European Commission Consultation on Indirect Land Use Impacts of Biofuels – October 2010

Appendix 2:
Detailed Comments on:
"Indirect Land Use Change from Increased Biofuels Demand" ***(JRC, Edwards)***
"The Impact of Land Use Change On Greenhouse Gas Emissions From Biofuels And Bioliquids" ***(Literature Review)***
"Impacts of the EU biofuel target on agricultural markets and land use: a comparative modelling assessment" (*JRC, edited by Burnell*)

Legislators need to understand how ILUC differs between biofuels from different feedstocks and regions. However, there is currently no consensus on the modelling methods and model parameters that should be used to determine the GHG emissions from ILUC.

Several models and methods have been developed to calculate GHG emissions from indirect land use change (ILUC) due to biofuel production. The models are intended to be used to:

- Identify biofuel crops/regions where production is liable to lead to adverse land use changes, so that additional sustainability requirements can be applied to the production of such biofuels.
- Determine an indirect land use change factor (ILUC factor) in greenhouse gas calculations for biofuels. The ILUC factors would need to depend on type of biofuel, where the biofuel crop is used and the use of the biofuel co-products.

ILUC Modelling

It is generally recognised that ILUC models will need to include the following steps (DGTREN 2009)

- What crops are displaced by biofuel crop co-products?
- How much of the increased production of each crop in each region is met by land area change and how much by yield growth?
- How much of the increased demand in a region is met by increased production in the region land how much by changes in trade?
- Where extra cropland is required, what type of land is converted to cropland?
- What are the GHG emissions from the converted land?

It is also generally accepted that the effects of biofuels on land use change should be determined on a consequential (substitution or system expansion) basis, rather than an allocation (attributional) basis (DGENVI 2009, EPA 2009).

Some methods for estimating GHG emissions from ILUC use an allocation method and do not include the steps above. These methods are answering the question of GHG emissions from ILUC due to cultivation in general, rather than the ILUC effects of a biofuels policy. They do not attempt to adequately differentiate between the ILUC effects of different biofuel crops and regions and are not considered further.

Consequential modelling of demand and supply relationships must be done by establishing empirical economic driven relationships between variables by fitting historic data. Since biofuel targets are quantity driven, the effects can modelled directly, using direct elasticities related to demand growth, for example by establishing the proportion of demand changes that will be supplied by yield changes and area changes. Alternatively the effects can be modelled indirectly using price elasticity factors, for example by determining the effects of increased demand on prices and then fitting land area changes to these prices. Both approaches should give similar overall results, although there is more 'noise' in price relationships due to price volatility and variations in regional price and input costs.

Consequential modelling of the effects of biofuels can either be done using integral models to compare a biofuel scenario to a baseline scenario, or if response functions are linear, a differential model can be used to determine ILUC factors directly. With the use of integral models, there is much debate about what baseline and biofuel scenarios should be used, but with differential models this unnecessary for calculating the GHG emissions per MJ of biofuel.

Most of the work on ILUC modelling has been done using large macro-economic models or agro-economic models.

Macro-economic models

Macro-economic (macro-economic) models are integral models and can be divided into two types:

- Computable general equilibrium models.
- Partial equilibrium models

Computable general equilibrium (CGE) models.

These models are all based on the Global Trade Analysis Project GTAP (O'Hare 2009), which was written to determine the effects of tariff changes on trade flows. Various versions of the GTAP model are available and different versions have been or are being used by different groups. GTAP based models have or are being IFPRI (Valin 2009), LEITAP (Prins 2009). The California Air Resources Board (CARB) used a GTAP based model to calculate GHG emissions from indirect land use change (ILUC) due to biofuel production.

Partial equilibrium models

These models are more varied and flexible than the GTAP based models and some models have been developed specifically to model ILUC. Partial equilibrium models have been or are being developed by Aglink, ESIM, CAPRI, FAPRI. The US Environmental Protection Agency (EPA 2009) has used of FAPRI and others to determine ILUC factors for US biofuels.

