Global land use change and greenhouse gas emissions due to recent European biofuel policies

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Abstract:

The European Union (EU) has emerged as a major producer and consumer of biodiesel, due to policy initiatives. Recent policies seek to curb imports from USA, Argentina and Indonesia by imposing anti-dumping duties. Further, there has been a proposal to set a cap on First Generation Biofuels (FGBs) to reduce greenhouse gas (GHG) emissions from Land Use Change (LUC). In this paper, we employ the widely used GTAP-BIO model to examine these recent EU policies. Increased biodiesel consumption arising from the cap on FGBs and increased import prices arising from anti-dumping measures are both modeled as exogenous policy shocks. We find that the biodiesel imports increase despite these anti-dumping measures, because of the enormous expansion of domestic demand, mainly for palm biodiesel. Biodiesel producers in the EU benefit from these policies as well, especially those producing rapeseed and non-food-based biodiesel, but also palm biodiesel due to imports of vegetable oils. LUC is expected to occur at a global scale as a consequence of biodiesel trade and interactions in the food and feed markets. Besides the EU, other countries such as the US, Brazil or South-Saharan Africa can be affected.

1. Introduction

Biofuels production has been growing sharply all around the world during the last decade, as a consequence of rising prices of oil together with the approval of public policies to mitigate the effects of global warming. Most of these policies, such as the European Directive 2009/28/CE, aim at reducing the greenhouse gas (GHG) emissions while increasing energy independence by introducing a blending mandate. Specifically, this Directive (also known as the Renewable Energy Directive –RED-), establishes a 10% biofuel share in the motor fuel market of the Member States by 2020, while setting out a sustainability criteria that requires biofuels to emit at least 35% less GHG than the replaced fossil fuel. Biofuel emissions must be calculated over the entire life cycle and must include the corresponding losses in carbon stocks if land has been converted to biofuel production. This is to ensure that increasing biofuels consumption does not take place at the expense of carbon-rich ecosystems.

RED's approval was supposed to give a boost to the European biofuel industry. Indeed, both consumption and production of biofuel -particularly biodiesel- started to increase, as can be seen in Figure 1, especially in those countries that have been the leading producers from then onwards (Germany and France). The production of biodiesel grew from 5.49 billion liters (1.45 billion gallons) in 2006 to 10.28 billion liters (2.72 billion gallons) in 2011 (an increase of 87%), according to Eurostat (2013). At that time, the rapid expansion was driven by the increasing crude oil prices, together with subsidies on the production of oilseeds under Common Agricultural Policy set-aside programs (Flach et al., 2013). Generous tax incentives on biodiesel production –mainly in Germany and France– also played a great role, especially for the sector's development. However, direct payments to farmers have been progressively reduced (*decoupling* subsidies from particular crops since the 2003 reform), and tax exemptions have been substantially reduced in most of the Member States due to the cost for the public budget.

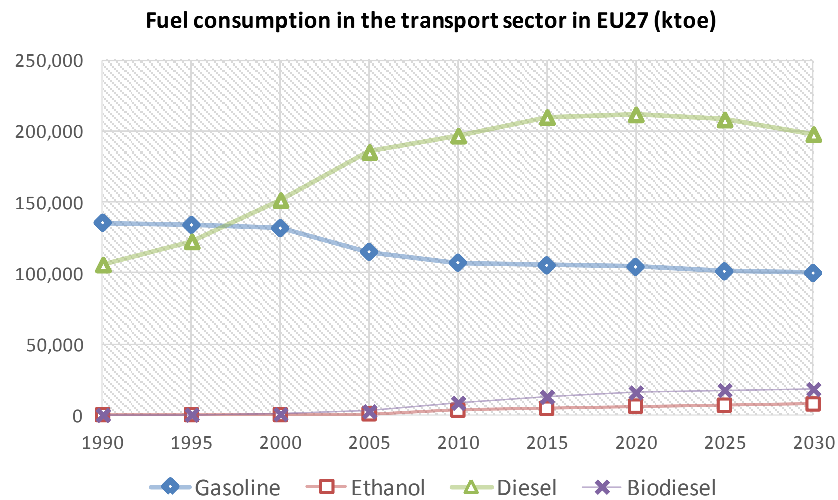

Figure 1. Data and projections for fuel and biofuel consumption in the European transport sector (EU27). Source: Eurostat.

The targets set out in the RED also encouraged the use of vegetable oils. At least 1.5 million tons of them were imported into the EU in 2012 only for biodiesel production (mainly palm oil, soybean oil, and to a lesser extent rapeseed oil). The increase in palm oil consumption in the biofuels sector was the highest: 365% over 2006–2012 (Gerasimchuk and Yam Koh, 2013). Domestic oilseed production was also stimulated by biofuels expansion, and it has substantially grown in recent years as well, although a significant share of the feedstock diverted to biodiesel production is actually imported (European Commission, 2011), as can be seen in Figure 2. It has to be pointed out that the support given by the Memorandum of Understanding on Oilseeds (often referred to as the *Blair House Agreement*) for the production of certain oilseeds also contributed to this outcome.

