View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Research Papers in Economics

ECONSTOR

WWW.ECONSTOR.EU

Der Open-Access-Publikationsserver der ZBW – Leibniz-Informationszentrum Wirtschaft
The Open Access Publication Server of the ZBW – Leibniz Information Centre for Economics

Mongelli, Ignazio; Löschel, Andreas; Neuwahl, Frederik; Delgado, Luis

Working Paper

Employment Impacts of EU Biofuels Policy: Combining Bottom-up Technology Information and Sectoral Market Simulations in an Input-output Framework

ZEW Discussion Papers, No. 08-049

Provided in cooperation with:
Zentrum für Europäische Wirtschaftsforschung (ZEW)

Suggested citation: Mongelli, Ignazio; Löschel, Andreas; Neuwahl, Frederik; Delgado, Luis (2008) : Employment Impacts of EU Biofuels Policy: Combining Bottom-up Technology Information and Sectoral Market Simulations in an Input-output Framework, ZEW Discussion Papers, No. 08-049, http://hdl.handle.net/10419/24745

Nutzungsbedingungen:
Die ZBW räumt Ihnen als Nutzerin/Nutzer das unentgeltliche, räumlich unbeschränkte und zeitlich auf die Dauer des Schutzrechts beschränkte einfache Recht ein, das ausgewählte Werk im Rahmen der unter
→ http://www.econstor.eu/dspace/Nutzungsbedingungen
nachzulesenden vollständigen Nutzungsbedingungen zu vervielfältigen, mit denen die Nutzerin/der Nutzer sich durch die erste Nutzung einverstanden erklärt.

Terms of use:
The ZBW grants you, the user, the non-exclusive right to use the selected work free of charge, territorially unrestricted and within the time limit of the term of the property rights according to the terms specified at
→ http://www.econstor.eu/dspace/Nutzungsbedingungen
By the first use of the selected work the user agrees and declares to comply with these terms of use.

ZBW Leibniz-Informationszentrum Wirtschaft
Leibniz Information Centre for Economics

Mitglied der Leibniz-Gemeinschaft

Discussion Paper No. 08-049

Employment Impacts of EU Biofuels Policy: Combining Bottom-up Technology Information and Sectoral Market Simulations in an Input-output Framework

Frederik Neuwahl, Andreas Löschel,
Ignazio Mongelli, and Luis Delgado

ZEW

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research

Discussion Paper No. 08-049

Employment Impacts of EU Biofuels Policy: Combining Bottom-up Technology Information and Sectoral Market Simulations in an Input-output Framework

Frederik Neuwahl, Andreas Löschel,
Ignazio Mongelli, and Luis Delgado

Non-Technical Summary

This paper analyses the employment consequences of policies aimed to support biofuels in the European Union. The promotion of biofuel use has been advocated as a means to promote the sustainable use of natural resources and to reduce greenhouse gas emissions originating from transport activities on the one hand, and to reduce dependence on imported oil and thereby increase security of the European energy supply on the other hand. The employment impacts of increasing biofuels shares are calculated by taking into account a set of elements comprising the demand for capital goods required to produce biofuels, the additional demand for agricultural feedstock, higher fuel prices or reduced household budget in the case of price subsidisation, price effects ensuing from a hypothetical world oil price reduction linked to substitution in the EU market, and price impacts on agro-food commodities. This paper uses input-output methods to combine information originating from bottom-up studies and energy and agricultural simulations that were conducted in parallel and used as input to the input output (IO) model. This paper complements the existing literature in several ways. From a policy point of view, it provides a rich set of simulation results for several policy-relevant biofuels penetration scenarios under different financing schemes including a set of sensitivity runs. From a methodological point of view, we provide an extension of previous input-output approaches by combining bottom-up technology information and sectoral market simulations in our input-output framework. The input-output model is based on a 57-sector input-output table for the EU-25, whereas 7 new sectors were then added to the IO table to describe petrol and diesel fuels and their bio-based substitutes - bioethanol and biodiesel each produced by two different technologies - and a sector providing the capital goods for the production of biofuels. The input-output model incorporates different modules, including a mixed endogenous-exogenous variables IO model (which was used to accommodate constraints on agricultural production), an IO price model that computed the endogenous vector of commodity prices after an exogenous price increase, and a Quadratic Almost Ideal Demand System, which calculated the final demand vector subject to prices and to the household budget. The calculations refer to scenarios for the year 2020 targets as set out by the recent Renewable Energy Roadmap. The results indicate that policies that effectively promote the use of biofuels in the EU-25 up to a substitution share of some 15% would not cause adverse employment effects, assuming that sufficiently mature biofuel production technology is at our disposal. In the build-up of the approximately neutral net employment effects, several sectoral and causal chain effects interact to compensate inefficiency losses. Particularly important factors that show the potential to yield positive contributions are the development of a strong

EU industry in the world market for biofuel technology and the possible impacts in terms of moderating world oil price through reduction in demand. Finally, the results do not indicate major differences of net employment impacts in two alternative policy cases envisaging either subsidising the cost disadvantage of biofuels through increased direct taxation or mandating a minimum biofuels blending share, in which case the fuel price at the filling station would reflect the additional production cost.

Das Wichtigste in Kürze

In diesem Papier werden die Beschäftigungswirkungen der Förderung von Biokraftstoffen in der Europäischen Union untersucht. Die Förderung von Biokraftstoffen wird mit der nachhaltigen Nutzung natürlicher Ressourcen, der Reduktion von Treibhausgasemissionen im Transportsektor und der Verminderung der Erdölabhängigkeit und damit einhergehender erhöhter Energiesicherheit in Europa begründet. Bei der Quantifizierung der Beschäftigungseffekte der Biokraftstoffförderung in Europa wurden verschiedene Effekte berücksichtigt: gesteigerte Nachfrage nach Agrarerzeugnissen und Kapitalgütern zu Herstellung von Biokraftstoffen, höhere Kraftstoffpreise, Preisrückgänge auf dem Rohölmarkt infolge der Substitutionseffekte des Biokraftstoffeinsatzes und Preissteigerungen bei Agrarprodukten und Lebensmitteln. Dazu wird ein Input-Output Modell um die Biokraftstofferzeugung erweitert und mit Partialmodellen des Agrar- und Energiesektors gekoppelt. Als besonders wichtige Faktoren für potentielle Beschäftigungseffekte haben sich die Entwicklung einer auf den Weltmärkten führenden EU Biokraftstoffindustrie und der abschwächende Effekte der Biokraftstoffe auf den Ölpreis erwiesen. Die Simulationen legen nahe, dass sich die verschiedenen positiven und negativen Effekte weitgehend kompensieren und ein Biokraftstoffanteil von 10 – 15 Prozent ohne signifikant negative Beschäftigungseffekte erzielt werden kann.

Employment impacts of EU biofuels policy: Combining bottom-up technology information and sectoral market simulations in an input-output framework *

Frederik NEUWAHL [a], Andreas LÖSCHEL [b],
Ignazio MONGELLI [a], and Luis DELGADO [a]

[a] European Commission, Joint Research Centre,
Institute for Prospective Technological Studies (IPTS)
Edificio Expo, c/ Inca Garcilaso s/n, 41072 Seville, SPAIN
[b] Centre for European Economic Research (ZEW),
L7,1, 68161 Mannheim, GERMANY

ABSTRACT: This paper analyses the employment consequences of policies aimed to support biofuels in the European Union. The promotion of biofuel use has been advocated as a means to promote the sustainable use of natural resources and to reduce greenhouse gas emissions originating from transport activities on the one hand, and to reduce dependence on imported oil and thereby increase security of the European energy supply on the other hand. The employment impacts of increasing biofuels shares are calculated by taking into account a set of elements comprising the demand for capital goods required to produce biofuels, the additional demand for agricultural feedstock, higher fuel prices or reduced household budget in the case of price subsidisation, price effects ensuing from a hypothetical world oil price reduction linked to substitution in the EU market, and price impacts on agro-food commodities. The calculations refer to scenarios for the year 2020 targets as set out by the recent Renewable Energy Roadmap. Employment effects are assessed in an input-output framework taking into account bottom-up technology information to specify biofuels activities and linked to partial equilibrium models for the agricultural and energy sectors. The simulations suggest that biofuels targets on the order of 10-15% could be achieved without adverse net employment effects.

KEYWORDS: Biofuels, Input-output, Employment

* Corresponding author: F. Neuwahl, E-mail address: Frederik.Neuwahl@ec.europa.eu, Tel.: +34 95 448 8323, Fax: +34 95 448 8279. The views expressed in this paper belong to the authors and should not be attributed to the European Commission or its services.

1. INTRODUCTION

Despite the overwhelming predominance of refinery products as transportation fuels, liquid biofuels have been known as a technically viable alternative ever since the early development of the internal combustion engine. The vast availability of cheap crude oil throughout much of the 20th century sealed the fate of plant-derived substitutes in comparison to gasoline and diesel fuels almost ubiquitously until recent times. In the last decade a combination of factors, including climate change mitigation agreements, agro-economic strategies and geopolitical reasons, has renewed a strong interest in biofuels. Policies aimed at the promotion of biofuels have been designed and adopted by a number of countries.

The European Union has demonstrated substantial interest in the promotion of biofuels in recent years, as they are considered to be the only substitute for oil-derived fuels available in sufficient amounts and at reasonable costs in the short-to-medium term. Biofuels have therefore gained particular attention in the light of the perceived precarious security of oil supply and of its potential repercussions on the transport sector, and in 2003 the EU adopted the Biofuels Directive (2003/30/EC) with the objective of achieving a biofuels substitution share of 2% in 2005 and of 5.75% in 2010 (EC, 2003a). Progress in achieving the Biofuels Directive targets was however uneven among the Member States and overall distant enough from the target to generate the widely shared opinion that the 2010 targets would be missed in the absence of additional policies (the overall share in 2005 was 1%). One of the key factors leading to the insufficient progress towards the Biofuels Directive targets has in fact been identified as the lack, in most Member States, of an appropriate support system compensating for the additional production cost of biofuels compared to the cost of producing conventional fuels.