Details of issues with macro-economic models

Transparency

In order to check the validity of a modelling approach, or to understand why different models give different results, it is important to know the justification for the modelling approaches that are adopted, the data fitting processes and data that have been used to determine parameters, for example elasticities, in the model. In many cases this is lacking in macro-economic models.

Although the database and source code for the GTAP model is available on the internet, this does not provide the data needed to validate the models.

Some examples of the transparency issue are listed below and explained more fully under relevant sections.

- Lack of clarity of modelling approach: modelling of oil seed markets and changes in trade patterns

- Lack of justification of modelling approaches: assumption of constant yield growth rate and use of Armington elasticities for changes in trade patterns.
- Lack of references: sources for the model elasticities factors are not provided.
- Lack of a firm basis for assumptions: the elasticity used to account for lower yield on new land used to grow biofuel crops is justified by "best judgement".

Accounting for biofuel co-products

Biofuel co-products used for animal feed displace other crops and can provide a substantial credit to the GHG emissions from ILUC. The production of biofuels from crops such as cereals and oilseeds gives high protein co-products that are normally used for animal feed. They will replace the variable animal feed components in the production regions, which for the EU, are wheat exports and soy meal imports.

In the US substantial quantities of corn DDGS are used as liquid feeds or other direct feeds in local feedlots, so mainly displace corn feed. However, the animal feed industry in the EU operates differently from in the US. In the EU, most of the DDGS from bioethanol plants is dried and used in formulated animal feed. The costs of high protein animal feed i.e. imported soy meal in the EU are substantially higher then energy feeds such as wheat. Therefore animal feed compounders will maximize the use of DDGS and rape meal (as with other co-products) to displace soy meal (CE Delft 2008, Lywood 2009a), to minimize the overall cost of the feed. The levels of essential amino acids (EAAs) in DDGS are supplemented by addition of synthetic EAAs such as lysine, threonine and methionine to boost protein quality. The price of DDGS and rape meal (as with other co-products) used in EU animal feed adjust so that they will be fully utilised for animal feed. Therefore in the EU, biofuel co-products will economically displace a mixture of soy meal and cereal. The digestible protein level of DDGS is greater than that of all oilseed meals except soy meal, so will displace soy meal on the same basis as for rape meal and sunflower meal. The substitution ratios of co-product for soy meal and cereal are such as to give the same digestible energy and digestible protein level of the resulting animal feed (Marshall 2006, Lywood 2009a).

Accounting for co-products in models

Many studies and macro-economic models do not account properly for biofuel co-products. Some models such as LEITAP, do not account for co-products at all, while others such as AGLINK do not account for the high protein value of DDGS co-products and simply substitute DDGS for corn on a weight basis. Some models e.g. IFPRI allow for rape meal to substitute for soy meal, but do not allow DDGS to substitute for soy meal, even though DDGS has a higher digestible protein content than rape meal.

A primary reason why the displacement of soy meal by DDGS is not modelled in many macro-economic models is that the architecture of the macro-economic models does not allow it. Most macro-economic models are segmented into different sectors, for example oilseeds (or oilseed meals) and cereals and this segmentation simply does not allow for the co-product from one sector i.e. cereals to substitute for part of a different sectors i.e. oilseeds (or oilseed meals).

Instead of correcting the models to enable DDGS to displace soy meal, it has apparently been argued by some modelers that although DDGS is not properly accounted for in GTAP based models, the effect of this on GHG emissions from land use change is small. On a weight basis, the amount of soy meal displaced (0.18 t / t wheat) may be regarded as small. However, when translated into GHG emissions from ILUC, the effects are far greater. The reasons (Lywood 2009b, ADAS 2010) for this are:

- The yield of soy is substantially lower than the yield of EU wheat
- The increased demand for EU wheat is primarily met by yield increases, whereas the increased demand for soy is primarily met by land area increases

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- New wheat land in the EU will be obtained from using unused land or reducing the rate of creating idle land, while new soy land in S America is obtained from a mixture of deforestation and conversion of grassland to cropland.

Modelling of biofuel co-products used for animal feed, including their protein content, is essential and the results from models that do not include appropriate modelling should be discarded.

