stochastic process that is used here is the first step in a process to incorporate a range of uncertainties into the FAPRI-Europe modelling system. World prices are generated from the simulation of the US model and imposed on the EU system and so there is no feedback in these simulations onto world markets from changes in the EU. It is impossible to include all of the member states policies for biofuels, and in particular the option to not meet the mandates at high prices is not incorporated for any country other than for the UK under the RTFO as detailed below. In practice many countries have the possibility for this to happen in their policies.

UK Results

Biofuels Sector

As in the rest of the EU, the crude oil price has a positive impact on bioethanol and biodiesel prices in the UK (Figure 7). These in turn influence UK bioethanol and biodiesel production. However, net returns for biofuel production are also affected by input costs, wheat and vegetable oil prices, which also vary to some extent with oil prices (see below). Vegetable oil prices increase by more than the wheat price and hence biodiesel net returns are offset more by a higher oil price than bioethanol net returns. Overall, a higher crude oil price leads to an increase in bioethanol and biodiesel production in the UK (Figure 8). Projected UK bioethanol production is more responsive to the crude oil price than UK biodiesel production due to the differences in net returns.

Figure 7: Projected Stochastic Relationship between Oil Price and UK Biofuel Prices (2020)

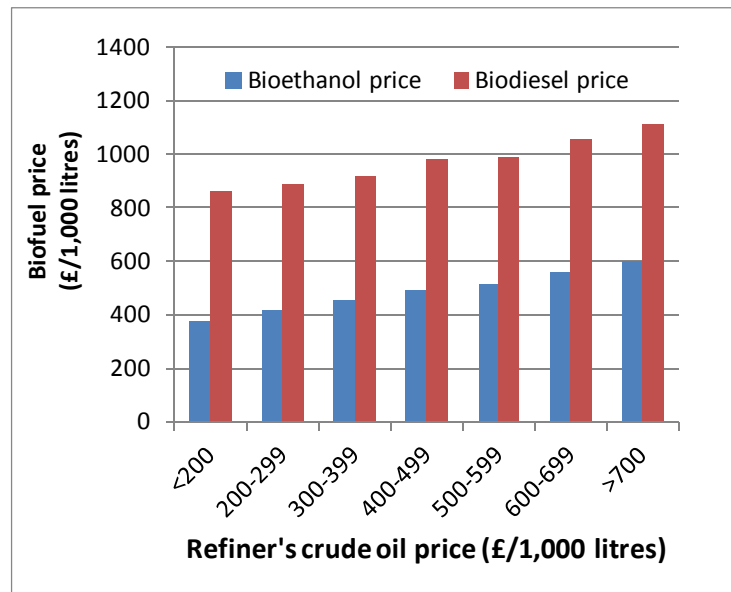
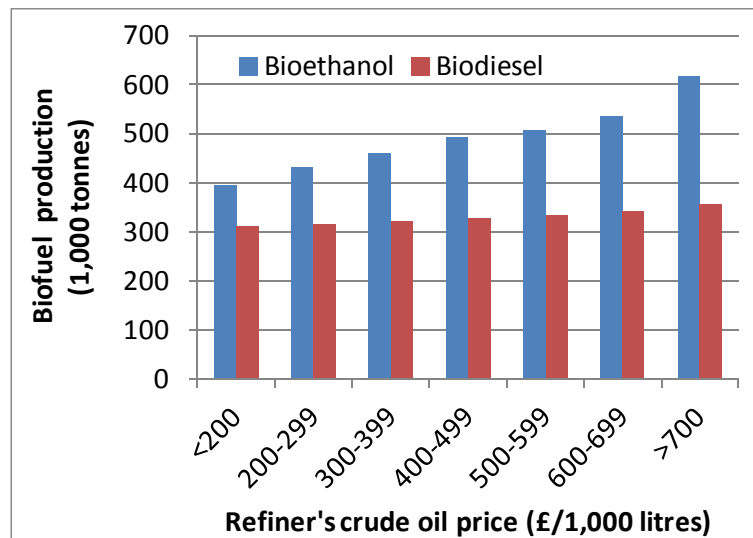


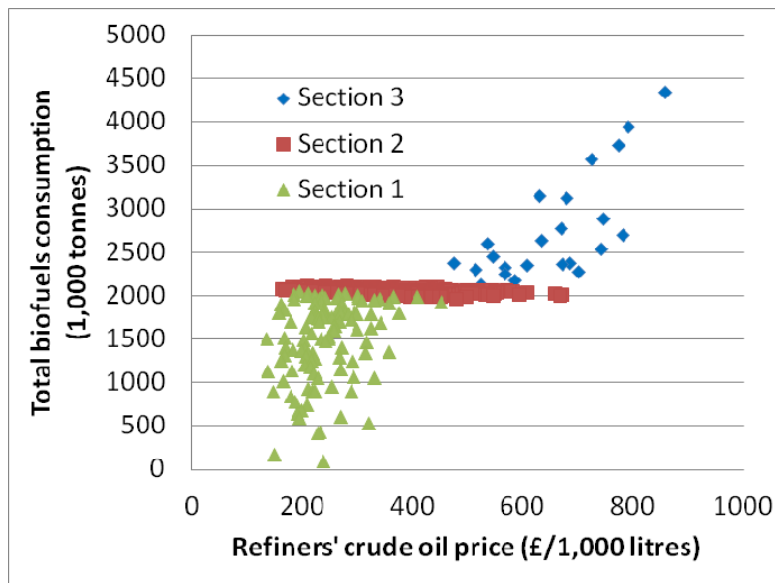
Figure 8: Projected Stochastic Relationship between Oil Price and UK Biofuel Production (2020)