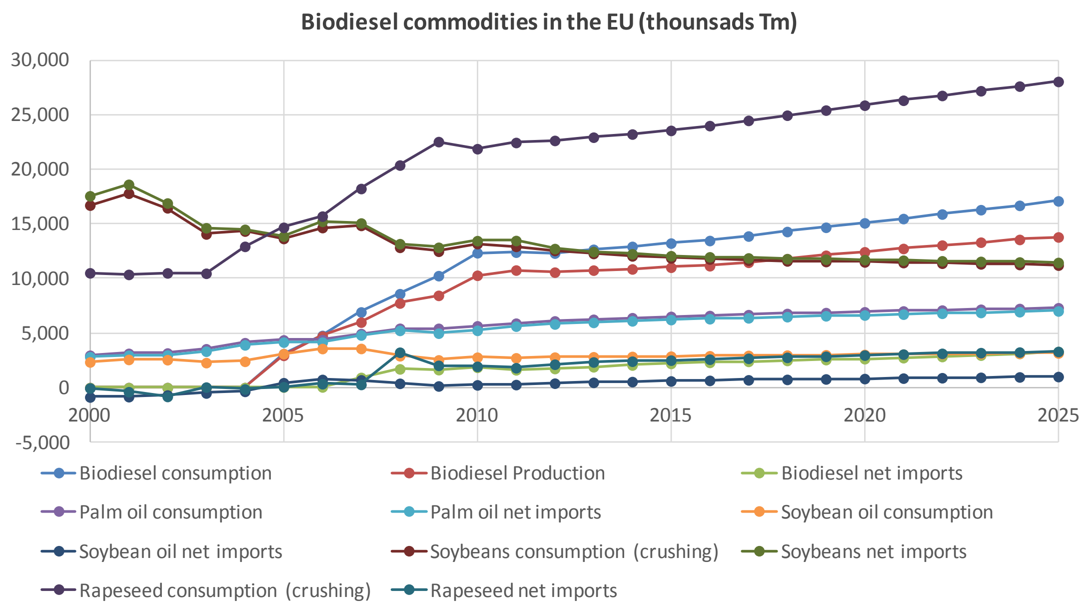

Figure 2. Evolution in biodiesel consumption, production and net imports in the European transport sector (EU27). Net imports of oilseeds into the EU are also represented, although uses other than biodiesel production are considered. Source: FAPRI.

Possibly driven by all these factors, the EU is currently the world's largest biodiesel producer. Biodiesel is also the most important biofuel and, on volume basis, represents about 80% of the total transport biofuels market (Hélaine, M'barek and Gay, 2013), in the same way that diesel prevails over gas in the motor fuel market. However, according to Flach et al. (2013), EU biodiesel consumption seems to have reached its peak after years of rapid increases. In addition, despite this huge demand for biodiesel, imports represent a large share (around 50%) since biodiesel from leading exporting countries is very competitive and usually cheaper than domestic biodiesel. In March 2009, the European Commission (EC) had to impose anti-dumping duties on all the biodiesel blends imported from the United States (US) (Regulation 444/2011), after having set provisional measures on B20 blends (Regulation 193/2009). As a consequence, biodiesel imports from Argentina and Indonesia took the US market share and have been growing since then, as shown in Figure 3. These two countries, very export-oriented, currently account for almost 40% of the total biodiesel imports into the EU (European Commission, 2013). The EU accounts for approximately 88% of the total biodiesel exports from Indonesia (Slette and Wiyono, 2013). In view of this situation, and after investigation, the EC has recently approved anti-dumping duties on biodiesel imports from both Argentina and Indonesia (Regulation 490/2013), and overall EU biodiesel imports are expected to almost half in 2013 (Flach et al., 2013).

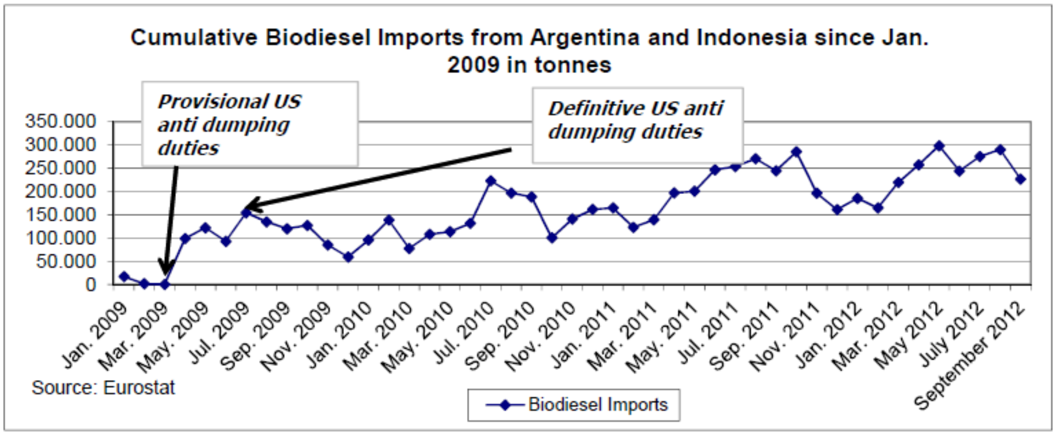

Figure 3. Biodiesel imports from Argentina and Indonesia. Effect of the anti-dumping duties on biodiesel from the US in 2009. Source: European Biodiesel Board (EBB).

Furthermore, besides the constraint imposed by the sustainability requirements laid down in the RED for both domestic and imported biodiesel, the EC recently published a new proposal, known as COM 595 (European Commission, 2012), which still has to be ratified. The proposal aims at starting the transition to biofuels made from non-food feedstock, since first generation biofuels (FGBs) –or biofuels manufactured from biomass which is generally edible– can negate the environmental benefits as compared to the fossil fuels they replace. This is meant to be done by setting a cap on, while phasing out of public support for FGBs after 2020 and establishing a GHG saving requirement of at least 60 percent for new installations. After intense debate, it is expected that the contribution of FGBs to the target in the RED will be limited to 6%. Although this value was initially set at 5%, producers within the rapeseed biodiesel supply chain of Central Europe still reject this proposal.