Recent examples of studies that examined biofuels policies in developed and developing economies and analysed the efficiency of these policies in comparison with other low-cost carbon reduction options are for instance Ryan et al. (2006) and Mc Donald et al. (2006). Several other studies with regional, national or EU focus have addressed the additional benefits of renewable energy policies in terms of employment or of competitiveness in the international markets. At a regional level, Moreno and Lopez (in press) estimated the employment effects related to the deployment of renewables in the region of Asturias (Spain) for the period 2006-2010 under three scenarios that assume different penetration rates for renewables corresponding to more or less proactive policies. The authors found positive employment impacts especially in the construction and installation phase of the production plants. At a national level, the German Federal Ministry for the Environment

(2006) published a prediction regarding the labour market impacts of the national renewable energy policy in 2020. The study uses an econometric input-output (IO) model and forecasts a substantial and lasting increase in employment for the renewable-intensive scenario fulfilling the climate policy target with respect to the reference case, provided that exports of technology for the production of renewables are supported and maintained. A similar analysis, again with econometric IO modelling, has been conducted for Germany by Hillebrand et al (2006), who also predict an initial positive effect on employment in 2010, mainly driven by the increase in investment in the renewables sectors. However, after this first positive effect, the authors estimate a slight employment drop in some sectors due to the contraction of demand triggered by the more expensive renewable energy supply.

For the EU15, Whitley et al. (2004) analyse the employment effects associated with the penetration of renewables in the energy market under two different scenarios featuring existing or reinforced policy initiatives. Their model combines the PRIMES model for energy-intensive sectors with an input-output model for the rest of the economy. The authors estimate an increase in employment in the renewable energy sectors and in agriculture, and a decrease in the conventional energy sectors. For the EU-25, a study carried out for the European Commission, DG Environment, analysed the effects on employment up to 2030 under three different policy scenarios: a business-as-usual scenario that does not reach the European climate targets is contrasted with two alternatives that comply with the CO2 reduction targets, either through a larger share of renewables and active energy policies with no new nuclear power or an increase in nuclear power generation. Sectoral employment coefficients are used to quantify the employment levels associated with the level of activity of the key sectors predicted by PRIMES simulations. The study finds that in none of the two analysed scenarios do the climate policies cause job losses, albeit some sectors are positively affected (e.g. the construction sector, industrial branches linked to renewables and to power generation from renewables) while others experience losses (e.g. the refinery sector and power generation from coal). Results are not conclusive for some sectors: iron and steel, the automotive industry and road freight transport (ETUC et al., 2007).

Reilly and Paltsev (2007) use a recursive-dynamic CGE model that incorporates bottom-up technology specifications for the production of electricity and of liquid fuels from biomass to analyse the competition for land related to biomass energy production. These authors examine a set of scenarios, with and without climate change policy, for the world economy and the U.S. economy up to the year 2100, under which global biomass production for energy use may expand to and constitute up to 220-250 EJ/year by 2100, requiring as much land as is currently used for crop production worldwide. One of the conclusions of their study is that a biofuels industry that supplied a substantial share of the liquid fuels demand would have a very pronounced effect on land use and price, and on the agricultural markets. Reilly and Paltsev also discuss in some detail the consequences of a policy constraint that would require the energy crops to be domestically produced in the USA. It emerges that the USA would lose 100 billion US$ of net exports of agricultural crops, turning form a net exporter to a large net importer, and the authors conclude by disputing the idea that biomass energy could be a significant domestic energy resource in the USA.

Not surprisingly, the situation turns out to be very different for Brazil, where the analysis conducted by Scaramucci and Cunha (2007), who use an input-output model enriched with bottom-up technology specification, concludes that replacing 5% of the world gasoline demand with ethanol from sugar cane produced in Brazil by the year 2025 would increase Brazilian GDP by more than 11% and generate more than 5 million jobs. The approach described by Scaramucci and Cunha is in many ways similar to the model presented in this paper, with some differences, which are also discussed in chapter 3. On the one hand, these differences are due to the incorporation of the results of sectoral simulations that in our case would have made it difficult to apply the method adopted by Scaramucci and Cunha in its entirety. On the other hand, these differences are due to the type of policy scenario examined. The Brazilian case, for instance, essentially deals with additional demand for exports and does not require taking into consideration subsidy schemes, government budget and households' expenditure.

This paper analyses the employment effects ensuing from the implementation of selected biofuels policy scenarios in Europe in the year 2020, based on the Impact Assessment of the Renewable Energy Roadmap and the Biofuels Directive Progress Report (EC, 2006a and 2006b). It uses input-output methods to combine information originating from bottom-up studies and energy and agricultural simulations that were conducted in parallel and used as input to the IO model. This paper complements the existing literature in several ways. From a policy point of view, it provides a rich set of simulation results for several policy-relevant biofuels penetration scenarios under different financing schemes including a set of sensitivity runs. From a methodological point of view, we provide an extension of previous input-output approaches by combining bottom-up technology information and sectoral market simulations in our input-output framework. The input-output model – which is the focus of this paper – is based on a 57-sector input-output table (IOT) for the EU-25, whereas 7 new sectors were then added to the IOT to describe petrol and diesel fuels and their bio-based substitutes - bioethanol and biodiesel each produced by two different technologies - and a sector providing the capital goods for the production of biofuels. The description of these sectors has been derived from bottom-up techno-economic data adapted from the Well-to-Wheels report (EUCAR et al., 2006). The input-output model incorporates different modules, including a mixed endogenous-exogenous variables IO model (which was used to accommodate constraints on agricultural production), an IO price model that computed the endogenous vector of commodity prices after an exogenous price increase, and a Quadratic Almost Ideal Demand System (QUAIDS), which calculated the final demand vector subject to prices and to the household budget.

A set of scenarios was derived from the energy system models Primes and Green-X. The agricultural model ESIM was run in parallel to calculate production levels and prices of agricultural commodities as a consequence of the policy shock. The results of the energy system models and the agricultural market model were then used to simulate economic and employment impacts in the input-output model described in detail in this paper. Compared to previous economy-wide analyses our approach allows for a detailed analysis of the implications of biofuel promotion using partial equilibrium models for the agricultural and energy sector and the consistent integration of these results in a macro-economic framework. Compared to previous IO analyses, the alignment of the IO model results and agricultural market simulations provides consistency with a series of factors, including, for instance, land availability, which would not hold in the case of the plain demand-driven IO model where demand always leads to additional production. However, the reader should bear in mind some limitations of the adopted modelling approach: due to the absence of full factor utilisation assumptions, no full crowding out occurs neither for employment (additional output leads to additional employment in the sector without losses elsewhere) nor for investments. Besides, the model does not include an explicit labour market block, which results in neglecting the fact that additional employment demand could partially lead to wage reactions (depending on the explicit modelling of the labour market) that would reduce the original employment demand impulse.

2. THE POLICY-TECHNOLOGY SCENARIOS

This paper analyses four of the larger scenarios for biofuels penetration in the year 2020 that were employed by the European Commission in the recent Renewable Energy Roadmap (EC, 2006b) and Biofuels Progress Report (EC, 2006a). All scenarios were adapted to be consistent with the EU energy outlook as calculated separately by the energy systems PRIMES (Capros and Mantzos, 2000) and Green X (Huber et al, 2004). The four scenarios are a business-as-usual scenario, entailing modest biofuels penetration as expected in the absence of further specific policies in addition to those already in place, and three high renewables share scenarios, in one of which additional constraints on cost minimisation were introduced:

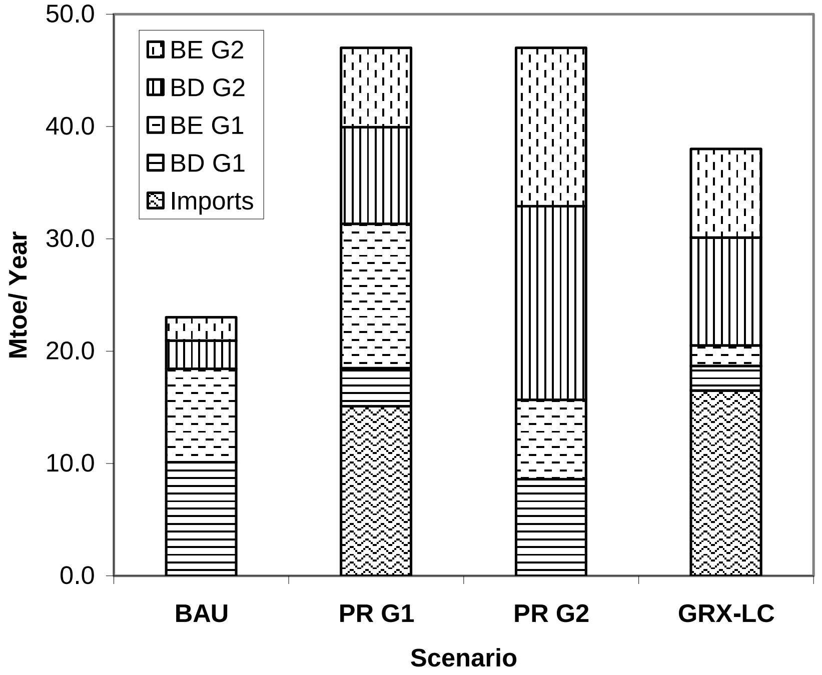
- *Business as Usual (BAU)* scenario: 6.9% total biofuels share (25.1 million tons yearly reduction in imported crude oil), mostly first generation (80% of total biofuels consumption). The extra-EU import price of biofuels is 717 €/toe
- *PRIMES Hi Res. 1st generation (PRIMES G1)* scenario: 15.2% total biofuels share (51.2 million tons yearly reduction in imported crude oil), with EU production mostly based on first generation technologies (2/3 of total biofuels consumption). The extra-EU import price of biofuels is 746 €/toe
- *PRIMES Hi Res. 2nd generation (PRIMES G2)* scenario: 15.2% total biofuels share (51.2 million tons yearly reduction in imported crude oil), with EU production mostly based on second generation technologies (1/3 of total biofuels consumption is obtained from first generation technologies). The extra-EU import price of biofuels is 755 €/toe
- *Green X least cost (GX-LC)* scenario: 12.3% total biofuels share (41.4 million tons yearly reduction in imported crude oil), with a larger share of imported biofuels and 46% of total biofuels consumption obtained from first generation technologies. The extra-EU import price of biofuels is 717 €/toe
- A hypothetical case with no biofuels at all was also specified as a reference (*Zero* scenario).