The projected relationship between the oil price and total UK biofuels consumption at the end of the projection period (i.e. 2020) is shown in Figure 9. The dispersal of the observations reflects the specified kinked demand curve discussed in Section 3. The green observations refer to simulations in which the price difference between weighted biofuels and weighted fossil fuel exceeds the buy-out price (30 pence/litre) and obligated fuel suppliers have little incentive to meet the RTFO target, i.e. Section 1 of Figure 1. In general, this is more likely to occur when the oil price is low and accounts for 23 per cent of the 500 observations. The red observations denote simulations in which the price difference lies in between zero and the buy-out price, i.e. Section 2. Under these

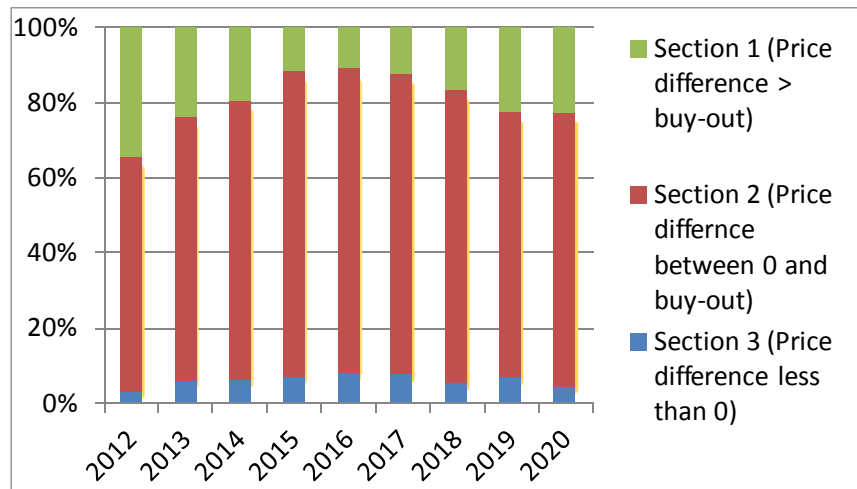
circumstances there is an inelastic relationship between the oil price and total biofuels consumption since obligated fuel suppliers opt to simply fulfil the RTFO target. This section covers a wide range of oil prices and accounts for 73 per cent of the 500 observations. The blue observations refer to simulations in which the weighted biofuel price is less than the weighted fossil fuel price, i.e. Section 3. Under these circumstances biofuels is competitive relative to fossil fuels and biofuels consumption increases significantly. This is more likely to occur when oil prices are high and only accounts for 4 per cent of the observations.

Figure 9: Projected Stochastic Relationship between Oil Price and Total UK Biofuel Consumption (2020)



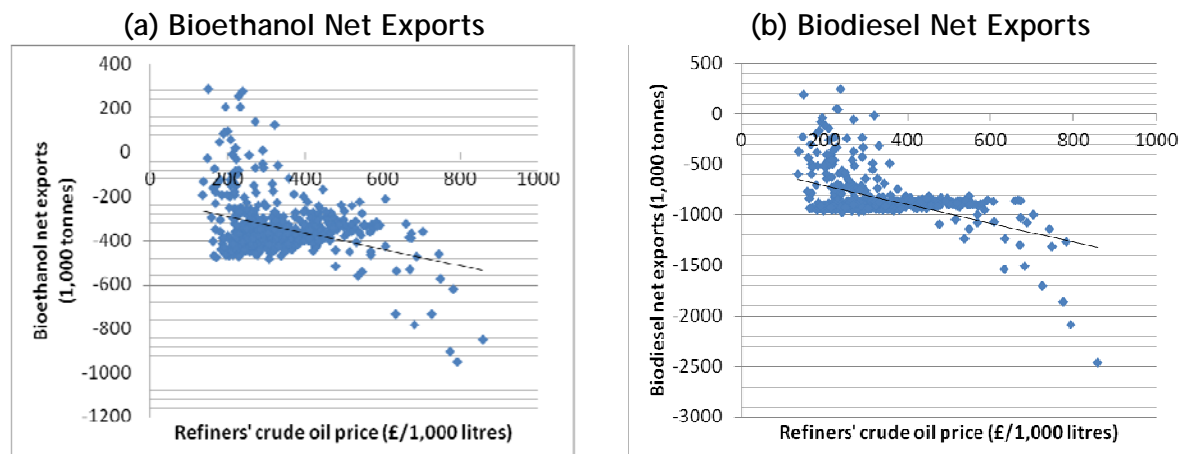
The proportion of observations that fall within different sections of the kinked demand curve depends upon the projected paths of biofuel and fossil prices over time. Within the baseline biofuels improves in competitiveness between 2011 and 2016, before decreasing in competitiveness. Consequently, the proportion of observations that achieve the RTFO target increases between 2011 and 2016, but decline slightly at the end of the period (Figure 10). However, as expected, the stochastic simulations indicate that only a small proportion of observations lie within Section 3 where biofuels is competitive relative to fossil fuel.