The underlying reason of this threshold is to reduce the emissions associated with changes in the carbon stock of land resulting from biofuels expansion. Specifically, the COM 595 is focused on limiting the emissions from Indirect Land Use Change (ILUC), which were not subject to reporting requirements under the previous legislation. This effect is the result of increased consumption of feedstock for biofuel production in different parts of the world, since previous crops have to be diverted to bioenergy. Apart from the direct conversion of land to satisfy demand of the Member States, production of energy crops on current land can induce ILUC elsewhere, since the displaced activities are subject to be implemented in other regions. In other words, ILUC is the result of global shifts in land cover and crop patterns in response to price changes, referred to as *market-mediated impacts* by Hertel and Tyner (2013). Ultimately, ILUC leads to changes in the carbon stock of the soil and the biomass, modifying the carbon balance of the land and releasing GHG emissions into the atmosphere (among other social and economic effects). Hence, the COM 595 urges the Member States to report ILUC values associated to the biofuels used to meet the 10% target, while providing ILUC factors depending on the feedstock. However, all the pressure groups such as European farmers, crushers, traders and biofuels producers reject the ILUC political compromise of the EU (EBB, 2013a,b), even they argue to remove ILUC considerations of any future Directive (COPA-COGECA, 2012).

Since the first studies warning against the risk of indirect GHG emissions from the biofuels boom (Fargione et al., 2008; Gibbs et al., 2008; Searchinger et al., 2008), much research work has been conducted on the ILUC effects from increased demand. While some authors developed different accounting methods relying on statistical data and methodological assumptions (Kim and Dale, 2011; Overmars et al., 2011), most of the latest studies agree on the use of Computable General Equilibrium (CGE) models, due to the global dimension of the bioenergy development. These are based on model projections of future responses rather than on historical observations. Specifically, the Global Trade Analysis Project (GTAP) (Hertel, 1997) has been broadly used in the study of ILUC responses, since Taheripour et al. (2007) introduced biofuel commodities in the version 6 of the GTAP database. This model provided the basis for further improvement and yielded a large number of studies addressing ILUC mainly due to US and EU policies (Banse et al., 2008; Hertel et al., 2010; Kløverpris, Baltzer and Nielsen, 2010; Taheripour et al., 2010; Taheripour et al., 2012). They consider that biofuel targets will be met by both land and yield adjustments, proving that significant changes in land use are expected to occur not only in those countries driving the demand for biofuels, but also in other parts of the world due to the interaction among agricultural-biofuel markets. In fact, one of the largest sources of potential GHG emissions associated with biofuels production results from the ILUC, which will take place in different regions of Latin America, Asia or Africa. Although the recent study of the EBB (Darlington et al., 2013) used a version of the GTAP database to calculate land conversion and ILUC emissions from increased consumption of FGBs in the EU according to an 8.75% target -as projected for 2015-, the effects of the COM 595 together with the anti-dumping duties have not been studied yet. Similarly, Al-Riffai, Dimaranan and Laborde (2010) applied the MIRAGE model, based on the GTAP 7 database (Narayanan and Walmsley, 2008), to analyze the interaction between a 5.6% target for FGBs in 2020 and trade liberalization measures on imports from the MERCOSUR countries, also in terms of LUC effects.

In the light of a growing concern about the ILUC effects of the biofuels expansion, the objective of the present study is thus to analyze the global environmental consequences of these different strategies recently proposed by the EC to stimulate the domestic biodiesel production while reducing GHG emissions. One single experiment is performed to get the full picture of how the market will react to the new cap on FGBs and the existing anti-dumping measures on biodiesel from Argentina, Indonesia and the US. It is found that LUC will take place not only in the EU but also at a global scale as a consequence of biodiesel trade and interactions in the food and feed markets. While the US gains of market share at the expense of Argentina, exports of palm biodiesel from Malaysia and Indonesia to the EU are even fostered by the increase in the import price, since European consumers continue to depend on them to meet the targets. Biodiesel producers in the EU benefit from these policies as well, especially those producing rapeseed and non-food-based biodiesel, for which the increase in demand is the highest. The expansion in the European biodiesel sector triggers demand for both vegetable oils and oilseeds, altering crop patterns in other countries not directly affected through biodiesel trade relations. As a result, not even the biodiesel self-sufficiency is completely achieved, since the EU needs to import biodiesel feedstock, while global GHG emissions from LUC significantly increase. This paper is organized into the following sections: Section 2 describes methodology; results are analyzed and discussed in Section 3, in regard to market responses and environmental effects; finally, conclusions are drawn in Section 4, providing insights for further improvement.

2. Methodology

2.1. The GTAP-BIO version

A version of the standard GTAP model (Hertel, 1997) has been used. Specifically, the latest version of the GTAP-BIO, described by Golub and Hertel (2012), and built on the version of Birur, Hertel and Tyner

(2008). This version modified the GTAP-E model (Burniaux and Truong, 2002), whose main contribution was to incorporate energy substitution in the production nest by allowing capital and energy to be either substitutes or complements. Substitution follows a nested CES function, based on the separability between primary factors and intermediate inputs (Figure A.1., Annex A). The energy inputs are aggregated with capital in a composite, allowing for capital-energy substitution with other factors. The separability assumption in the standard model was then relaxed to make labor-energy substitution different from capital-energy in the value added sub-nest. The non-electric intermediate inputs include petroleum-based fuels. Carbon emissions from the combustion of them are included too, as well as a mechanism to trade these emissions internationally.