The scenarios introduce different replacement shares of conventional fuels by four different kinds of biofuels, i.e. bioethanol and biodiesel, each produced using two different technologies: *First generation bioethanol* (Ethanol from fermentation of sugar and starch crops. domestically produced from a mix of cereals and sugar beet, from sugar cane when imported); *First generation biodiesel* (Vegetable oils from crushed oil seeds: EU-grown rapeseed, imported soybean and palm oil); *Second generation bioethanol* (Ethanol from fermentation of lignocellulosic feedstock); *Second generation biodiesel* (Synthetic Fischer-Tropsch liquid fuel from biomass gasification). Although second generation technologies are still at demonstration plant stage today, the main biofuel conversion process cost was decreased by introducing learning effect cost reductions on capital costs, labour costs and other fixed operating cost for the year 2020 as compared to Well-To-Wheels (EUCAR et al, 2006, hereinafter WTW) data. The offsetting of oil-derived fuels with biofuels was made on energy equivalence basis, assuming the tank-to-wheel efficiency (MJ per 100km travelled) to

be constant. Most of the well-to-wheels difference is in fact in the well-to-tank component, which is included in the production technology specified in the IO table (see section 3).
It was also assumed that the development of a strong European biofuels industry would result in a competitive edge of European firms in the world market for biofuel plant technology. This was rendered by setting an export volume for biofuel technology (expressed as capital goods and engineering services) proportional to the world market for biofuels and to the EU production share in the world market; the resulting overall yearly export volume was 1427 Mio € in the BAU scenario, 1657 Mio € in the PRIMES G1 scenario, 1800 Mio € in the PRIMES G1 scenario, and 2435 Mio € in the GX-LC scenario. Figure 1 summarises the key substitution quantities assumed in the four scenarios. The default import price for crude oil was 58 USD/bbl (308 €/ton), the production cost of conventional fuels was 397.7 €/toe and fuel taxes were 666 €/toe for petrol and 460 €/toe for diesel oil. One of the sensitivity runs (see section 3.6) considered a 50% higher oil price and production cost of fossil fuels.

With respect to the financial support scheme for the biofuels policy, it was assumed in the main policy case that the additional costs of biofuels were fully compensated by fuel tax breaks and the price of blended transport fuels at the filling station remaining consequently unchanged throughout all scenarios. The cost-compensating tax reductions were recollected from private consumers through an increase in general taxation of equal amount, reflected by a reduction in the disposable income of consumers and therefore in aggregate demand. An alternative policy case was also considered, in which the biofuels targets were enforced by mandatory blending share obligations instead of cost-compensating tax breaks. In this case the household budget was not affected directly, but the fuel prices were allowed to increase to bear the extra cost of the blended biofuel.

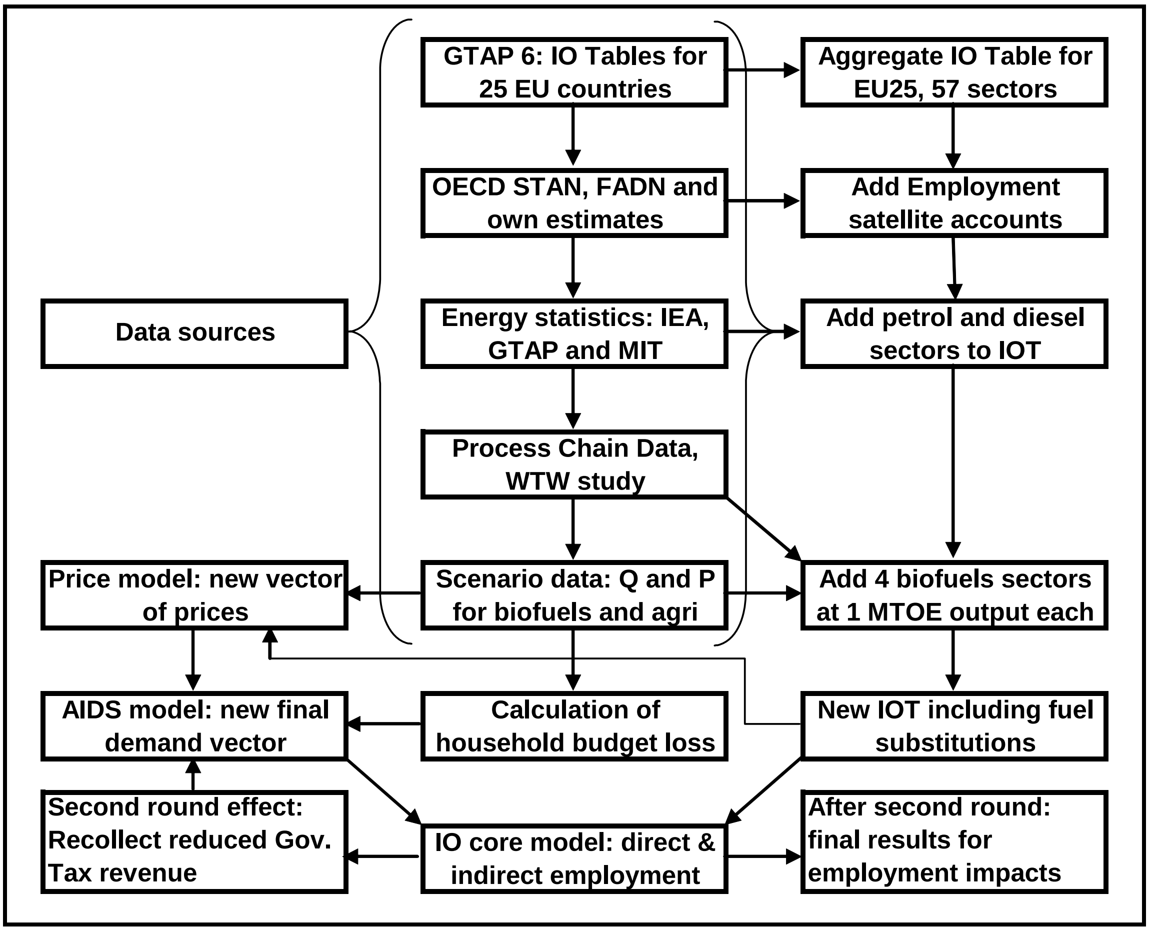
Figure 1: Key biofuels substitution quantities for the four scenarios



3. THE MODEL

The general aim of the modelling endeavour was to calculate the employment impacts in the EU-25 as a consequence of achieving the biofuels targets, subject to the following main drivers: contraction of the oil refinery sector, expansion of biofuel production and of the biofuels industry, expansion of the agricultural sector for cultivation of starch, sugar and oil bearing crops, increasing prices (with budgetary consequences for consumers) of food products due to increased competition for agricultural commodities because of fuel production, fall of crude oil price due to diminishing EU oil demand on the world market, and finally the financial support scheme for the biofuels policy. Figure 2 is a schematic block diagram of the input-output model that was developed for this study. It shows data input flows into the key modelling steps. The IO model was composed of three main modules reflecting the logical order of the modelling exercise: an IO price model, a Demand System, and a mixed endogenous-exogenous variables IO core model. The price model was used to translate the exogenous agricultural (and other) commodity price variations in a new final vector of prices reflecting the price components of intermediate inputs. The Demand System was then used to compute a new household consumption vector consistent with the new vector of prices and constrained by the total household budget. The mixed endogenous-exogenous variables IO model was finally used to calculate sectoral gross output and employment figures, subject to production quantities in the key agricultural sectors constrained to the values calculated by the ESIM model for each scenario. The following sections expand on the key data and modelling issues; section 3.4 contains a detailed commentary to Figure 2.

Figure 2: Schematic block diagram of the overall modelling setup



3.1. Input-output table and satellite accounts

An input-output framework was set up to account for direct and indirect employment effects associated with the targets specified in each scenario. This was done using an input-output table aggregated for the whole EU-25 and derived from the GTAP6 database, using the original 57-sector classification without further aggregation (Dimaranan and McDougall, 2005). This classification includes 22 agricultural and food sectors with sufficient detail of the main agricultural commodities either used by the biofuels industry or affected by the biofuels policy as a consequence of land competition or in relation to price effects on by-products. Later, liquid fuels were further disaggregated and five new sectors were introduced as described in section 3.2. The base year of GTAP6 is 2001. The integrated EU-25 IOT was generated using the method described by Rueda-Cantuche et al. (2007), which requires the splitting of the IO table for imports of each EU country into imports from other EU countries and imports from the rest of the world. This was done by equiproportional allocation according to the aggregate shares of imported commodities by country of origin (information readily available in the GTAP database). After summation of the tables of the 25 member states, the IOT for imports *within the EU-25* thus estimated was summed to the interindustry flows. Accordingly, the row sums of the additional flows were subtracted from the vector of exports so that it only includes exports to non-EU countries. A few iterations of the procedure were necessary due to the generation of a few negatives (most importantly in GTAP sector 16, crude oil) in the resulting vector of exports. This was assumed to be related to inconsistencies in the trade data and corrected by redefining the proportion of intra-to-extra EU imports of the commodity until the (negative) exported quantity went back to zero. This method allowed defining a supranational analytical table which, by considering intra-EU trade as domestic transactions, takes into account the multiplier effects due to intra-EU transactions.

Note, as a final insight, that the intra-EU trade integrated IO table is nothing else than a type II input-output model with endogenised intra-EU transactions, which can be written down in two equivalent representations: either by augmenting the interindustry marix $Z_{1:n,1:n}$ with the additional row of intra-EU imports $Z_{n+1,1:n}=M_{1:n}$ and additional column of intra-EU exports $Z_{1:n,\ n+1}=X_{1:n}$, or by summing to the interindustry matrix Z an "additional demand" matrix Z' obtained by equiproportionally splitting the vector M according to the shares of X:

$$Z'_{i,j} = \frac{Z_{n+1,j} \cdot Z_{i,n+1}}{\sum_{k=1}^{n} Z_{k,n+1}} \qquad (1)$$

The latter representation uses the supra-national interindustry flows matrix $Z''=Z+Z'$ and has the advantage that, whenever more detailed information on the destination of imports is available (in this case in the form of an IO table for imports that have not yet distinguished between intra- and extra- EU origin), Z' contains real data instead of being obtained mechanically through equation 1.