The lack of proper accounting for co-products used as animal feed, in macro-economic models will cause a substantial overestimation of the GHG emissions from ILUC for biofuels from cereals and oilseed rape in the EU.

Modelling of the oilseeds market

Modelling of the oilseeds market is needed to understand the land use changes resulting both from making biodiesel from vegetable oil and to determine the credit for high protein biofuel co-products, such as DDGS and rape meal, that are used for animal feed. Different oilseeds have very different oil and meal yields. Most oilseeds are grown primarily for the oil, with a lower value meal by-product, while soybean is primarily grown for the meal.

It may be seen that for rape, sunflower and palm, the vegetable oil is significantly more valuable than the meal and it is generally accepted that the crop is being grown primarily for the vegetable oil. However, in the case of soy bean, the meal has a significantly higher value than the oil and the typical oil yield from soy is substantially lower than for other oilseeds. It cannot therefore be economic to grow soy primarily for the oil (USDA 2009).

FAO work on animal feed demand (FAO 2006) concluded that soy meal is the variable global source of protein meals to meet the demand for high protein animal feed. Soya bean growth is being driven by the global demand for soy meal to meet the increasing demand for animal feed protein. It follows that the substitution of soy meal by high protein biofuel co-products will reduce the growth rate of soya bean output growth.

80% of the increase in trade in vegetable oils over the last decade has been from palm oil (USDA 2009). Since the soy oil increase is driven by the increased demand for soy meal, 89% of the increase in the marginal trade of vegetable oils has been met by increased palm oil production. It may therefore be concluded that palm oil is the primary variable global source to meet the growing global demands for vegetable oil. It follows that the use of soy oil to make biodiesel will not primarily affect the growth rate of soya bean and will be replaced in the vegetable oil market by increased production of palm oil.

The GTAP models aggregate all the oilseed crops into a single sector. Therefore as well as not being able to model the soy meal substitution of co-products, it also has to assume some sort of average yield of vegetable oil for the production of biodiesel. The oil yield of palm oil is about ten times that of soy oil, so the increase in land area for vegetable oil for biodiesel will be very sensitive to the split of vegetable oils that is used to calculate the average oil yield, the split is not provided. Since soy oil used to make biodiesel will be replaced by increased production of palm oil, the soy oil yield is not relevant in calculating the average oil yield. Inclusion of the soy oil yield in the calculation of the average oil yield will overestimate the land area required for biofuels.

FAPRI appears to assume that soybean is grown primarily for the meal and the demand for vegetable oil will be met by imported soy oil. It can be shown below that soy is grown primarily for the meal, rather than primarily for the oil. The assumption that soy is just grown primarily for its oil, rather than primarily for its meal will lead to an overestimation of the overall land used for the production of soy biodiesel and underestimate the land saved by soy meal replacement by other high protein biofuel co-products. These will both cause an overestimation of indirect land use change.

Relating land area growth and yield growth to demand growth

Economics of supply and demand dictate that higher demand for crops for biofuels will drive higher prices, which will in turn drive investment for increased output. Increased output will require additional investment and can either arise by land area increase, yield increases, or by increases in the frequency of cropping. Therefore in the medium term, the proportion of the increased supply of crops that will be met by land area change, or yield change, will differ by crop and region, depending on the relative economics of obtaining increased output from additional cultivated land area, additional yield and increased cropping frequency. Most of the available data on crops, e.g. FAO provides crop yield and crop harvested area, but there is much less data on cropping frequency. The effects of cropping frequency are therefore not often considered.

There are many ways in which crop yields can be improved, for example: crop variety development, fungicide treated seeds, adoption of technology, increases in inputs such as fertilisers and pesticides, increased mechanisation allows a longer growing season, precision farming allows improved timing selective spatial input addition, improved drainage, use of improved crop varieties and pesticides allows changes to the crop rotation to reduce the proportion of fallow land and maximise the use of higher yielding crops.

Relating land area and yield growth to prices

While many views have been expressed on the relationship between yield growth and price, little analytical work has resulted in statistically significant elasticity factors. Keeney & Hertel (2008) summarised some of this work and concluded that taken as a group, the studies show that there is a relationship between price and yield growth.