The GTAP-E version was extended by McDougall and Golub (2007) to improve its applicability to a wider range of energy-environmental policy scenarios. Taheripour et al. (2007) further modified it to incorporate the potential for biofuels to substitute for petroleum products. Biofuel commodities were included, based on the International Energy Agency (IEA) database and plant-level, biofuel processing models. As a result, three biofuel sectors were included: ethanol from coarse grains, ethanol from sugarcane and biodiesel from oilseeds. In addition, the model includes Dried Grains with Solubles (DDGS) as a byproduct of corn-based ethanol production and protein meals from biodiesel production, which can displace other protein sources for animal feed (with the subsequent consequences on the feed market). As Golub and Hertel (2012) commented on this version, the prominence given to energy substitution makes it a very useful tool for the study of biofuel mandates implications, since the mandate will be more costly for the economy if alternative fuels are not good substitutes for petroleum products and the other way round. Finally, Birur, Hertel and Tyner (2008) took advantage of these feature implementations in order to associate land use information to biofuels consumption. Specifically, they implemented a land use module allowing to estimate LUC in different agroecological zones (AEZ) and the associated emissions. By using the GTAP land use database developed by Lee et al. (2005), 18 AEZs were defined according to two dimensions: growing period (6 categories of 60 day growing period intervals) and climatic zones (3 categories: tropical, temperate and boreal). The competition for land within a given AEZ across uses, triggered by biofuel policies, is modeled in this way, based on historical observations to determine which activities have been observed to take place in each AEZ.

The latest GTAP-BIO version is in turn based on the version 8 of GTAP database, depicting the world economy in 2004. It is similar to the one created by Taheripour et al. (2011) (GTAP-BIO-ADV) but the feature that makes it more interesting for our analysis is that this particular version disaggregates biodiesel into soybean biodiesel, rapeseed biodiesel, palm biodiesel and biodiesel from other feedstock (*Biod_soy, Biod_rape, Biod_palm* and *Biod_oth*) (as explained in Figure B.1., Annex B). Four different agricultural commodities (soybeans, rapeseed, palm and other oilseeds) are considered for biodiesel production as well, and these four agricultural industries compete in land, capital, labor, and intermediates, and sell their products to other industries (mainly vegetable oil, food and feed industries) and households (HH). The vegetable oil industry in GTAP is thus divided accordingly into *Vol_soy, Vol_rape, Vol_palm* and *Vol_oth*. Substitution among all these types of vegetable oils in the HH and firm demand for goods and services is possible thanks to a new elasticity parameter. This tries to represent how demand for oils shifts to cheaper oils when the price of one particular type of oil increases sharply as a consequence of the increased demand by biodiesel firms. It is assigned a high value in the regions which produce different oilseeds or import them from other regions (e.g. China and EU members), while is small in the regions which mainly produce one type of vegetable oil (e.g. Brazil and the US). As a result, the database covers 19 regions, 42 industries and 48 commodities, as is shown in Table C.1. (Annex C).The land use module allows competition among traditional crops and dedicated energy crops for idle land and cropland pasture. Among other characteristics, it offers greater flexibility in acreage switching among uses in response to price changes and includes an endogenous yield adjustment for cropland pasture (which represents marginal land previously used for agriculture) in response to changes in cropland pasture rent but only for the US and Brazil; other regions do not have this possibility. The ratio of marginal and average productivities (ETA), which measures the productivity of new cropland versus the productivity of existing cropland, now varies across regions and among AEZs.

2.2. Intensive and extensive margins

As the version used by Hertel et al. (2010), this version models the changes in the *intensive* and *extensive margins* of yield responses due to increased biofuels demand. Whereas the intensive margin captures the increase in yields as a response of higher prices of agricultural commodities, the extensive margin is defined as the change in yield when land employed in other uses (crop, pasture or forest) is converted to grow oilseeds. If oilseeds production expands onto lower productivity land, then the extensive margin will be negative, capturing the tendency to reduce yields as less productive land -even idle land- must be brought into production.

In regard to the extensive margin, two main causes are considered: when demand for oilseeds increases, other crops can be displaced on existing agricultural land. This displacement is estimated from the differential in net returns to land in existing uses, based on the assumption that land will be allocated to its highest value use. A nested CET structure of land supply is implemented (Ahammad and Mim 2005) whereby the land owner first decides on the allocation of land among three uses (forest, cropland and pasture) in order to maximize his rent. The second cause arises from the change in average crop yields as cropland area is expanded into land not previously used for agricultural purposes, such as pasture or forest. The extensive margin is determined by the ETA parameter (elasticity of output with respect to acreage expansion), which varies between 0.42 and 1 depending on the region and the AEZ. The lowest value means that diverting three hectares of current cropland to biofuel feedstock production takes seven additional hectares of marginal land (cropland pasture), implying the lowest productivity of the land which can be potentially diverted for biofuels production. On the contrary, if ETA is 1, the converted land has the same productivity as existing cropland in that AEZ, such as the case of other crops. Each land conversion in each AEZ is assigned a CO_2 emission factor (based on estimations of the California Air Resources Board) in the land use module.

2.3. Closure and shocks

The standard GE closure has been used. The policy experiment presented has been inspired by the policies mentioned in the introduction (the new proposal COM 595, and the Regulations 444/2011 and 490/2013), and based on statistical data and energy projections from Eurostat (2013). The ratio ethanol-biodiesel calculated is around 3/8 for 2020.

One single experiment has been performed, in order to shock simultaneously: 1) increased biodiesel consumption due to the new target for FGBs (6%); 2) increase in the CIF price of biodiesel imports into the EU from Southeastern Asia (Mala-Indo) by 18.9%, from South America –excluding Brazil– (S-Amer) by 24.6% and from the US by 10.8%, and see how these policies interact in the same time frame. For 1), private demand for *Biod_soy, Biod_rape* and *Biod_palm* has been expanded by using current shares on first generation biodiesel consumption in the EU (26.3%, 56.2% and 12.3%, respectively), while *Biod_oth* has been increased according to the remaining 4% target in the COM 595. Bilateral trade flows of *Biod_soy*, *Biod_palm* and *Biod_oth* between the EU27 and the main exporting regions were previously introduced by using the Altertax closure (documented in Malcolm, 1998), according to data reported by Lamers et al. (2011). Biodiesel production and consumption in the EU were updated in the initial dataset as well. All the shocks and swaps for this experiment are summarized in Table 1. It has to be pointed out that the sharp increase in demand for *Biod_oth* is due to very low consumption levels in the base data together with the projected consumption in 2020 (3.03 thousand million gallons).