The input-output table was complemented with labour input data adapted from the OECD's STAN database. The classification of the STAN database can be mapped straightforwardly on most of the GTAP sectors but not on the 22 agricultural and food sectors. Additional data for labour inputs to different agricultural activities was then collected and adapted for this study. One particular issue concerns the measurement units: due *inter alia* to the large number of seasonal workers, the number of people engaged in agriculture is much larger than the number of full yearly incomes generated; employment data in agriculture are therefore often expressed in Annual Work Units (AWU), with full-time employment equivalents assuming an average of 1800 yearly hours per full time job in this case. The starting point for constructing detailed employment accounts for the different agricultural activities was the official data on AWU per country from EUROSTAT (EC, 2003b, EC, 2006c) and DG Agriculture (EC, 2006d). The total AWU assumed were 9.8 million for the EU-25 and 6.3 million for the EU-15.

Farm Accountancy Data Network (FADN) data were then reviewed to obtain realistic labour input per ha and per crop, as FADN is based on data from real farms which in general produce more than only one crop (EC, 2006d). Whenever possible, the values from specialized types of farming were used to extract labour input per ha per crop. In parallel, a literature review (Nix, 2003, De Juan et al 2003, Guerrero, 1999, Schenkel et al., 2005) and expert judgment were used to estimate the range of the maximum and minimum number of hours per ha. In three cases (olives, sugar beet, vines), the FADN AWU were adjusted taking into account our own estimated values. The total number of AWU for the EU-25 obtained at the end of this estimation procedure was checked against the official data for AWU published by DG AGRI (EC, 2003b, EC, 2006d) and found to be very close.

Since the scenarios analysed refer to the year 2020, in principle one should endeavour to project the input-output table to this year. However, since the official macro aggregates necessary for the projection were not available, it was decided to disregard the dynamic dimension and to interpret the results not as directly representative of a hypothetical year 2020 but as "what if" scenarios with no specific time label. All baseline employment figures were accordingly frozen to 2001 levels without considering forecasts for demographic evolution, for sectoral growth rates, or the long-standing downwards trend in agricultural employment.

3.2. Further specification of liquid fuels in the IOT

The two products "diesel oil" and "petrol" were disaggregated from the GTAP sector 32 "petroleum and coal products" based on information from two sources: refined petroleum products use (in physical units) from the GTAP satellite accounts; and a MIT CGE study on transportation (Choumert et al, 2006), in which International Energy Agency data was mapped to obtain liquid fuel inputs to GTAP sectors. The diesel and petrol sectors were further inflated in order to account for: a) increased fuel consumption from 2001 levels to 2020 projections consistent with the policy scenarios considered; b) increased fuel prices in accordance with DG TREN estimates. This partial updating of the IO table was done only for the fuel sectors, with a view to streamlining the incorporation of scenario data related to production cost and production/ consumption quantity of the fossil and bio-based fuels. The resulting IO tables should therefore not be confused with a projection to the year 2020.

Finally, five new sectors were added to generate a different IO table for each scenario: the four biofuels sectors and a sector providing the capital goods for the production of biofuels; the IO table used in the modelling had therefore 64 sectors (the original 57 GTAP sectors, petrol, diesel, the four biofuels and biofuel investment goods). The sale structure of the four fuels was assumed to be the same as that of the fuel they replace (diesel and petrol), inflated by the ratio of the basic prices. The inputs to the biofuels sectors, including employment coefficients, were constructed based on process chain data derived from the WTW study (EUCAR, 2006) and feedstock prices as calculated by the agricultural system ESIM for each scenario. Instead of having a different IO table for each scenario, Scaramucci and Cunha (2007) use –more elegantly- an IO model with mixed technologies which, transposed to our case, would result in a Leontief specification of each production technology (e.g. petrol, ethanol from sugar crop and ethanol from cellulose) and an overall gasoline sector specified –simply by three coefficients- as a linear combination of the three technologies. In our case this would, unfortunately, be more laborious and less rewarding to implement since the scenarios differ not only in the replacement shares but also in the Leontief structure of each technology due to different technology learning rates and crop prices. Tables 1-4 resume the parameters used for specifying the four biofuel production technologies (sectors) in the four scenarios.

Table 1: Parameters used for the production technology of 1st generation biodiesel (all values in €/ ton oil equivalent except shaded fields)

	Inputs to EU production of 1st gen. biodiesel, €/toe			
Scenario:	**BAU**	**PRIMES G1**	**PRIMES G2**	**GX-LC**
oil seed price in €/t	**251.2**	**275.4**	**249.0**	**246.3**
domestic share of oil seed supply in %	**45.2**	**38.8**	**46.8**	**51.3**
total oil seed cost	**739.5**	**808.1**	**733.6**	**727.3**
domestic oil seed cost	**334.3**	**313.5**	**343.3**	**373.1**
imported oil seed cost	**405.2**	**494.5**	**390.3**	**354.2**
alcohol (MeOH) cost	**29.2**	**29.2**	**29.2**	**29.2**
capital costs (biofuels technologies)	**23.5**	**23.5**	**23.5**	**23.5**
annual debt service	**18.8**	**18.8**	**18.8**	**18.8**
labour cost at production plant	**8.5**	**8.5**	**8.5**	**8.5**
other fixed operating cost	**2.4**	**2.4**	**2.4**	**2.4**
electricity consumption	**10.0**	**10.0**	**10.0**	**10.0**
chemicals consumption	**1.3**	**1.3**	**1.3**	**1.3**
natural gas consumption	**23.8**	**23.8**	**23.8**	**23.8**
credit for cake sale	**-145.7**	**-145.7**	**-145.7**	**-145.7**
credit for glycerine sale	**-3.1**	**-3.1**	**-3.1**	**-3.1**
total production cost	**708.1**	**776.7**	**702.2**	**696.0**
differential cost biodiesel - pet. diesel	**310.4**	**378.9**	**304.5**	**298.2**

Table 2: Parameters used for the production technology of 1st generation bioethanol (all values in €/ ton oil equivalent except shaded fields)

	Inputs to EU production of 1st gen. bioethanol, €/toe			
Scenario:	**BAU**	**PRIMES G1**	**PRIMES G2**	**GX-LC**
wheat-based ethanol share in total domestic production in %	**79.0**	**80.0**	**78.0**	**0.0**
wheat corn price in €/t	**124.5**	**130.5**	**132.0**	**124.5**
sugar beet mix price in €/t	**29.0**	**29.6**	**29.0**	**29.0**
EU share of wheat corn supply in %	**100.0**	**100.0**	**100.0**	**100.0**
EU share of sugar beet supply in %	**100.0**	**100.0**	**100.0**	**100.0**
total wheat corn/sugar beet cost	**641.2**	**669.3**	**671.5**	**598.7**
total domestic wheat corn cost	**506.6**	**535.5**	**523.8**	**0.0**
total domestic sugar beet cost	**134.7**	**133.9**	**147.7**	**598.7**
total imported wheat/sugar beet cost	**0.0**	**0.0**	**0.0**	**0.0**
capital costs (biofuels technologies)	**81.7**	**81.8**	**81.5**	**66.8**
annual debt service	**64.6**	**64.8**	**64.4**	**49.9**
labour cost at production plant	**27.3**	**27.4**	**27.3**	**22.2**
other fixed operating cost	**8.8**	**8.9**	**8.8**	**5.4**
electricity consumption	**-113.7**	**-115.3**	**-112.1**	**13.8**
diesel consumption	**14.9**	**15.1**	**14.7**	**0.0**
natural gas consumption	**146.4**	**147.3**	**145.4**	**74.5**
credit for cake sale	**-128.0**	**-128.5**	**-127.5**	**-88.1**
total production cost	**743.3**	**770.8**	**774.1**	**743.2**
differential cost bioethanol - petrol	**345.5**	**373.1**	**376.3**	**345.5**

Table 3: Parameters used for the production technology of 2nd generation biodiesel (all values in €/ ton oil equivalent except shaded fields)

	Inputs to EU production of 2nd gen. BTL, €/toe			
Scenario:	**BAU**	**PRIMES G1**	**PRIMES G2**	**GX-LC**
learning effect cost reduction in %	**3.7**	**12.5**	**25.0**	**14.0**
farmed wood price in €/t	**67.5**	**67.5**	**67.5**	**67.5**
straw price in €/t	**51.3**	**51.3**	**51.3**	**51.3**
% of wood in EU biomass supply	**0.0**	**54.1**	**75.9**	**58.5**
% of straw in EU biomass supply	**100.0**	**45.9**	**24.1**	**41.5**
EU share of feedstock supply in %	**85.0**	**85.0**	**85.0**	**85.0**
total biomass cost	**256.8**	**292.4**	**306.8**	**295.3**
total domestic farmed wood cost	**0.0**	**134.4**	**198.0**	**146.8**
total domestic straw cost	**218.3**	**114.1**	**62.7**	**104.2**
total imported wood cost	**38.5**	**43.9**	**46.0**	**44.3**
capital costs (biofuels technologies)	**264.6**	**240.3**	**205.9**	**236.3**
annual debt service	**211.5**	**219.6**	**164.6**	**188.9**
labour cost at production plant	**134.8**	**122.4**	**140.0**	**120.4**
other fixed operating cost	**44.1**	**40.0**	**34.3**	**39.4**
chemicals consumption	**44.9**	**44.9**	**44.9**	**44.9**
total production cost	**956.7**	**959.6**	**896.4**	**925.1**
differential cost BTL - pet. diesel	**559.0**	**561.9**	**498.6**	**527.3**

Table 4: Parameters used for the production technology of 2nd generation bioethanol (all values in €/ ton oil equivalent except shaded fields)