It cannot be assumed that just because a statistically significant relationship between yield changes and prices has not been found, that the effect of price on yield growth is negligible. To justify the assumption of "inelastic yield", analysis must show that there is a relationship between land area growth and prices with no corresponding relationship between yield growth and prices. Little if any evidence has provided on this.

Clearly since increased crop output is driven by higher prices, there must be relationships between land area growth, yield growth and prices or margins. If it is not possible to find significant price elasticities from simplistic models, then more appropriate ways of relating yield growth and area growth to prices must be found. Three reasons why elasticity factors relating yield changes and area changes to price changes, have been difficult to determine are:

- the timescale for yield increases,
- large year to year yield changes due to weather.
- use of prices rather than price changes

Most of the analysis work has focused on short term relationships between price changes and yield changes to obtain a yield vs price elasticity, it takes time to obtain increased output as a result of higher margins. The effect of prices takes between one and five years to be fully reflected in yield and land area changes due to the investment timescale of cultivating new land, infrastructure improvements, introduction of modern machinery, and adoption of higher yielding crop varieties in the years following high prices.

As pointed out by Searchinger (2008), high yields in one year will tend to produce abundant crops that lower prices and low yields result in high prices, confusing the causal relationship. These problems can be largely overcome by using a one year lag between prices and yield changes and by averaging yields changes and prices over a few years.

Technology improvements are not discarded in the case of falling prices (Kloverpris 2008). The increase in output growth is therefore related more closely to prices, or margins than to price changes.

Reasonable fits to historic data can be found, by fitting to the prices relative to the long term trend price as long as it is done in an appropriate way (Lywood 2009b). Lywood showed that:

- There is a statistically high confidence that yield growth is not independent of price
- There is therefore no apparent 'normal' rate of yield growth independent of prices.
- Most of the increased output of wheat is from higher yield growth, not from higher land area growth.

It is therefore not valid as in many macro-economic models to assume that the rate of yield growth is unrelated to price or to the growth in demand.

For some crops in some regions, it is still difficult to find relationships between changes in output and prices, due to other factors such as changes in variable input costs and changes in agricultural subsidies. In these cases alternative approaches can be taken to determine the split between yield growth and area growth.

IFPRI (Rosegrant *et al.* 2001) assume that yield growth and area growth both respond to increased prices, and derives elasticity factors for yield and area based on expert estimates.

Some models, include an elasticity factor for yield changes with price changes, the source data for the elasticity factor is not provided. Since neither an output vs price or area vs price elasticity is provided, the relative proportions of the demand growth that is met by yield growth and area growth is not known.

Relating land area growth and yield growth to demand growth

Most macro-economic models do not account for the increased yield growth due to increased demand growth and determine the land area growth indirectly by subtracting a yield growth estimate from the demand growth. The yield growth estimate is often an exogenous value that does not properly account for changes in yield growth as a result of demand growth. The models therefore assume that all the increase in demand above the estimated yield growth is met by land area change.

The lack of modelling of the proportion of demand growth from yield growth and area growth will cause an overestimation of the GHG emissions from ILUC.

Modelling of yield growth in models

It might be expected that economic models would determine the proportion of the increased demand of crops from land area change and yield change, by relating these changes to prices in the same way as they determine output/price elasticities. However none of the macro-economic models determine crop land area changes in this way. Even though the determination of land area changes is a primary step in the calculation of ILUC, few macro-economic models determine or use factors to relate land area changes to prices.

Most macro-economic models attribute increases in yield to technological gains that are independent of market signals, while attributing year to year variations in yield to the weather (Keeney and Hertel 2008). Other models split yield growth into increased inputs and improved technology. The models determine the land area growth indirectly by subtracting a yield growth estimate from the demand growth. The yield growth is estimated in different ways. FAPRI assumes an exogenous yield growth rate based on average historic yield growth rates. Thus in these models, yield growth is not related to price or to output growth at all. The effect of this assumption is that if the forecast output growth is greater than the exogenous yield growth rate, the incremental land area growth will be assumed to be met entirely by land area growth. While this approximation may not matter for some uses of macro-economic models, for example determining trade flows, the proper representation of crop yield and land area growth is absolutely critical for the determination of ILUC and accurate representations must be used.