Table 1. Shock statements to perform the experiment.

Shocks and swaps statements	
swap del_taxrpcbio("EU27") = tpbio("EU27")[1]	-
swap qp("biod_soy","EU27") = tpd("biod_soy","EU27")	-
swap qp("biod_palm","EU27") = tpd("biod_Palm","EU27")	-
swap qp("biod_rape","EU27") = tpd("biod_Rape","EU27")	-
swap qp("biod_oth","EU27") = tpd("biod_Oth","EU27")	-
shock qp("biod_rape","EU27")	685.0
shock qp("biod_palm","EU27")	119.6
shock qp("biod_soy","EU27")	45.12
shock qp("biod_oth","EU27")	7327.8
shock tms("biod_palm","Mala-Indo","EU27")	18.9
shock tms("biod_soy","S-Amer","EU27")	24.6
shock tms("biod_soy","USA","EU27")	10.8

3. Results

Market responses have been estimated by analyzing changes in the most significant variables (shown in Table D.1., Annex D), as compared to the same changes without the anti-dumping measures. Changes in the harvested area in the regions directly affected by the policy measures are shown in Table 3 (EU-27), Table 4 (S-Amer), Table 5 (US) and Table 6 (Mala-Indo). Extensive and intensive margins have been analyzed separately for each of these regions and for different agricultural commodities competing with biodiesel feedstock for land.

3.1. Market responses through the biodiesel supply chain

3.1.1. Biodiesel imports

As was mentioned previously, biodiesel imports into the EU have been updated until they reached 2009 levels by using the Altertax closure (Malcolm, 1998), in order not to underestimate the global effects of the blending mandate arising from bilateral trade. However, these trade flows involve only major biodiesel exporters to the EU, which were Argentina, the US, Indonesia, Canada and Malaysia in 2009, according to Lamers et al. (2011). The consumption share of imported biodiesel relative to domestic one has then changed from less than 0.05% for *Biod_soy, Biod_palm* and *Biod_oth* to 78.48%, 83.23% and 47.06%, respectively, depicting a more realistic situation. The share of imported *Biod_rape* has remained around 0%, which is consistent with current consumption patterns in the EU. On the contrary, the shares

[1] This statement prevents the tax revenue for the government from being affected when tpbio adjusts for allowing qp to change, by evenly distributing the tax changes across all biofuels. Tpbio is a tax to implement a blending mandate, originally created for the LCFS.

of imported oils in biodiesel firms' demand are around 50% for soybean, palm and rape, whereas the entire demand for palm oil is met with imported oil. All these shares are summarized in Table 2. Overall, S-Amer accounts for 10.9% of the EU private consumption of biodiesel, while the US and Mala-Indo account for 6.1% and 3.5%, respectively.

Table 2. Import share within the biodiesel supply chain in the EU-27

	Share of imported biodiesel in HH demand	Share of imported oils in biodiesel firms' demand	Share of imported oilseeds in crushing industries' demand
Soy	78.5%	50.3%	96.6%
Palm	83.2%	100.0%	97.4%
Rape	0.0%	49.6%	36.1%
Others	47.1%	49.6%	43.2%

By applying the updated shares, the expansion in demand for biodiesel in the EU following the requirements in the COM 595 is met by both, imports and domestic production. In this section, the experiment results may be compared to results arising from the mandate shock alone for further interpretation. Without the tariff shock, the increased demand for soybean biodiesel causes an increase in exports from S-Amer (67.29%), while exports from the US only expand by 2.70%. In addition, imports from other European countries increase by 426.77%, from both imported and domestic soybeans. The corresponding shock on EU demand for palm biodiesel increases exports from Mala-Indo by 32.79%. Since this is the only biodiesel source of palm biodiesel to the EU, these two countries account for the entire import share in the European market in the database. Even introducing the tariff shock, exports from these three countries to the EU expand, triggered by the sharp increase in private consumption. As can be observed in Table D.1. (Annex D), imports from S-Amer increase less (24.91%) due to the anti-dumping duties, which are the highest for that country of origin. The expansion in exports from Mala-Indo is slightly greater (34.19%), while exports of soybean biodiesel from the US increase much more (93.20%), since they take part of the S-Amer's market share despite the anti-dumping duties on its own exports. It can be said that the anti-dumping duties have the most detrimental consequences on soybean biodiesel exports from S-Amer, since these consequences are determined in accordance of the shock on tms.

To explain the consequences of the tariff shocks on biodiesel exports from Mala-Indo, the US and S-Amer, we should look at the equations used to explain exports from each country in the model:

```
qxs(i,r,s)= qim(i,s) - ESUBM(i)*[pms(i,r,s)- pim(i,s)];                    (1)
```

Where qxs(i,r,s) are the export sales of commodity i from r to region s; qim(i,s) are the aggregate imports of i in region s (weighted according to market prices); ESUBM(i) is the region-generic elasticity of substitution among imports of i in Armington structure; pms(i,r,s) is the domestic price for good i supplied from r to region s; and pim(i,s) is the market price of composite import i in region r.