	Inputs to EU production of 2nd gen. bioethanol, €/toe			
Scenario:	**BAU**	**PRIMES G1**	**PRIMES G2**	**GX-LC**
learning effect cost reduction in %	**3.7**	**12.5**	**25.0**	**14.0**
farmed wood based ethanol share in total domestic production in %	**0.0**	**54.1**	**75.9**	**58.5**
farmed wood price in €/t	**67.5**	**67.5**	**67.5**	**67.5**
straw price in €/t	**51.3**	**51.3**	**51.3**	**51.3**
% of wood in EU biomass supply	**0.0**	**54.1**	**75.9**	**58.5**
% of straw in EU biomass supply	**100.0**	**45.9**	**24.1**	**41.5**
EU share of feedstock supply in %	**85.0**	**85.0**	**85.0**	**85.0**
total feedstock cost	**373.0**	**421.4**	**441.0**	**425.4**
total domestic farmed wood cost	**0.0**	**212.7**	**298.6**	**230.0**
total domestic straw cost	**303.6**	**139.4**	**73.1**	**126.0**
total imported wood cost	**69.4**	**69.4**	**69.4**	**69.4**
capital costs (biofuels technologies)	**192.5**	**168.7**	**142.5**	**165.4**
annual debt service	**153.5**	**134.5**	**113.6**	**131.9**
labour cost at production plant	**42.5**	**37.0**	**31.2**	**36.3**
other fixed operating cost	**146.5**	**110.6**	**87.1**	**107.0**
electricity production credit	**-42.4**	**-63.4**	**-71.9**	**-65.1**
total production cost	**865.6**	**808.9**	**743.4**	**800.8**
differential cost bioethanol - petrol	**467.8**	**411.2**	**345.7**	**403.0**

3.3. Impacts on the agricultural markets

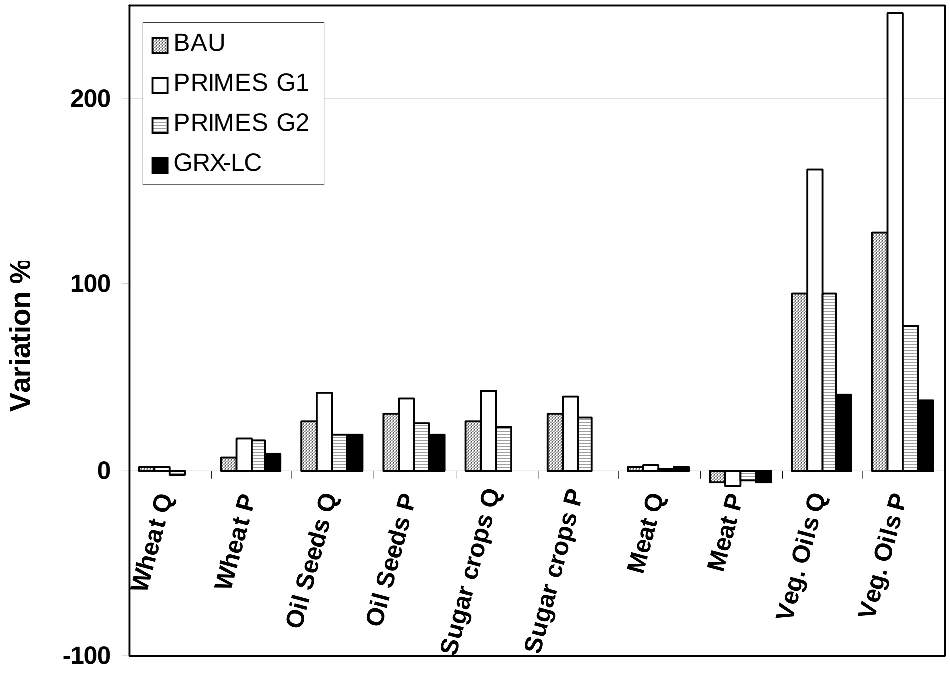
In the usual demand-driven input-output model, the additional intermediate demand for agricultural commodities as feedstock to produce biofuels would translate one to one into additional production (fully elastic supply). This would imply neglecting a number of important factors such as price impacts, substitution effects, impacts on traded quantities with the rest of the world, and land constraints. Agricultural production in the EU cannot in fact expand *ad libitum* to satisfy the demand of feedstock for producing biofuels without affecting the agricultural markets, as land is constrained by physical availability and by set-aside schemes.

The impacts on the agricultural sector were therefore modelled separately and in detail using the European Simulation Model ESIM (Banse et al, 2005) and simulating scenarios consistent with the four energy system scenarios considered. For each domestic biofuel type, it was assumed that an increased domestic production caused an increase in (world) feedstock price, a decrease of the value of by-products and of the price of the products they substitute. Moreover, the domestic production of feedstock for biofuel production in part substitutes land formerly used for the production of agricultural products for export (cereal grains and sugar), causing the decrease of export activities of the agricultural sector at higher domestic biofuel production rates.

Since the classification of ESIM commodities is different and more detailed than the GTAP classification, aggregate parameters for the price and quantity changes of agricultural commodities were obtained by mapping the detailed ESIM commodities to the GTAP classification and weighting the value increases according to the relative baseline shares. Figure 3 recaps the quantity and price percentage changes calculated with the ESIM model for agricultural and food commodities in the four policy scenarios.

Aggregation of the ESIM commodities to the GTAP classification was straightforward in most cases except for animal feed and vegetable oils. Since GTAP does not include a separate animal feed commodity, the price drop calculated by ESIM for protein cake by-produced with biodiesel could not be translated in price effects on pork, poultry and beef; livestock price changes were instead taken as calculated by ESIM. The mapping in GTAP of the rapeseed oil, sunflower oil and soybean oil commodities in ESIM also required separate treatment. In ESIM the three vegetable oils together make some 4 billion € output volume in the year 2001. The GTAP sector 21 [*vegetable oils and fats*] accounts instead for some 54 billion € gross output. This sector includes in fact olive oil and other relatively high value-added products. It was assumed that the price of those additional products is not affected by the biofuels market, and the average price increase of sector 21 was estimated by downscaling the average of the three vegetable oils form ESIM according to the output volume.

Figure 3: Percentage quantity (Q columns) and price (P columns) changes under different biofuels policy scenarios in the EU-25 for key agricultural and food commodities (values for GTAP sectors obtained from ESIM simulations)



3.4. Model Structure

As summarised in Figure 2, the first step in the modelling exercise was the definition of an aggregate input-output table for the EU-25 to which employment satellites were added as well as separate sectors for the four biofuel types considered and for the conventional fuels, petrol and diesel, that are partially replaced. A different IO table was generated for each scenario. Although other options are in principle possible, this choice was made since it is a straightforward way to account for changing demand of fuels as intermediate inputs.

The impacts on the agro-food sectors, taking into account the production constraints, were introduced exogenously based on the ESIM results by implementing the input-output model through a mixed exogenous-endogenous variables calculation algorithm (see for instance Miller and Blair, 1985), in which a modified demand-driven Leontief model admits as exogenous inputs the final demand in a subset of sectors and the gross outputs in the remaining ones, returning as endogenous variable the gross output and the final demand respectively. In this scheme the usual Leontief equation $X=(I-A)^{-1}Y$ is replaced by Equation 2, assuming that the gross output X of sectors *1 to m* and the final demand Y of sectors *m+1 to n* are specified exogenously, and the final demand of sectors *1 to m* and the gross output of sectors *m+1 to n* are calculated endogenously. In the present case, Sectors *1 to m* are the agricultural commodities listed in Figure 3, for which the output was constrained to the Q levels (expressed as percentage changes in Figure 3) given by the ESIM results. The dashed lines in eq. 2 show the matrices partitioned by endogenous specification of the variable.

$$\left[\begin{array}{c} Y_1 \\ Y_2 \\ \vdots \\ Y_m \\ \hline X_{m+1} \\ X_{m+2} \\ \vdots \\ X_n \end{array}\right] = \left[\begin{array}{cccc|c} -1 & 0 & \cdots & 0 & \\ 0 & -1 & \cdots & 0 & -A_{1:m,m+1:n} \\ \vdots & \vdots & \ddots & \vdots & \\ 0 & 0 & \cdots & -1 & \\ \hline 0 & 0 & \cdots & 0 & \\ 0 & 0 & \cdots & 0 & I_{m+1:n,m+1:n} - \\ \vdots & \vdots & \ddots & \vdots & A_{m+1:n,m+1:n} \\ 0 & 0 & \cdots & 0 & \end{array}\right]^{-1} \cdot \left[\begin{array}{c|cccc} & 0 & 0 & \cdots & 0 \\ A_{1:m,1:m} - I_{1:m,1:m} & 0 & 0 & \cdots & 0 \\ & \vdots & \vdots & \ddots & \vdots \\ & 0 & 0 & \cdots & 0 \\ \hline & 1 & 0 & \cdots & 0 \\ & 0 & 1 & \cdots & 0 \\ A_{m+1:n,1:m} & \vdots & \vdots & \ddots & \vdots \\ & 0 & 0 & \cdots & 1 \end{array}\right] \cdot \left[\begin{array}{c} X_1 \\ X_2 \\ \vdots \\ X_m \\ \hline Y_{m+1} \\ Y_{m+2} \\ \vdots \\ Y_n \end{array}\right] \qquad (2)$$

A demand system, described in more detail in section 3.5, was included to assess the impact of financing schemes for the promotion of biofuels. The demand system was used to capture consumers' substitution behaviour subject to consumption losses due to increased direct taxation aimed to compensate the cost disadvantage of biofuels and to different price impacts ensuing from the demand shocks related to biofuel production.

Price effects over all commodities were further calculated by an IO price model. While the standard price model computes a new vector of commodity prices subject to an exogenous factor price shock, the interest in the present case was to derive price impacts ensuing from the price change not of a factor but of an intermediate input. The method followed was analogous to Lee (2002) in calculating the impact of intermediate price changes of food prices, assuming that all increases in costs are passed through to final consumers as intermediate input prices increase. In this approach, the endogenous normalised prices P are calculated by eq. 2, in which the matrix of output coefficients is post-multiplied with a diagonal matrix T defined by eq. 3, where the elements t_i are the relative exogenous price increases of each commodity i. The value-added coefficients V are taken as constant.

$$P = \left[I - A' \cdot T \right]^{-1} \cdot V \tag{3}$$

$$T = \begin{pmatrix} 1+t_1 & 0 & \cdots & 0 \\ 0 & 1+t_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1+t_n \end{pmatrix} \tag{4}$$

The exogenous price changes introduced in eq. 3 were the following:

- Agricultural commodities used as feedstock for the production of biofuels, due to increased demand. The percentage changes are listed in Figure 3.
- Crude oil, due to reduced demand driven by substitution with biofuels. Crude price drop was assumed to be 1.5% in the BAU scenario, 3% in the PRIMES scenarios and 2.5% in the GX-LC scenario, in accordance with the energy outlook data.
- Fossil fuels, due to crude price drop. The oil price change was transferred to the [refined petroleum products], [diesel] and [petrol] sectors assuming a share of about 68% crude oil cost in the total production cost, consistent with the share given by the technical coefficients of the sector in GTAP.
- Diesel and Petrol due to mandatory blending of the more expensive biofuels. The exogenous price shock was calculated by multiplying the scenario-dependent blending percentage by the average relative extra production cost of biofuels compared to oil-based fuels. The extra cost was averaged between the two production technologies considered for each fuel type (see tables 1-4). The extra cost was zero in the default policy case, where it is compensated by an equal fuel tax reduction.
- Livestock, due to price drops of animal fodder as a by-product of biofuel production. Livestock price changes, listed as "Meat" in Figure 3, were taken as calculated by ESIM.