Figure 10: Proportion of Observations Within Different Sections of the Kinked UK Biofuel Consumption Function



The projected variability in total biofuel consumption impacts projected trade of biofuels in the UK. As shown in Figure 11 (figures refer to the end of the projection period, i.e. 2020), projected net exports of bioethanol and biodiesel are largely unresponsive to variations in oil prices. However, under certain circumstances when the RTFO target is not filled (Section 1 of the kinked consumption function) the need for imports falls sharply. Conversely, at very high oil prices when biofuels are competitive (Section 3 of the kinked consumption function), imports increase dramatically to meet the significant increase in biofuels consumption.

Figure 11: Projected Stochastic Relationship between Oil Price and UK Biofuel Net Exports (2020)

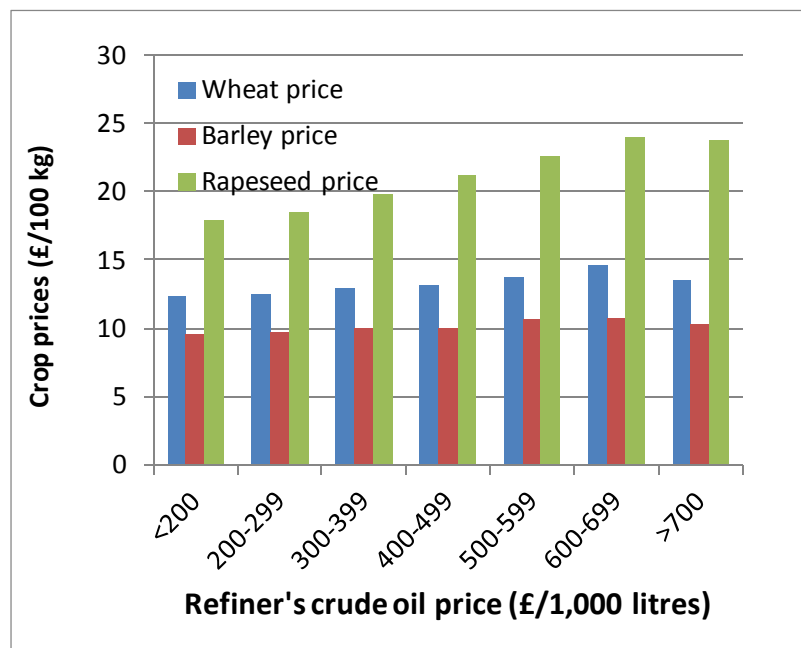


Note: diagrams refer to production minus consumption

Agricultural Sector

As shown in Figure 12, there is a positive relationship between the crude oil price and the price of crops, but the rapeseed price is more correlated to oil price changes than wheat and barley. As the crude oil price increases there is increased demand for feedstocks for biofuels production. This increased demand for feedstocks exerts an upward impact on the price of crops used for biofuel production. The lower transmission for cereals is partly due to the potential for substitution between grains for use as feedstocks and within the demand for each grain (alternative uses such as for animal feed and human consumption), which means that individual grain feedstocks are less affected compared to individual oilseeds where there are fewer substitution possibilities. In addition, higher biofuels production leads to increased DDGS production (as a by-product of bioethanol production), which replaces the feed grains. This exerts a downward impact on domestic wheat and barley use and hence the price of grains. Moreover, as discussed below, livestock numbers fall in response to higher crude oil prices, partly due to higher feed costs, but also due to higher fertiliser costs. The reduction in livestock numbers has a depressing impact on the demand for animal feed.

Figure 12: Projected Stochastic Relationship between Oil Price and UK Crop Prices (2020)



It is projected that crop areas and production in the UK are unresponsive to variable crude oil prices. While an increase in the crude oil price leads to higher crop prices, which exerts an upward impact on the returns to crop production, this is offset by higher input costs. Similarly, it is projected that there is a weak relationship between crude oil prices and wheat and barley domestic use since the demand for biofuel feedstocks is offset by the demand for animal feed. Higher crude oil prices increase the competitiveness of

biofuels and, once the price difference between biofuels and fossil fuels is below zero, lead to increased biofuel demand. However, higher crude oil prices also increase input costs for livestock production, which in turn reduces animal feed demand.

In contrast, rapeseed domestic use increases slightly in response to higher vegetable oil demand for increasing biodiesel production when oil prices are higher. Although an increase in the oil price increases input costs for livestock production, which in turn reduces animal feed demand, rapemeal demand does not show a corresponding decline. Increasing biodiesel production leads to increased rape meal production, as a by-product of biodiesel made of rape oil, which in the model is domestically used for animal feed as a replacement for soymeal.