Since Mala-Indo enjoys a share of 100% for *Biod_palm* imports into the EU, the third term in (1) goes to zero and qxs(i,r,s) = qim(i,s). In the market clearing equation for imported *Biod_palm* entering the EU:

```
qim(i,s) = sum(j,ALL_INDS,SHRIFM(i,j,s)* qfm(i,j,s)) + SHRIPM(i,s)* qpm(i,s) +
SHRIGM(i,s)* qgm(i,s);                                                      (2)
```

In which SHRIFM(i,j,s), SHRIPM(i,s) and SHRIGM(i,s) are the shares of imports i used by sector j, by private HH and by the government in region s, respectively. Similarly, qfm(i,j,s), qpm(i,s) and qgm(i,s) are the demands for imports of good i by sector j, by private HH and by the government in region s. In this case, the entire demand for imported *Biod_palm* in (2) is generated by the private HH, qpm(i,s), being qfm(i,j,s) = qgm(i,s) = 0.

```
qpm(i,s) = qpt(i,s) + ESUBD(i)*[ppt(i,s) - ppm(i,s)];                    (3)
```

Where qpt(i,s) is the private HH demand for commodity i in region s; ESUBD(i) is the region-generic elasticity of substitution between domestic and imported goods for all agents; ppt(i,s) is the private consumption price for commodity i in region s; and ppm(i,s) is the price of imports of i by private HH in s. Since the private HH demand for *Biod_palm* increases sharply in the EU, the increase in demand for imported one (qpm) is much greater too, but this is the same with and without the tariff shock. The elasticity of substitution between domestic and imported biodiesel is 2 for *Biod_palm* (the lowest), while it is almost 5 for the rest. However, the variable which makes the difference is ppt, the private consumption price for the composite commodity *Biod_palm*, which in turn depends on:

```
ppt(i,s) = PMSHR(i,s)* ppm(i,s) + [1 - PMSHR(i,s)]* ppd(i,s);            (4)
```

Being PMSHR(i,s) the share of imports of i by private HH at agent's prices, while ppd(i,s) is the price of domestic i to private HH in region s. In our case study, ppm of *Biod_palm* in the EU is zero and PMSHR is the highest (Table 1). As a result of the tariff shock, the decrease in ppd is slightly smaller than without it, despite the increased demand in qp. This is the ultimate cause for the higher increase in exports of *Biod_palm* from Mala-Indo when there is a shock on tms(biod_palm,Mala-Indo,EU).

The situation is different for *Biod_soy* imports. As we can see in eq. 1, since the increase in the market price of the biodiesel from S-Amer is greater than for the biodiesel from the US due to the higher anti-dumping duty, the decrease in qxs is much greater for S-Amer as well. In addition, the Armington elasticity of substitution ESUBM(i) among *Biod_soy* imports, is more than twice than that for *Biod_palm*. In other words, consumers are substituting for *Biod_soy* from S-Amer due to its higher price. Since there are no other partners exporting *Biod_soy* to the EU, consumers cannot choose any other biodiesel which is not-dumped, as it occurs for *Biod_palm* from Mala-Indo. It has to be pointed out that the same shock was previously performed without considering anti-dumping duties in US biodiesel. In that case, exports of *Biod_soy* from the US expanded by more than 100%, since exports from S-Amer decreased by 25% and the US filled the gap left by S-Amer in the *Biod_soy* market in the EU.

3.1.2. EU biodiesel sector

On the other hand, as could be expected, the greatest benefits of the combined shock are enjoyed by the biodiesel producers in the EU, regardless the feedstock they use for biodiesel production. Specifically, the production of *Biod_oth* expands the most (16,313.78%), followed by *Biod_palm* (852.94%), *Biod_rape* (685.00%) and *Biod_soy* (36.37%). These changes are also driven by the shocks on qp. However, the increase in domestic production can differ from the magnitude of the shock for each type of biodiesel depending on the difference in the equation:

```
qpd(i,s) = qpt(i,s) + ESUBD(i) * [ppt(i,s) - ppd(i,s)];                  (5)
```

Where qpd(i,s) is the private HH demand for domestic i in region s. ESUBD(i) is the same for all types of biodiesel. The last term is negative for *Biod_soy*, zero for *Biod_rape*, slightly positive for *Biod_oth* and positive for *Biod_palm*. For instance, ppt(biod_palm,EU27) = -21.83, whereas ppt(biod_soy,EU27) = 0.48; ppd(biod_palm,EU27) = -62.47, whereas ppd(biod_soy,EU27) = 1.75. This difference is ultimately determined by the shares of domestic consumption in total private demand for each type of biodiesel in the EU after the shock, as we saw in eq. 4. In the case of *Biod_rape,* since demand for *Biod_rape* is entirely met by domestic production, this increases at exactly the same rate as the qp shock (ppt(biod_rape,EU27) = ppd(biod_rape,EU27) = -63.88). However, the domestic production of *Biod_soy* and *Biod_palm* in the EU increases less than with the mandate shock alone because exports of both increase even more, as explained in the previous paragraphs. Simultaneously, the private demand for *Biod_soy* decreases in S-Amer and the US, and the private demand for *Biod_palm* decreases in Mala-Indo, depending on how large is the increase in exports to the EU. As a result of the combined shock, the market prices are 8.51% higher for *Biod_soy*, 4.03% higher for *Biod_palm,* 11.46% higher for *Biod_rape* and 12.33% higher for *Biod_oth.*

3.1.3. Biodiesel inputs in the EU

Given the expansion in the European biodiesel sector, consumption of vegetable oils has to expand too. This increased demand is met by both imported and domestic vegetable oils in similar proportions since the shares in firms' demand are around 50% for all the oils except palm oil. Demand for palm oil crushed in European industries increases even more than for imported *Vol_palm*. However, it has to be taken into account that the value of domestic purchases of *Vol_palm* in the database is zero. Similarly, despite the higher increase in demand for imported *Vol_oth* than for domestic one, the value of imports into the EU is very low, thus the increase is not as remarkable as it seems in Table D.1. (Annex D). Imports of *Vol_rape*, *Vol_palm* and *Vol_soy* into the EU are actually substantial also according to the European Commission (2013).