- All imports, due to oil price reduction. In accordance with the ECOTRA study (Energy uses and COsts in TRAnsport chains), it was assumed that an average 1% of the price of imports is transport fuel cost (ECOTRA, 2005). Further differentiation of transport and fuel costs for different imported commodities was not attempted since the contribution of this driver to the overall impacts of the biofuels policy interventions considered turned out to be small.

The tax exemption that needs to be financed by direct taxation was then calculated as the difference between the production cost of the biofuel and the production cost of the conventional fuel replaced, multiplied by the replaced fuel quantities. This amount was subtracted from the disposable income (aggregate consumption vector).

The consumption model, set up as a QUadratic Almost Ideal Demand System (QUAIDS), was run having as input data the new (reduced) household budget and the new vector of prices. The demand system, including model parameters, is described in section 3.5. Output of the QUAIDS was the new (reduced) consumption vector used as input for running the mixed endogenous-exogenous variables IO model, from which a new vector of sectoral outputs was obtained. Although some sectors experience an output increase, the aggregated production of the overall economy as a consequence of promoting biofuels diminishes in accordance with intuition, as the deliberate substitution of an input with a more expensive one implies decreased efficiency. Therefore, before computing the new employment vector, the reduction in government income from ad-valorem and production taxes as a consequence of reduced sectoral output was calculated and again subtracted from the households' disposable income to ensure government budget neutrality. The model was looped again on the demand system/ core IO modules with this new budget constraint to calculate the 2nd round effect on employment. Since this effect is relatively small (about 10% of the first round effect), no further rounds were considered.

3.5. The Demand System

The core of the household consumption block was a demand system that determines the households' budget allocation decision among different consumption categories as a function of the total expenditure and of the relative prices of all the specified consumption categories. Private consumption by commodity was modelled in a two-stage nested model in which the second layer corresponds to the 64 commodities of the IO model and the first (aggregate) layer comprised seven consumption categories. The allocation of total private consumption to these seven broad groups was implemented as a Quadratic Almost Ideal Demand System

(QUAIDS) model, which was proposed by Banks et al (1997) and extensively used in empirical research (Tiezzi, 2002; Labandeira et al., 2006; Brännlund and Nordström, 2004). The demand system specification is derived as a generalization of the Almost Ideal Demand System (AIDS) proposed by Deaton and Muellbauer and also largely applied in empirical research (Deaton and Muellbauer 1980; Labeaga et al., 1997; Michalek et al 1992; Kletzan et al. 2006), the main advance with respect to the AIDS being that QUAIDS allows for non-linear Engel curves and yields flexible income and price responses since its price and income elasticities depend on the expenditure level. Thanks to this feature, the QUAIDS can capture household behaviours at different levels of income distribution, and allows consumed goods to be either luxuries (consumption increases more than linearly with income) or necessities (consumption increases less than linearly with income) at different expenditure levels. Equation 5 defines the empirical specification of the QUAIDS:

$$w_i = \alpha_i + \sum_{k=1}^{n} \gamma_{ik} \ln p_k + \beta_i \ln\left[\frac{m}{a(\mathbf{p})}\right] + \frac{\lambda_i}{b(\mathbf{p})}\left\{\ln\left[\frac{m}{a(\mathbf{p})}\right]\right\}^2 + \varepsilon_i \tag{5}$$

w_i stands for budget share of the *ith* consumption category; α_i is the intercept and can be thought as the minimum subsistence at zero utility level for the *ith* consumption group; γ_{ik} are the own and cross price coefficients, while β_i and λ_i the linear and quadratic income terms respectively. ε_i is a random disturbance error. $a(\mathbf{p})$ and $b(\mathbf{p})$ are two price indices that are used for deflating the total expenditure m.

In particular, the two price indexes $a(\mathbf{p})$ and $b(\mathbf{p})$ take the following form:

$$\ln a(\mathbf{p}) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{k=1}^{n} \gamma_{ik} \ln p_i \ln p_k \tag{6}$$

$$b(\mathbf{p}) = \prod_{i=1}^{n} p_i^{\beta i} \tag{7}$$

where $a(\mathbf{p})$ is a translog price index and $b(\mathbf{p})$ is a Cobb-Douglas price aggregator**.**

In order to establish a valid representation of consumers' preferences and at the same time to reduce the number of parameters to be estimated, the adding up, homogeneity and symmetry restrictions are imposed. The adding up restriction ensures that the budget shares always sum up to one and it is specified as follows:

$$\sum_{i=1}^{n} \alpha_i = 1 \qquad \sum_{i=1}^{n} \beta_i = 0 \qquad \sum_{i=1}^{n} \lambda_i = 0 \tag{8}$$

The homogeneity restriction is specified as:

$$\sum_{i=1}^{n} \gamma_{ik} = 0 \qquad \forall j \tag{9}$$

and assumes demand functions that are homogeneous of degree zero, so that if both prices and income increase by the same proportion the budget allocation choice remains unchanged (absence of money illusion).

The Slutsky symmetry restriction finally implies that:

$$\gamma_{ik} = \gamma_{ki} \qquad \forall \mathrm{i, k} \tag{10}$$

In the empirical model specification, the expenditure shares for the selected consumption categories are dependent variables and the logarithm of price, linear income and quadratic income are explanatory variables. Finally, a country dummy variable is used in order to allow for country-specific fixed effects.

Income and price coefficients are estimated for the following consumption categories: Food, Beverage and Tobacco, Clothes and Footwear, Housing, Energy, Transport, Health and Services. Tables 5 and Table 6 show the estimated parameters, as well as their *p*-value, that relate expenditure with income and prices, respectively.

Table 5: Average income and price coefficients of consumers' demand for EU 15 (*p*-value in brackets)

	alpha	beta	lambda
Food	0.1359	0.0062	0.0000
	(0.00)	(0.00)	(0.00)
Bev. & Tob.	0.0463	-0.0008	0.0000
	(0.00)	(0.001)	(0.00)
Cloth. & Footw.	0.0708	0.001	0.0001
	(0.00)	(0.00)	(0.00)
Housing	0.1737	0.0005	0.0000
	(0.00)	(0.196)	(0.093)
Energy	0.0904	0.0013	-0.0001
	(0.00)	(0.00)	(0.00)
Transport	0.1288	-0.0013	0.0000
	(0.00)	(0.001)	(0.308)
Services	0.3541	-0.0069	0.0000

Table 6: Average cross price coefficients of consumers' demand for EU 15 (*p*-value within parenthesis)

	Food	Bev. & Tob.	Cloth. & Footw.	Housing	Energy	Transport	Services
Food	-0.0225 (0.003)						
Bev. & Tob.	0.0661 (0.00)	-0.038 (0.00)					
Cloth & Footw.	0.0271 (0.00)	0.0012 (0.94)	-0.052 (0.00)				
Housing	-0.0651 (0.00)	-0.0311 (0.00)	0.0041 (0.218)	-0.0678 (0.00)			
Energy	-0.0004 (0.894)	-0.0012 (0.598)	0.0151 (0.00)	-0.0023 (0.336)	-0.0084 (0.00)		
Transport	0.0293 (0.00)	-0.0169 (0.00)	-0.006 (0.127)	0.0294 (0.00)	0.0110 (0.00)	-0.1118 (0.00)	
Services	-0.0345	0.0199	0.0105	0.1328	-0.0138	0.0650	-0.1799

The estimated income and price parameters refer to consumption categories that result as an aggregation of the COICOP classification. The COICOP classification refers to consumption purposes. In the general case, a consumption purpose is fulfilled by combining different products (e.g. driving a car requires the car, fuel and insurance services), and a mismatch ensues between this representation of household consumption and the final demand vector that drives the input-output model. The same holds for the price effects obtained through the price IO model (i.e. per products) and those used as exogenous input parameters in the demand system (i.e. per consumption purpose). A correspondence scheme is therefore necessary to convert expenditure per consumption purpose into purchase of goods and services, or to convert a price increase by product into a price index increase per consumption category. This correspondence was implemented by means of a single bridge matrix, which allows a consistent interaction of the demand system with the input-output model, since it represents the consumption categories as a fixed share (Leontief technology) combination of single durable and non-durable goods and services. The demand system and bridge matrix employed have been estimated by Mongelli et al. (2007) based on aggregate consumption expenditure of households statistics that are publicly available from Eurostat.