Even though work was been done (IFPRI 2001) to provide yield vs price and area vs price elasticities, IFPRI are not using these factors in the IFPRI model.

It is not clear that any current macro-economic models have validated their approach by demonstrating that their predictions of past perturbations in crop land areas satisfactorily match those observed.

The lack of proper modelling of land area change in macro-economic models, by assuming that yield growth rate is unrelated to output growth rate causes an overestimation of the GHG emissions from ILUC for most crops.

Factor for lower yield on new land area

It is possible that when new land is needed to grow extra crop, the new land will be more marginal than the existing cropland, so the yield on the new land will be lower than on existing land. In the models this effect is termed “slippage” and the models use an elasticity factor to relate the yield on new land to the yield on existing cropland. The effect of slippage is subtracted from the yield growth. However little empirical evidence exists to guide modellers in selecting the most appropriate value.

Historic yield change data for example from FAO is collected on an average regional or country basis and is the net yield growth. Therefore these yield changes already take into account any effect of lower yield on new land. As long as a relationship derived from historic yield data is used to relate yield growth to prices or to demand growth, then these relationships already includes the effects of slippage and there is no justification for a separate elasticity factor for a fractional yield on new land area.

If modellers believe that changes in demand effects net yield growth, they must derive a relationship between demand growth and yield growth. If modellers believe that changes in demand growth do not effect net yield growth, they cannot justify the use of a slippage factor. A choice has to be made between the two methods

The use of an elasticity factor to relate the yield on new land to existing yields is not justified. When yield growth estimates are based on historic regional yield data. The effect of introducing such a factor results in overestimating land area changes as a result of crop demand increases.

Increased yield with increased price

Some models include a yield vs price elasticity such that the yield in any year may be higher due to a higher price in that year. This is attributed to increased crop inputs such as fertiliser. However, this effect of price only applies to the specific year, so has a minimal effect on the yield increase over a period of years. It does not model the increased yield growth with increased demand over a multi-year period, which has a major effect on the proportion of demand growth that is met by yield growth and area growth.

Relationship between yield changes and fertiliser prices.

A factor is introduced in some GTAP based models (Valin 2009a) to relate yield changes to fertiliser prices. This would be useful in modelling of historic data, in order to see the effect of energy prices on fertiliser prices and yield growth. However, the justification for this in macro-economic models is that increased crop demand will increase fertiliser demand, which will increase fertiliser prices, which will lead to lower fertiliser application and hence lower yields. Since all the evidence (Figures 1-3, IFPRI 2001) shows that higher demand and higher prices increase yield growth, fertiliser prices will be a second order feedback effect in this relationship. The effect of changes in fertiliser prices will be included within any relationship between yield growth and price or output growth and should therefore not be included as a separate factor.

The use of a factor to relate the yield changes to fertiliser prices is not justified and the effect of introducing such a factor results in overestimating land area changes as a result of crop demand increases.

Changes to trade in biofuel crops

When crops are used for biofuel production, in is important to determine in which country or region the additional crop will be grown, in order to determine the land use changes. If there is an increased demand for a crop, for example in the EU, due to increased biofuel demand, then some of this demand is met within the EU, while some of the demand is met by changes in trade: reduced exports or increased imports. For biofuel crops that are primarily imported into the EU or where a crop product or the biofuel itself is imported into the EU, it may be assumed that increased EU demand will be met primarily or entirely by increases in imports.

Crops, such as cereals, which are widely grown locally, the transport costs are high compared to the value of the crop and therefore many regions maintain a self sufficiency of these crops and the crop output is adjusted to meet demand. Increased demand for crops for which the region is self sufficient will primarily be made up by increased production in that region.

Lywood (Lywood 2010) showed that although cereal yields continued to increase in the EU, increased production has been avoided by idling of excess land. The EU maintains a rough trade balance on cereals because of the significant differences in logistics costs associated with being a net importer and net exporter.