In regard to the oilseed sector, since the expansion in the biodiesel sector affects the crushing industry, firms' demand for oilseeds expands too. Given the share of imported feedstock in total firms' demand in Table 2, the demand for oilseeds by the European crushing industry increases for both domestic and imported feedstock. Accordingly, demand for imported feedstock increases more than for domestic one in the cases of soybean and palm, whereas it increases less than for domestic rapeseed and other feedstock. As a consequence, the production of oilseeds also expands in those countries exporting to the EU, with the subsequent LUC due to crops displacement. This effect is further analyzed in the following section. In terms of prices, all the oilseeds become more expensive: the increase in the rapeseed price is the highest, for both domestic and imported rapeseed (14.96% and 11.12%, respectively), followed by the increase in the price of other oilseeds (14.45% and 11.12%). On the other hand, the price of both domestic and imported soybean increases the least (3.05% and 0.62%, respectively), since soybean production is also oriented to several sectors such as food and feed in many countries.

3.2. Environmental effects

3.2.1. Direct LUC in the EU

Regarding to the land use and yield implications of the mandate, there is obviously a significant expansion in the harvested area for oilseeds in the EU, mainly rapeseed and other oilseeds, for which firms' demand increases the most due to the shocks on biodiesel private consumption. Production of soybeans decreases, as a consequence of the increase in imports from both S-Amer and the US, as discussed in the previous section. Even if the model's output shows an increase in the production of palm, it has to be pointed out that the initial level of production in the database is zero. As can be seen in Table 3, 52.84% more land is diverted to rapeseed and 52.18% is diverted to other oilseeds. This expansion takes place not only at the expense of soybean (which is not a widespread crop in the EU) but also at the expense of other crops, especially paddy rice, wheat, other coarse grains and other crops. However, these four commodities still account for 80.2% of the overall agricultural land in the EU. Higher oilseeds prices lead to higher yields under the intensive margin. There is also a significant yield adjustment in the rest of the crops for which area is contracting, in order to avoid greater production slowdowns. The extensive margin prevails though, which is positive in this case, suggesting that in much of the EU the productivity of land that might be converted to cropland is about the same as existing cropland. This happens because LUC takes place at the cost of land previously used for agricultural production and not from idle land, as shown in Table 3. Indeed, neither pasture nor other agri-industrial sectors are affected. These values are mostly the result of the shock on biodiesel consumption and hardly change due to the tariff shock.

Table 3. Change in harvested area by crop for the EU-27

	Soybeans	**Rapeseed**	**Palm**	**Other oilseeds**	**Wheat**	**Sorghum**	**Other coarse grains**	**Paddy rice**	**Sugarcane**	**Other crops**
Decomposition of output changes (%)										
Output	-7.76	61.10	15.51	61.48	-3.50	1.09	-0.33	-4.79	-0.70	-2.80
Yield	4.43	5.40	0.00	6.10	4.54	4.80	4.94	4.72	4.58	4.63
Area	-11.69	52.84	0.00	52.18	-7.41	-3.55	-5.03	-9.16	-4.90	-6.89
Decomposition of yield changes (%)										
Yield	4.40	5.33	0.00	6.02	4.51	4.76	4.89	4.70	4.54	4.59
Intensive margin	0.60	1.90	0.00	1.95	0.87	1.18	1.18	0.68	0.97	1.01
Extensive margin	3.80	3.43	0.00	4.07	3.64	3.58	3.71	4.02	3.57	3.58
Harvested area (Mha)	0.35	6.83	0.00	13.60	24.51	0.10	32.05	0.39	2.12	35.94

3.2.2. Global LUC and GHG emissions

The effects in the biodiesel exporting countries are similar. There is an increase in the land dedicated to rapeseed and other oilseeds in the three regions, although it has to be pointed out that Mala-Indo does not produce rapeseed. This is a result of the huge expansion in demand for these oilseeds by the European crushing industries, but also the expansion in domestic demand to produce biodiesel for export. On the contrary, the production of soybean decreases to meet this greater demand for other oilseeds. This suggests that part of the available soybeans is no longer used in other sectors in the US and S-Amer, in order to increase *Biod_soy* exports to the EU. In fact, oilseeds demand by other important sectors decreases in these two countries, mainly livestock and feed processing industries. The area diverted to palm in S-Amer expands as well, to increase exports of *Vol_palm* to the European market. Other LUC effects can be observed for S-Amer: the area diverted to most of coarse grains decreases (except for other coarse grains) and the intensive margin still prevails, even if the converted land is, in some cases, less productive for current uses than for the previous ones. However, LUC effects in S-Amer are the least remarkable, since demand for oilseeds is much diversified across sectors, and the effect of the increased demand for biodiesel is diluted; the livestock sector is indeed very important in countries such as Argentina. In the US, production of all the coarse grains expands at the expense of idle land and pasture, and that is why yields decrease. It has to be recalled though that transformation from pasture is only possible in the model for the US and Brazil. Finally, in Mala-Indo, production of palm increases the most, while the increase in rapeseed production is not relevant because it is initially zero. As can be seen in Table 6, the resulting area dedicated to rapeseed, wheat and sorghum is zero in Mala-Indo, whereas only palm and rice account for 60.2% of the total acreage in the region. As a consequence, the land used for the rest of crops must decrease, except for other oilseeds. The intensive margin again determines the subsequent yield adjustments, while the extensive margin is negative leading to the conclusion that the new cropland is less productive, coming at the expense of degraded land (due to overdrainage) or anthropogenic grassland, with high acidity level and low content of organic matter (Chouychai et al., 2009; Germer and Sauerborn, 2008).