3.6. Sensitivity Analysis

A series of sensitivity runs were conducted with a view to singling out the following components in the overall results: (i) Reduction in employment in conventional fuel sectors;

(ii) Increase in employment in the biofuels sectors; (iii) Generation of employment in the biofuel technology sector, both for EU biofuel production and for exports; in the aggregated results presented in tables 8 and 9, this is included in the industry sector; (iv) Increase in employment in the agricultural sectors; (v) Overall decrease of production (and related employment) due to reduced household disposable income, in the case of the default policy case that envisages compensating for the biofuels price disadvantage with a full tax rebate to be financed by increased direct taxation; and (vi) Effects of price changes and ensuing changes in consumers' expenditure. Therefore, in addition to the base simulation setting, four sensitivity runs have been conducted on all scenarios, corresponding to the following assumptions:

- *Sensitivity run S1:* no exports of biofuel technology.
- *Sensitivity run S2:* no crude oil price effects. This parameter was deemed particularly uncertain, as exact predictions of the consequences of biofuels substitution in the EU for the world oil market are extremely difficult.
- *Sensitivity run S3:* without considering any price changes (except, in the case of the mandatory blending obligation policy option, the price of petrol and diesel). This sensitivity case put in evidence the magnitude of the price effects for the sake of transparency, as the price transmission mechanisms in the IO price model bear significant approximations.
- *Sensitivity run S4:* vegetable oil price increase locked to the lower level experienced by oil seeds. This sensitivity case was examined since the agricultural simulation model calculated price changes as high as a threefold increase for vegetable oils. Such high price changes, in part originating in ESIM from insufficient oilseed crushing capacity in the EU, were considered unrealistic by some actors within the inter-service consultation of the EC.
- *Sensitivity run S5:* world crude oil price increased by 50% (87 USD/bbl)

4. RESULTS AND DISCUSSION

The four biofuels penetration scenarios – business-as-usual scenario, entailing modest biofuels penetration as expected in the absence of further specific policies in addition to those already in place, and three scenarios with a large share of renewables, in one of which additional constraints on cost minimisation were introduced – are assessed under two different financing schemes: (i) Tax exemption equivalent to the cost disadvantage of biofuels (subsidised biofuels). This was the default policy case assumed also in the EC Renewable Energy Roadmap; (ii) Mandatory blending obligation, in which case the fuel prices at the filling station would increase as the extra cost is transferred to the consumer rather than billed to the taxpayer. For the sake of handiness the results are presented at a higher level of aggregation that allows putting in evidence the most important factors in the build-up of total net employment effects. The displayed aggregation level contains the following 8 broad sectors: 1. Agriculture; 2. Energy (including electricity and the coal, oil and gas sectors); 3. Food (including the vegetable oil sector, as mentioned in Section 3.3); 4. Industry (including the novel [Biofuel Technologies] sector); 5. Services; 6. Transportation; 7. Fuels (refined petroleum products including Petrol and Diesel); 8. Biofuels.

Table 7 summarises, for the four scenarios, the total direct cost of policy (default case: total tax exemption to be financed by increasing direct taxes) and the percentage price increase of petrol and diesel due to mandatory blending of more expensive biofuels (alternative policy case; price increases calculated from blending shares and production cost differentials as from Tables 1-4 (main sensitivity case).

Table 7: Direct annual policy cost in 2020 for the four biofuels penetration scenarios (fuel tax exemption policy) and alternative percentage price increase of fuels (mandatory blending obligation), main sensitivity case

Scenario	Tax exemption	Mandatory Blending Obligation	
	Direct Policy Cost	**Diesel % price increase**	**Petrol % price increase**
BAU	**8.4 Billion €**	**5.9**	**6.4**
PRIMES G1	**19.5 Billion €**	**12.7**	**13.6**
PRIMES G2	**18.7 Billion €**	**15.2**	**12.8**
GX-LC	**15.6 Billion €**	**10.2**	**9.6**

Table 8 shows, for the default policy case (subsidised biofuels), sectoral results aggregated to the eight macro sectors for the base simulation case as well as total variations for the different sensitivity runs; Table 9 idem for the alternative policy case in which a non-subsidised mandatory biofuels blending obligation causes fuel price increases.

Table 8: Aggregate employment impacts, in number of jobs, for the four scenarios and six sensitivity cases, default policy option (subsidised biofuels cost disadvantage)

	BAU	PRIMES G1	PRIMES G2	GX-LC
AGRICULTURE	118,051	176,360	76,678	64,850
ENERGY	-2,833	-15,672	-23,031	-19,441
FOOD	29,663	28,942	-1,062	-3,557
INDUSTRY	24,797	37,813	55,232	47,679
SERVICES	-73,040	-171,899	-176,077	-138,786
TRANSPORT	-2,078	-1,103	-14,939	-4,476
FUELS	-8,967	-18,165	-18,666	-14,554
BIOFUELS	14,629	34,002	61,892	29,946
TOT BASE	100,222	70,280	-39,974	-38,340
TOT S1	70,828	37,291	-75,816	-86,822
TOT S2	52,044	-31,806	-145,174	-121,400
TOT S3	155,814	161,051	-133,958	-206,696
TOT S4	220,701	324,247	25,112	-14,758
TOT S5	191,773	197,137	146,945	47,165

Table 9: Aggregate employment impacts, in number of jobs, for the four scenarios and six sensitivity cases, alternative policy option (non-subsidised mandatory biofuels blending obligation)

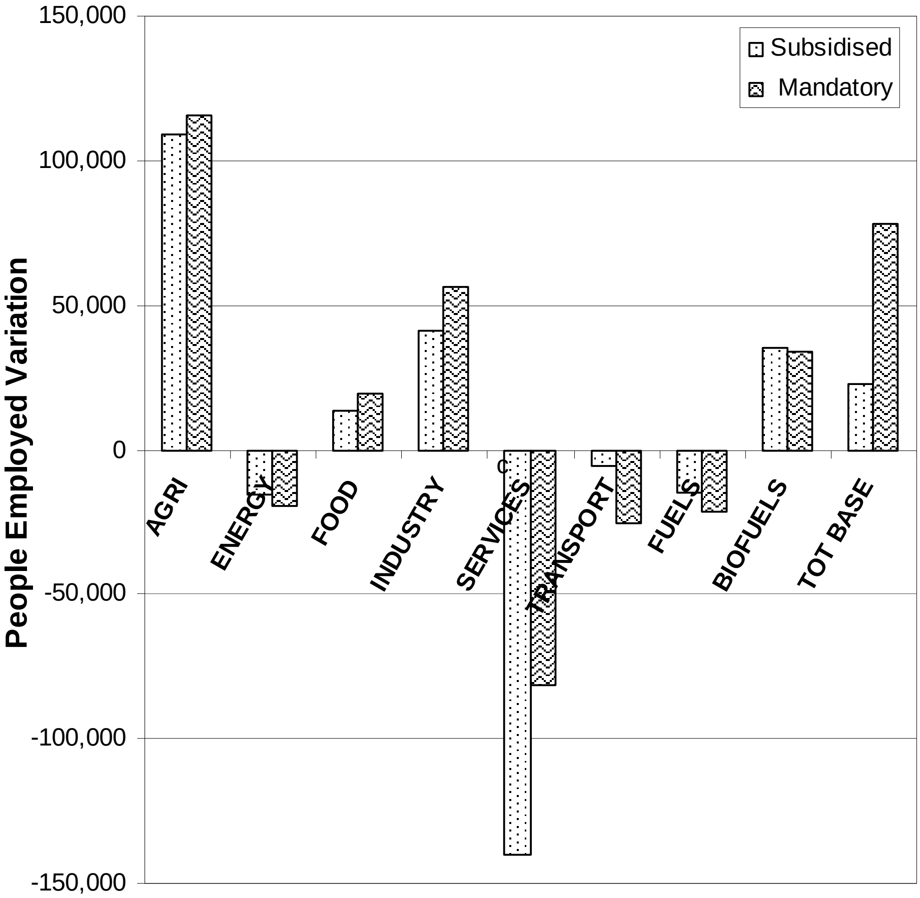
	BAU	PRIMES G1	PRIMES G2	GX-LC
AGRICULTURE	121,217	186,853	83,170	72,189
ENERGY	-6,487	-20,447	-27,868	-23,015
FOOD	31,668	37,774	5,853	2,748
INDUSTRY	26,299	62,240	72,161	65,564
SERVICES	-85,114	-68,639	-104,370	-66,494
TRANSPORT	-15,952	-21,741	-42,104	-21,436
FUELS	-13,032	-25,756	-26,264	-20,571
BIOFUELS	14,201	32,154	59,186	28,977
TOT BASE	72,799	182,438	19,764	37,961
TOT S1	44,411	149,464	-16,060	-10,499
TOT S2	27,578	91,984	-72,688	-37,815
TOT S3	53,404	134,716	-110,436	-148,361
TOT S4	115,565	288,562	37,443	37,961
TOT S5	105,297	235,448	70,536	84,164

The first conclusion one may draw from Tables 8 and 9 is that overall calculated employment effects, resulting from the balance of positive and negative contributions in different sectors and due to different factors describing the scenarios considered, are modest in all cases, as they are in the range +/- 300,000 against a base of close to 200 million jobs in the EU-25 in the year 2001. Depending on the scenario, on the financing scheme and on the conditions introduced by the sensitivity runs, the net effects switch sign from slightly positive to slightly negative. Slightly positive net figures are, however, predominant not only for moderate biofuels penetration scenarios (BAU, 6.9% replacement share) but also for the scenarios assuming a higher substitution rate (up to 15.2 %). Nevertheless, one should not forget that these results are subject to a relatively high number of approximations, first of all that the description of the EU economy was not meant as a representation of the EU in the year 2020; the absolute numbers should therefore be looked at with the knowledge that there is a significant margin of uncertainty. Assuming biofuel production costs to be slightly higher than those reported in Tables 1 to 4 would for instance be enough to flip the sign of the net average results to the modestly negative range. The main message should thus be understood as the expected neutrality of overall employment effects of biofuels substitution policies examined up to a substitution rate of 15.2%. The simulation results show that overall net employment results are the balance between the following components: Positive effects in the agriculture and (in some cases) food sectors, with those in the food sector being mainly due to the inclusion of vegetable oils; positive effects in the industry sector, mainly due to the high capital intensity of biofuel production, in particular for second generation processes; positive effects in the biofuels industry; losses in the refinery sector, due to substitution with biofuels and losses in the energy and transportation sector. Finally, the largest absolute employment losses are in the service sectors. This can be explained mainly by: a) the absence of significant specific direct employment gains in the service sectors; b) the largest overall employment base in the service sectors.