Volatility in crude oil prices also exerts a moderate impact on the livestock sector. It is projected that cattle numbers and sheep numbers decline in response to higher crude oil prices (Figures 13 and 14). As discussed above, crude oil prices have a limited impact on crop prices and consequently, the knock-on impact on feed ingredient prices is small. Livestock input costs are impacted to a greater extent by variable fertiliser costs. At the same time, returns to livestock production are affected by output prices. Crude oil prices are weakly positively correlated with output prices. Overall, the rise in input costs outweighs the rise in output prices in the beef and sheep sectors. The pig sector is less responsive to variable oil prices due to the weak impact on feed ingredient costs.

Figure 13: Projected Stochastic Relationship between Oil Price and UK Total Cattle (2020)

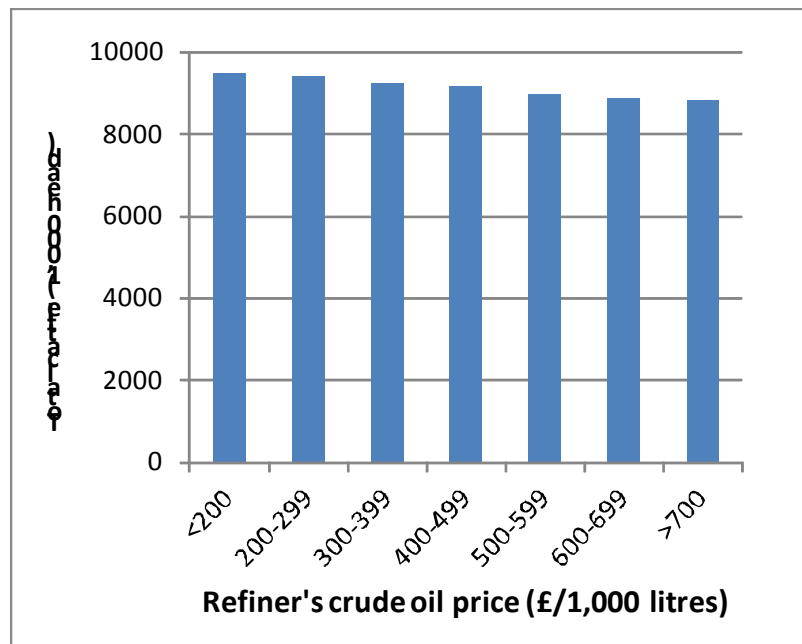
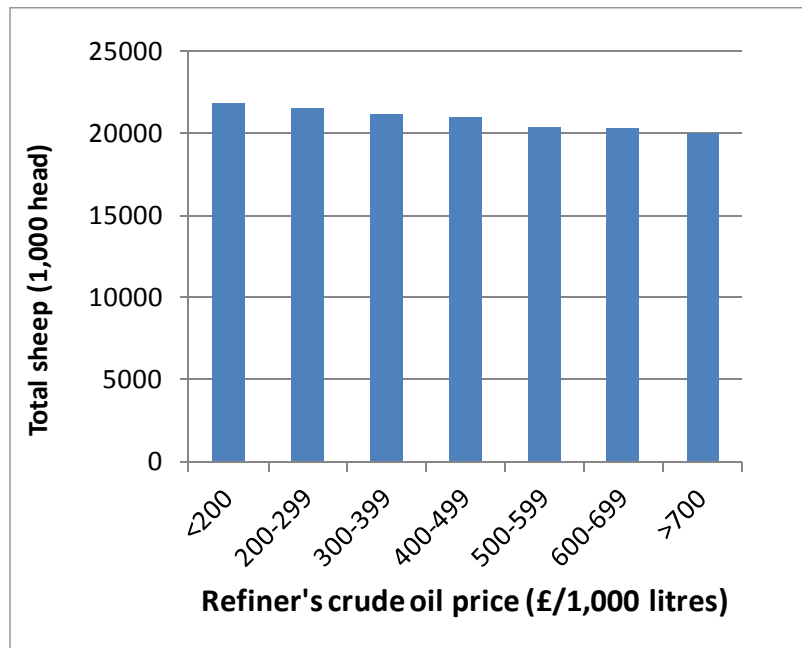
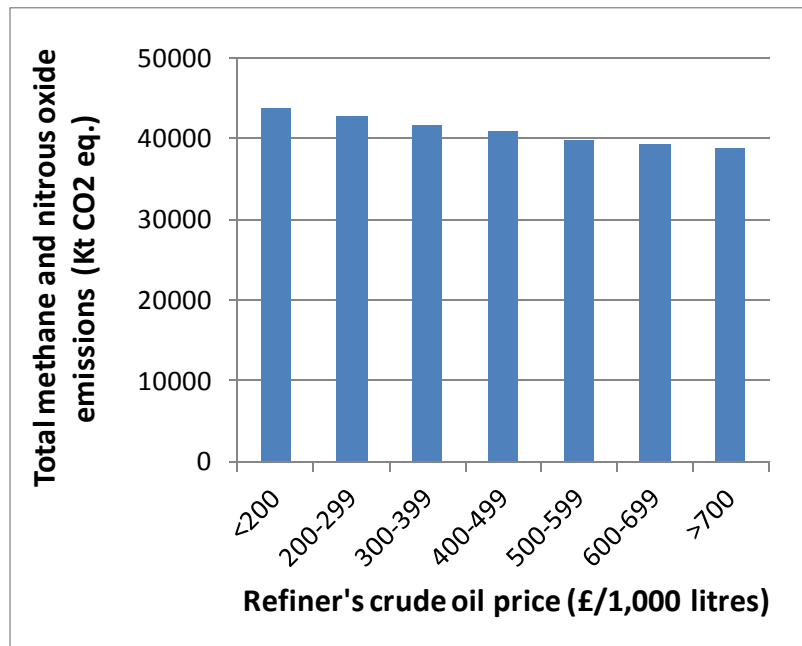