The proportions of increased crop demand that will be met by increased production and by changes in trade can be determined directly using factors to relate the change in trade flows and change in production to changes in demand. However, there is no statistically significant relationship between EU demand changes and changes in net imports. Lywood [Lywood 2010] showed that nearly all the change in EU demand for cereals is provided by changes in EU production and very little will be met by changes in trade.

FAPRI for example does not even state how changes in trade are modelled. Often an elasticity of substitution (Armington elasticity) is used to determine how much of the change in crop demand due to biofuels crops is met by increased imports or reduced exports. The elasticity relates the change in marginal imports to changes in prices in trading countries or regions. None of the models details the value or the source of the elasticity of substitution being used, let alone provide any justification of the factor.

There are some concerns about the use of the Armington model for modelling cereals in the EU:

- The Armington elasticity model assumes that each country produces its own set of products which are somewhat differentiated from products from elsewhere and therefore products from different countries are imperfect substitutes of each other. However, cereals, for example wheat used in animal feed rations from different sources is interchangeable and not differentiated between countries.
- The Armington elasticity model does not take account of changes in logistics costs associated with switching from net import to net export or vice versa, when a country or region is close to a trade balance. Due to the high transport cost, relative to the production cost of cereals, it would be expected that local production changes would be used to meet changes in local demand.
- There has been much debate on what is the correct value of Armington elasticity factors to be used for changes in trade as a result of duty changes. (McDaniel 2002).

The issue of modelling changes in trade was not addressed in the DGENERGY literature review.

If macro-economic modellers still want to use Armington elasticity factors, based on theoretical price changes and hypothetical demand elasticities, they should validate their factors, by back testing with historic data.

Type of Land Changes

Various approaches have been taken by different models to determine what types of land are converted to cropland in different countries. As the Literature review points out there is 40% discrepancy in the current crop area between the different methods, the accuracy of satellite data must be considerably improved before it can be used for monitoring land use changes.

The elasticities used for the EU work are listed (Valin 2009) based on OECD work [OECD2008]. The substitution elasticity factors between agricultural v forest and cropland v pasture can be used to determine the proportions by which new cropland will displace forest and pasture, or by which forest and pasture will arise on idled cropland.

The IFPRI (Valin 2009b) LEITAP (Prins 2009) models are also evaluating an option to use land supply curves in a deterministic modelling approach to determine the lowest cost option for obtaining new cropland from different areas of natural vegetation.

These approaches have been developed for global land use change modelling and do not take into account changes in fallow land, temporary grassland and unused land, which are relevant in the EU and CIS. Also they do not take account of specific policies that have been driving land use change in the EU. About 4 million ha of former set-aside idle land were created within the EU, which have now been released for cropland to meet the increased demands for biofuels.

A detailed analysis of agricultural land in the EU, using FAO data (Lywood 2010) shows that:

- The area of arable land in the EU has reduced continuously since 1961 with an average reduction of 0.4 million ha/year from 1985 to 2007 (FAO 2009a)
- The rate at which EU cropland is idled is related to the EU demand of arable crops.
- Therefore the increase in demand for EU biofuel crops will be met by use of former set-aside land and a reduction in the rate of creation of idle land in the EU.
- Most of the idled land in the EU is left for natural succession and only 12% of the idled land is subsequently afforested.
- Using carbon accumulation rates of 0.34 t C/ha/yr for natural succession (Post and Kwon 2000 and 1.5 t C/ha/yr for afforestation (Greig 2007), the average level of foregone sequestration is 0.48 t C/ha/yr

The lack of inclusion in the macro-economic models of unused and idle land in the EU and abandoned land in CIS will cause an overestimate of the GHG emissions from ILUC of biofuel crops grown in the EU and CIS.

Validation of models

It may be seen that several of the issues of concern with macro-economic models are common to several of the models. Also nearly all of the issues of concern appear to lead to an overestimation of the GHG emissions from ILUC, especially for crops grown within the EU. It is therefore not valid to draw any conclusions on the accuracy of macro-economic models, or the uncertainties in ILUC factors, or the potential range of ILUC factors by comparing the results of macro-economic models with each other.