In addition to the quasi-neutrality of net employment and GDP effects in the explored scenarios one may, however, draw some further conclusions. The comparison of the Base run with the sensitivity runs S2 and S3 indicates in fact that crude oil price reductions of the range considered would be able to overcompensate the negative effects due to the price increase of agricultural commodities. The S1 runs also indicate that the positioning of European firms in the world market for biofuel technology is a factor to be taken into account for the overall attractiveness of the explored policy scenarios. Furthermore, the S4 results point at the relatively strong impacts on the price of vegetable oils and at possibly unforeseen consequences of the policy. This may be discussed, for instance, in the light of the debate sparked by the large price increase of maize corn in the US since the introduction of bioethanol promotion policies, and the adverse consequences it is having on food security in Mexico (see, for instance, Crenson, 2007). The results of the S5 set of runs are analogous to S4 with the difference that, in the case of a higher crude oil price, the cost disadvantage of biofuels is reduced irrespectively of the feedstock (vegetable oils or sugar crops) used in the biofuel mix; this is why the S5-BASE differentials are more even in all four scenarios rather than being concentrated mainly in those scenarios more relying on first generation biofuels.

As regards the comparative analysis of the two different financing schemes (subsidisation vs. blending obligation, Table 8 vs. Table 9), the first and foremost observation is that the results do not differ much. Taking into consideration the ubiquitous penetration of fuel use in all sectors of the economy, this is not surprising. Figure 4 summarises the differences between the two alternative policy cases by comparing the employment impacts on the eight macro sectors, for the base case and, for ease of visualisation, averaged across the four scenarios. The impacts on the comparatively more fuel-intensive sectors are relatively more pronounced in the non-subsidised case where fuel prices increase than in the subsidised case, the same applies (vice versa) to the impacts on the least fuel-intensive sectors; indeed the negative effects on the services sectors are reduced and the impact on the transportation sector is more severe. The additional benefits in terms of fuel savings brought about by the non-subsidised mandatory blending option are analysed by Mongelli et al. (Mongelli et al. 2007). The impacts of the two options could differ more when analysing social equity considerations, which could be done by disaggregating different household types.

Figure 4: Employment impacts on eight aggregate sectors in the two alternative policy cases. All results are for the base sensitivity case and averaged across the four scenarios



5. CONCLUSIONS

This paper has analysed the employment impacts of different biofuels penetration scenarios as proposed in the European Commission’s Biofuels Progress Report and Renewable Energy Roadmap. In conformity with the Impact Assessment requirements applying to the items of the Commission's Annual Work Programme, the EC investigated the socio-economic consequences entailed by a predefined set of policy-technology scenarios, to ensure that the proposed policy, in achieving the main goals in terms of carbon savings and security of energy supply would not be unduly detrimental to the EU economy at large. To this end, an input-output based model was developed, which combined scenario information derived from energy systems simulations, process chain data, detailed simulations of the impacts of the feedstock demand on the agricultural markets, and a demand system that was used to capture the consumers' behavioural responses to the expected budget and price shocks.

The results indicate that policies that effectively promote the use of biofuels in the EU-25 up to a substitution share of some 15% would not cause adverse employment effects, assuming that sufficiently mature biofuel production technology is at our disposal. In the build-up of the approximately neutral net employment effects, several sectoral and causal chain effects interact to compensate inefficiency losses. Particularly important factors that show the potential to yield positive contributions are the development of a strong EU industry in the world market for biofuel technology and the possible impacts in terms of moderating world oil price through reduction in demand. Finally, the results do not indicate major differences of net employment impacts in two alternative policy cases envisaging either subsidising the cost disadvantage of biofuels through increased direct taxation or mandating a minimum biofuels blending share, in which case the fuel price at the filling station would reflect the additional production cost.

REFERENCES

Banks J., Blundell R., Lewbel A., 1997. Quadratic Engel Curves and Consumer Demand. The Review of Economics and Statistics 79, pp. 527-539.

Banse, M., Grethe, H. and Nolte, 2005. European Simulation Model (ESIM) in GAMS. User Handbook.

Brännlund R., Nordström J., 2004. Carbon tax simulations using a household demand model. European Economic Review 48, pp. 211-233.

Capros, P. and Mantzos, L, 2004. The European energy outlook to 2010 and 2030. International Journal of Global Energy Issues, 14, No.1/2/3/4 pp. 137 – 154.

Choumert F., Paltsev S., and Reilly J., 2006. Improving the Refining Sector in EPPA, MIT Joint Program on the Science and Policy of Global Change, Technical Note No. 9, July 2006.

Crenson, M., 2007. Biofuels Boom Raises Tough Questions. Associated Press, 12 March 2007.

Deaton, A., Muellbauer, J., 1980. Economics and Consumer Behaviour. Cambridge University Press.

EC - Commission of the European Communities, 2003a. Biofuels directive: DIRECTIVE 2003/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of

8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport.

EC - Commission of the European Communities, 2003b. EUROSTAT: Agricultural statistics, Farm Structure Survey.

EC - Commission of the European Communities, 2006a. Biofuels Progress Report: COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT: Biofuels Progress Report, Report on the progress made in the use of biofuels and other renewable fuels in the Member States of the European Union. Brussels, 10.1.2007, COM(2006) 845 .

EC - Commission of the European Communities, 2006b. Renewable Energy Roadmap: COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT: Renewable Energy Road Map, Renewable energies in the 21st century: building a more sustainable future, Brussels, 10.1.2007, COM(2006) 848.

EC - Commission of the European Communities, 2006c. EUROSTAT: Survey of the structure of agricultural holdings in the EU (2006).

EC - Commission of the European Communities, 2006d. DG Agriculture and DG Rural Development, FADN Structure Survey.

De Juna Valeto, J. A, Ortega Alvarez, J. F, Tanquelo Martín-Benito, J. M., 2003. Sistemas de Coltivo, Ed. Mundi-Prensa.

Dimaranan, B. V. and McDougall R. A. (eds), 2005. Global Trade, Assistance, and Production: The GTAP 6 Data Base, Center for Global Trade Analysis, Purdue University.

ETUC, CES, ISTAS, Wuppertal Institute, Syndex, 2007. Climate Change and employment. Impact on employment in the European Union-25 of climate change and CO2 emission reduction measures by 2030. Supported by the European Commission, DG Environment, Convention n° 07-0402/2005/420169/SUB/C2.

ECOTRA, 2005. Energy use and COst in freight TRAnsport chains. TRT Trasporti e Territorio, Milan, December 2005. Internal report, study conducted on behalf of DG Joint Research Centre/IPTS.

EUCAR, CONCAWE and JRC, 2006. Well-to-Wheels analysis of future automotive fuels and powertrains in the European context, 2006 update.

German Federal Ministry for the Environment, 2006. Nature Conservation and Nuclear Safety. Renewable Energy: Employment Effects. Impact of the Expansion of Renewable Energy on the German Labour Market. Summary.

Guerrero, A., 1999. Cultivos herbaceous extensivos, 6^{a} edicion, Ed. Mundi-Prensa

Hillebrand H., Buttermann G., Behringera J.M., Bleuel M., 2006. The expansion of renewable energies and employment effects in Germany Bernhard. Energy Policy 34, pp. 3484-3494.

Huber C., T. Faber, R. Haas, G. Resch, J. Green, S. Ölz, S. White, H. Cleijne, W. Ruijgrok, P.E. Morthorst, K. Skytte, M. Gual, P. Del Rio, F. Hernández, A. Tacsir, M. Ragwitz, J. Schleich, W. Orasch, M. Bokemann, C. Lins, 2004. Action plan for deriving dynamic RES-E policies and Green-X deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market, Wien.

Kletzan D., Köppl A., Kratena K., Schleicher S. and Wüger M., 2006. Towards sustainable consumption: Economic modelling of mobility and heating for Austria. Ecological Economics 57 (4), pp. 608-626.

Labandeira X., Labeaga J.M., Rodriguez M., 2006. A residential energy demand system for Spain. The Energy Journal 27, pp. 87-111.

Labeaga J.M., Lopez A., 1997. A study of petrol consumption using Spanish panel data. Applied Economics, 29, pp. 795 – 802.

Lee C., 2002. The Impact of Intermediate Input Price Changes on Food Prices: An Analysis of "From-the-Ground-Up" Effects. Journal of Agribusiness 20,1 (Spring 2002): 85-102.

Mc Donald S., Robinson S., Thierfelder K., 2006. Impact of switching production to bioenergy crops: The switchgrass example. Energy Economics 28 (2006), 243-265.

Michalek J., Keizer M.A., 1992. Estimation of a two stage LES-AIDS consumer demand system for eight EC countries. European Review of Agricultural Economics 19, 137-163.

Miller, R.E. and P.D. Blair, 1985. Input-output analysis: foundations and extensions, Prentice-Hall.

Mongelli I., Kratena K., Neuwahl F., Rueda-Cantuche J.M. An econometric estimation of a demand system for Europe to analyze the consumers' behaviour and their response to policy measures. 16th input-output conference, Istanbul (Turkey), 2-7 July, 2007.

Moreno B., López A.J. (In press), The effect of renewable energy on employment. The case of Asturias (Spain). Renewable and Sustainable Energy Reviews.

Nix, J., 2003. Farm Management Pocketbook, 33rd Edition, Ed. Imperial College at Wye.

Reilly, J. and Paltsev, S. Biomass Energy and Competition for Land, Report Series No 145, MIT Joint Program on the Science and Policy of Global Change, April 2007.

Ryan L., Convery F., Ferreira S., 2006. Stimulating the use of biofuels in the European Union: Implications for climate change policy. Energy Policy 34 (2006), 3184-3194.

Rueda-Cantuche J. M., Beutel J., Neuwahl F., Löschel A., and Mongelli I. A Symmetric Input-output table for EU27: Latest Progress, XVI IIOA Conference, Istanbul, 2-6 July 2007.

Scaramucci, J. A. and Cunha, M. P. Bioethanol as a Basis for Regional Development in Brazil: An Input-Output Model with Mixed Technologies, 16th input-output conference, Istanbul (Turkey), 2-7 July, 2007.

Schenkel Y, Temmerman M, Marchal M, Schaar C., 2005. A comparative analysis of the impact on employment of a wood-based heating system. Biotechnology, Agronomy, Society and Environment, 9 (1) pp 53-64.

Tiezzi S., 2002. Environmental Defensive Expenditures and Households Behaviour in Italy. Applied Economics 34, pp. 2053-2061.

The Associated Press. Mexican president signs accord to contain soaring tortilla crises. January 18, 2007.

Whitely M., Zervos A., Timmer M., Butera F., 2004. Meeting the targets and putting renewables to work. Overview Report for MITRE Project, ALTENER Programme. Directorate General for Energy and Transport. 2004.