Figure 14: Projected Stochastic Relationship between Oil Price and UK Total Sheep (2020)



The volatility in crude oil prices also has a knock-on impact on greenhouse gas emissions from agriculture. Linking the FAPRI-UK greenhouse gas sub-model (Patton *et al.* (2010)) to the stochastic modelling system, it is projected that total methane and nitrous oxide emissions in the UK are negatively related to crude oil prices (Figure 15). This partly reflects the projected fall in livestock numbers at higher crude oil prices, which impacts methane emissions from enteric fermentation and manure management and nitrous oxide emissions from manure management and agricultural soils. In addition, it is projected that there is a decline in grassland fertiliser application at higher oil prices, which impacts nitrous oxide emissions from agricultural soils. Grassland fertiliser application decreases in response to the projected fall in animal numbers and increases in the fertiliser price. However, it should be noted that there is uncertainty regarding the extent to which fertiliser application can fall, particularly at the very high oil prices.

Figure 15: Projected Stochastic Relationship between Oil Price and Total UK Methane and Nitrous Oxide Emissions (2020)



5.2. Sensitivity Analyses

(i) Different elasticities for the UK biofuel consumption function.

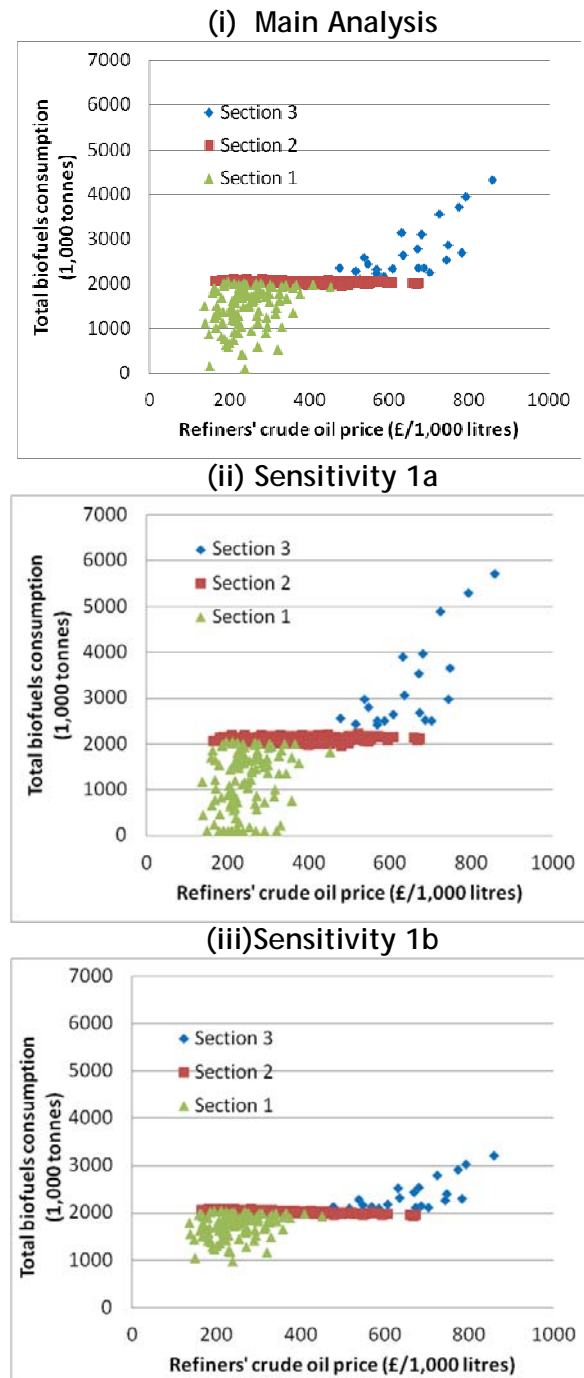
As an emerging sector, it is not possible to estimate coefficients for UK biofuel demand using historical data. Rather the elasticities for the different sections of the kinked UK biofuels consumption function are based on analyst judgement. In order to test the consequences of the assumptions used for the different sections of the UK biofuel consumption function in the main analysis, sensitivity analyses were undertaken using different elasticities.