For predictions to be trusted, the macro-economic models need to be validated, back testing predictions of past perturbations in crop land and grassland areas, trade flows etc satisfactorily match those observed. It is not clear whether any macro-economic models have been validated in this way.

There are problems with validating macro-economic models against recent predicted outcomes (Babcock 2009), due to other random variables that might affect these outcomes. However, other ways must be found of validating these models.

Evaluation of policy

Some macro-economic models are seeking to evaluate the land use changes and GHG emissions from ILUC associated with a complete policy, for example the EU 2020 renewable energy for transport target. Since macro-economic models are based on prices they can attempt to determine the most economic way for fuel producers to meet the target using biofuels. However, there are substantial difficulties with this approach:

- Some biofuel pathways will be restricted by the higher RED GHG savings thresholds that will be in place from 2014 and especially after 2017
- The choice of options for meeting the RED transport target will also depend on the GHG savings of different biofuel pathways and the need to meet the FQD target.
- The relative proportions of biodiesel, bioethanol and other renewable fuels will depend on vehicle limitations on the use of fuel blends in the EU
- The use of high blends such as E85 will depend on decisions by car manufacturers
- The uptake of high blends by motorists will depend on incentives provided in different Member States.

Since macro-economic modelling cannot take account these effects, the models should concentrate on the ILUC impacts of different biofuels.

Modelling Approach

Although macro-economic models use economic analysis for much of the modelling, there are several factors that have been modelled using exogenous factors, rather than by economic analysis. These are:

- Proportion of increased crop output supplied by land area changes
- Displacement ratios of other crops by biofuel co-products
- Proportion of demand changes that are met by changes in trade
- What type of land is converted to extra cropland

This may be because more work is needed to be able to use economic modelling, or because economic modelling is not appropriate for some of these relationships.

Different models have chosen different ways of modelling these and other factors. It is important to try to move to some level of agreement between modellers, as to which factors are best modelled by different methods i.e. deterministic cost optimisation, price elasticities, direct elasticities and other empirical models based on historic data. Use of "expert judgement" is not appropriate, for the derivation of ILUC factors that could determine the viability of some biofuel investments.

A substantial part of the reports and presentations on macro-economic models is associated with description and justification of model platforms, model structure and model linking. There are also descriptions of novel approaches or methods for modelling particular relationships. There is somewhat less justification for the method chosen for modelling different relationships. There is little or no justification of the parameters used in the models and the data sources.

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There is a concern that much of the effort has been in developing more complicated models, rather than determining and justifying values of the parameters used in the models. It may be of more value to develop simpler models, for example spreadsheet based differential models, which use agreed methods for modelling those factors and determine the parameters that are most important for determining GHG emissions from ILUC.

Comparison of Models

The JRC study provides a detailed comparison of three models: Aglink, ESIM (Banse) and Capri. The models were used to assess the impacts of the current EU biofuels policy on land use and on agricultural production. Results and model specifications are compared. The models show large differences with respect to level of aggregation (commodities, land units), which makes it difficult to compare spatial outcomes in a disaggregated way. Models also have different methods to incorporate policies, or biofuel supply and demand or in the way co-products are generated during biofuel production. Co-products can have a significant ILUC mitigating effect and the models do not have the correct mechanics to calculate this.

Given these differences, it comes as no surprise that modelling outcomes seem insufficiently unanimous as to predict what (indirect) land use effects the EU policy will have. Large differences are found as to what areas will be needed, both within and outside Europe, what crops will have to be produced and what GHG effects displacement of current food production may be expected. It must, therefore, be concluded that reliability of current model outcomes is insufficient to generate the information required to asses GHG impacts of ILUC for policy applications. The study also highlights the lack of data to back test modelling work against.

Models appear sensitive to assumptions and aggregations of data and outcomes, while essential elements of biofuel production such as generation of co-products either at the crop level or the biofuel production still are not fully accommodated.

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