Sensitivity analysis 1(a): it is assumed that the slopes of the different sections of the demand function are more elastic (slope of each section is doubled).

Sensitivity analysis 1(b): it is assumed that the slopes of the different sections of the demand function are more inelastic (slope of each section is halved).

The impact of these different assumptions on the relationship between the crude oil price and UK biofuel consumption is shown in Figure 16. The number of observations within the different sections of the demand function remains the same compared to the main analysis. Thus, the of majority of observations (73 per cent) under sensitivity analyses 1a and 1b lie within Section 2 of the demand function and it is projected biofuel demand is close to the RTFO target. However, when it is assumed that biofuel demand is more elastic (Sensitivity 1a), biofuel demand increases (decreases) sharply when the price difference is less than zero (greater than 30 pence/litre). Conversely, when it is assumed that biofuel demand is more inelastic (Sensitivity 1b), biofuels demand does not diverge from the RTFO target to the same extent.

Figure 16: Projected Stochastic Relationship between Oil Price and Total UK Biofuel Consumption (2020)



As shown in Figures 17 and 18, the main impact of the changes in projected biofuel consumption when the price difference either exceeds the buy-out price or is less than zero is on net trade of bioethanol and biodiesel. Under Sensitivity 1a, the need for imports increases significantly at high oil prices when biofuel is competitive and decreases sharply at very low prices when the price difference exceeds the buy-out price. In contrast, it is projected that bioethanol and biodiesel net trade does not change to the same extent at different oil prices under Sensitivity 1b.

Figure 17: Projected Stochastic Relationship between Oil Price and UK Bioethanol Net Exports (2020)

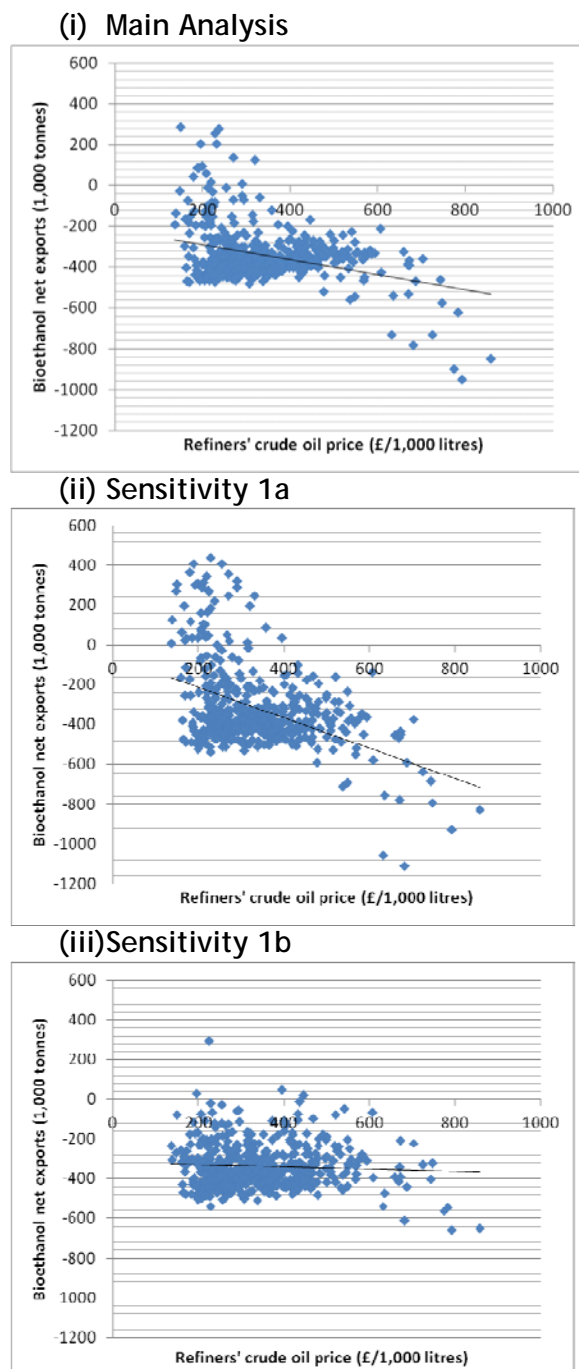
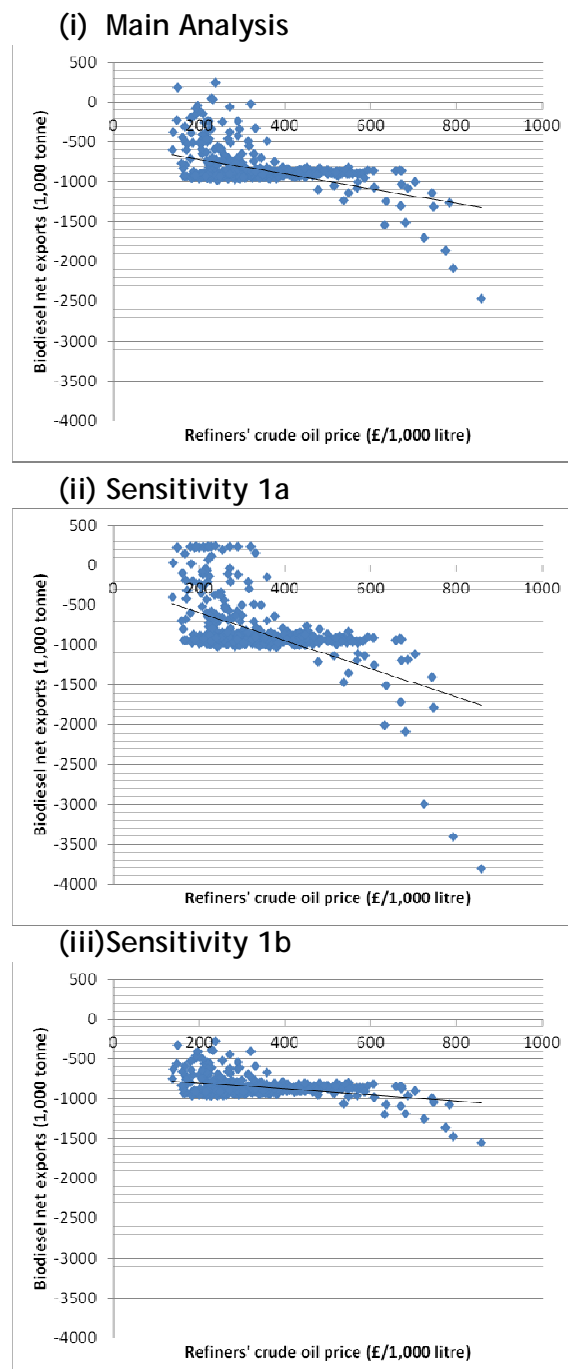


Figure 18: Projected Stochastic Relationship between Oil Price and UK Biodiesel Net Exports (2020)

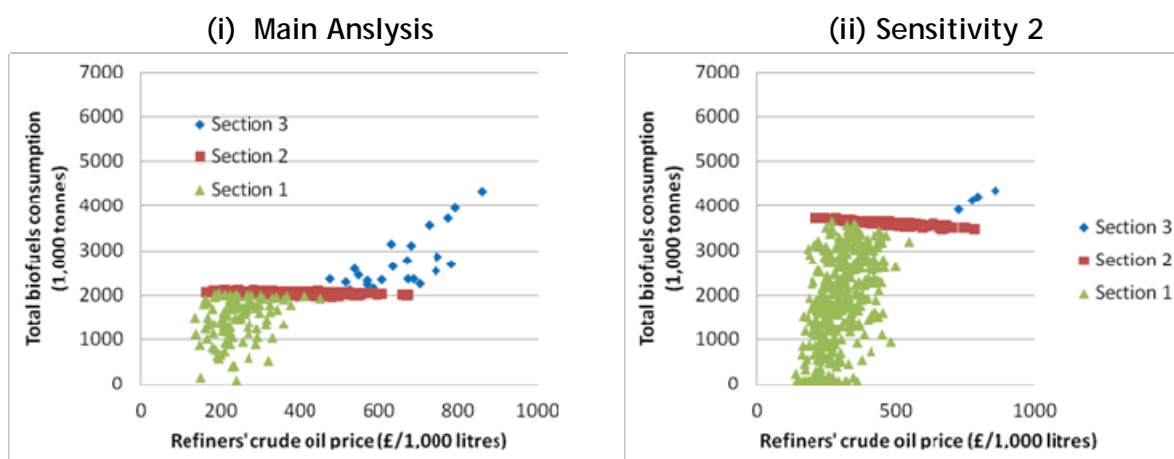


(ii) Increase EU biofuel consumption to 10 per cent of total transport fuel use in energy content.

As discussed in Section 4, underlying the main analysis it is projected that the EU obtains less than 10 per cent (on the basis of energy content) from first generation biofuels in 2020. Within this sensitivity analysis it is assumed that EU biofuels consumption reaches 10 per cent in 2018 (increases by a constant from 2012 to 2018) in order to gain a better understanding of the impact of this assumption. It should be noted that this is not a realistic assumption since the Commission expects to obtain at least some of this fuel from electricity or second generation biofuels. Thus, this sensitivity analysis should be interpreted as an extreme assumption.

Increasing the proportion of biofuels in total transport fuel use exerts an upward impact on the prices of biofuels. The average biodiesel and bioethanol prices increase by 20 and 13 per cent, respectively. The projected increase in biofuel prices reduces the competitiveness of this fuel relative to fossil fuel, impacting biofuel consumption in the UK. As shown in Figure 19, under the sensitivity analysis a greater proportion of observations exceed the buy-out price and biofuel consumption fails to meet the RTFO target (76 per cent in 2020 under the sensitivity, compared to 23 per cent under the main analysis). This suggests that it would be necessary to raise the buy-out price if first generation biofuel is solely used to meet the EU 10 per cent target.

Figure 19: Projected Stochastic Relationship between Oil Price and Total UK Biofuel Consumption (2020)



6. Conclusions

Within this study a partial equilibrium modelling system is used to examine the extent to which price volatility in the energy sector is transmitted to the biofuel and agricultural sectors. The model simulations highlight the complex interactions between the different sectors. In order to determine the overall impact of oil price volatility it is necessary to employ a comprehensive modelling system, which not only accounts for feedstock demand for biofuel production, but also the production of by-products and animal feed demands due to the impact of oil price volatility on input costs and hence animal numbers.

The stochastic results indicate that there is a positive correlation between crude oil prices, biofuels prices and feedstock prices. The UK biofuel modelling system has been adapted by incorporating a kinked demand curve, which reflects biofuel policy in the UK. Within the stochastic projections, the RTFO target is filled for the majority of observations under the main analysis. However, under certain circumstances UK consumption may diverge from the RTFO target. In particular, when oil prices are extremely low UK biofuel consumption may fall below the mandate level. Conversely, when oil prices are extremely high UK biofuel consumption may exceed the target, although this is unlikely as indicated by the small proportion of observations in which this occurs. As demonstrated by the sensitivity analysis (Sensitivity analysis 2), the proportion of observations in which the RTFO target is not filled increases when it is assumed that the EU mandate is met using first generation biofuels.

References

- Binfield J., Westhoff P. and Le Cadre E. (2008) Incorporating biofuels into a partial equilibrium model of the EU agricultural sector. Paper prepared for presentation at the 107th EAAE Seminar "Modelling of Agricultural and Rural Development Policies", Sevilla, Spain, 29 January - 1 February 2008.
- Busse S., Brümmer B. and Ihle R. (2010) The Pattern of Integration between Fossil Fuel and Vegetable Oil Markets: The Case of Biodiesel in Germany. Paper presented at the Agricultural & Applied Economics Association 2010 AAEA, CAES, & WAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010.
- Ciaian P. and d'Artis K. (2010) Interdependencies in the Energy-Bioenergy-Food Price Systems: A Cointegration Analysis. Paper presented at the Agricultural & Applied Economics Association 2010 AAEA, CAES, & WAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010.
- European Commission (2008) Commission's / EU's response to the high oil and food prices. European Commission memo 08/421, Brussels, 19 June 2008.
- Fabiosa J.F. (2009) The Impact of the Crude Oil Price on the Livestock Sector under a Regime of Integrated Energy and Grain Markets. Paper presented at the Agricultural &

Applied Economics Association 2009 AAEA & ACCI Joint Annual Meeting, Milwaukee, Wisconsin, July 26-29, 2009

Harri A., Nalley L. and Hudson D. (2009) The Relationship between Oil, Exchange Rates and Commodity Prices. *Journal of Agricultural and Applied Economics*, 41,2(August 2009):501-510.

Kim I.S., Moss J., Patton M., Zhang L., Binfield J. and Westhoff P. (2010) "FAPRI-UK Modelling of the UK Liquid Biofuels Sector." Final report submitted to Defra, DARD, SEERAD and WAG, 1 December 2010.

[http://www.defra.gov.uk/evidence/economics/foodfarm/reports/fapri/Biofuels%20paper%20\(Dec%202010\).pdf](http://www.defra.gov.uk/evidence/economics/foodfarm/reports/fapri/Biofuels%20paper%20(Dec%202010).pdf)

Meyer S., Binfield J. and Westhoff P. (2010) Interactions Between Energy Markets and Agriculture in the U.S.: A Stochastic Approach. *Journal of International Agricultural Trade and Development*, Vol. 6(1).

Moss J., Binfield J., Zhang L., Patton M. and Kim I.S. (2011) A Stochastic Analysis of the Impact of Volatile World Agricultural Prices on European and UK Agriculture. Paper presented at the 85th Annual Conference of the Agricultural Economics Society, Warwick University, 18 - 20 April 2011.

Moss J., Zhang L., Patton M., Kim I.S., Binfield J. and Westhoff P. (2010) "FAPRI-UK Analysis of Volatile World Agricultural Prices: A Stochastic Approach." Final report submitted to Defra, DARD, SEERAD and WAG, 1 December 2010.

[http://www.defra.gov.uk/evidence/economics/foodfarm/reports/fapri/GHG%20Paper%20\(Dec%202010\).pdf](http://www.defra.gov.uk/evidence/economics/foodfarm/reports/fapri/GHG%20Paper%20(Dec%202010).pdf)

Thompson W., Meyer S. and Westhoff P. (2009) How does petroleum price and corn yield volatility affect ethanol markets with and without an ethanol use mandate? *Energy Policy*, vol. 37, pp 745-749.

Tokgoz S. (2009) The Impact of Energy Markets on the EU Agricultural Sector. Working Paper 09-WP 485, Centre for Agricultural and Rural Development, Iowa State University, January 2009.

Yano Y., Blandford D., Surry Y (2010) The Impact of Feedstock Supply and Petroleum Price Variability on Domestic Biofuel and Feedstock Markets - The Case of the United States. Working Paper Series 2010:3, Swedish University of Agricultural Sciences (SLU), Department of Economics.