Despite the changes in crop patterns, overall GHG emissions in Table 7 show that the sharp expansion in worldwide oilseeds production not only takes place at the expense of other crops but also from land used for other activities. These GHG emissions are calculated by multiplying the acreage changes by the calculated CO_2 emission factors. Whereas transformation from arable land leads to carbon uptake in all the analyzed regions (since the new crops improve the GHG balance as compared to the previous ones), contraction in the area diverted to livestock and especially forestry generates substantial GHG emissions, with the subsequent global warming impact. This is the result of higher emission factors associated with transformation from grassland or forest to crops in each AEZ, since there are CO_2 emissions arising from changes in the carbon stock in soil and biomass. Finally, Figure 4 shows absolute changes in the distribution of the global agricultural land, by crop and region, as a consequence of the shock on biodiesel consumption in the EU by 2020. Apart from the LUC effects outlined in previous paragraphs, the expansion in acreage in Sub-Saharan Africa (SS-Africa), Brazil, other CEE countries, Russia and Canada is also remarkable, mainly to produce other oilseeds and rapeseed for export to the EU, or palm to produce oil for export too (e.g. in SS-Africa). As a result of the increased demand for biodiesel in the EU, overall LUC by 2020 will lead to an expansion in the worldwide agricultural land of 3.24 Mha, whereas area dedicated to oilseeds, cereals and sugarcane will increase by 6.50 Mha. Similarly, in the EU, there will be an increase of 7.01 Mha in the acreage for rapeseed and other oilseeds, which will partially take place at the expense of 6.76 Mha from other crops, wheat or other coarse grains, causing a net expansion of 0.25 Mha in the agricultural land, only surpassed by the expansion in Brazil and SS-Africa.

Table 4. Change in harvested area by crop for S-Amer

	Soybeans	**Rapeseed**	**Palm**	**Other oilseeds**	**Wheat**	**Sorghum**	**Other coarse grains**	**Paddy rice**	**Sugarcane**	**Other crops**
Decomposition of output changes (%)										
Output	-2.85	29.27	32.04	26.98	-0.67	0.46	0.74	-0.26	-0.18	0.54
Yield	-0.01	2.12	3.19	2.38	0.26	0.51	0.50	0.87	0.79	0.65
Area	-2.84	26.59	27.96	24.03	-0.99	-0.05	0.24	-1.04	-0.91	-0.21
Decomposition of yield changes (%)										
Yield	0.00	2.12	3.18	2.38	0.26	0.51	0.50	0.87	0.78	0.65
Intensive margin	0.27	2.40	2.70	2.43	0.49	0.57	0.59	0.58	0.49	0.68
Extensive margin	-0.27	-0.28	0.48	-0.05	-0.23	-0.06	-0.09	0.29	0.29	-0.03
Harvested area (Mha)	17.03	0.06	0.44	3.27	7.26	0.91	6.71	2.09	1.21	17.92

Table 5. Change in harvested area by crop for the US

	Soybeans	Rapeseed	Palm	Other oilseeds	Wheat	Sorghum	Other coarse grains	Paddy rice	Sugarcane	Other crops
Decomposition of output changes (%)										
Output	-4.74	40.68	3.84	32.73	2.50	0.26	0.52	0.51	-0.01	0.73
Yield	-0.73	1.60	0.00	1.11	-0.06	-0.33	-0.41	-0.68	-0.27	-0.21
Area	-4.05	38.47	0.00	31.27	2.56	0.59	0.93	1.19	0.25	1.03
Decomposition of yield changes (%)										
Yield	-0.73	1.60	0.00	1.13	-0.06	-0.33	-0.40	-0.67	-0.26	-0.21
Intensive margin	0.03	1.88	0.00	1.75	0.44	0.28	0.27	0.32	0.42	0.37
Extensive margin	-0.76	-0.28	0.00	-0.62	-0.50	-0.61	-0.67	-0.99	-0.68	-0.58
Harvested area (Mha)	28.71	0.46	0.00	2.03	20.24	2.65	32.17	1.37	0.93	39.16

Table 6. Change in harvested area by crop for Mala-Indo

	Soybeans	Rapeseed	Palm	Other oilseeds	Wheat	Sorghum	Other coarse grains	Paddy rice	Sugarcane	Other crops
Decomposition of output changes (%)										
Output	-1.13	19.08	5.14	0.75	3.68	-2.22	-0.58	-0.44	-0.30	-0.27
Yield	-0.11	0.00	1.56	0.43	0.00	0.00	0.09	0.15	0.23	0.25
Area	-1.03	0.00	3.53	0.32	0.00	0.00	-0.68	-0.58	-0.50	-0.45
Decomposition of yield changes (%)										
Yield	-0.11	0.00	1.56	0.44	0.00	0.00	0.09	0.15	0.24	0.25
Intensive margin	0.12	0.00	1.85	0.72	0.00	0.00	0.33	0.40	0.52	0.52
Extensive margin	-0.23	0.00	-0.29	-0.28	0.00	0.00	-0.24	-0.25	-0.28	-0.27
Harvested area (Mha)	0.56	0.00	6.96	0.00	0.00	0.00	3.37	12.53	0.43	8.53

Table 7. Global GHG emissions from LUC (Tg of CO_2-eq.)

	Forestry	Crops	Livestock	Total
In EU	46.71	-4.54	14.08	56.25
In Mala-Indo	83.20	-1.84	0.99	82.18
In S-Amer	-5.41	-2.11	10.58	3.07
USA	16.29	-1.12	42.43	57.59
Rest of the world	426.31	-51.25	101.44	476.50

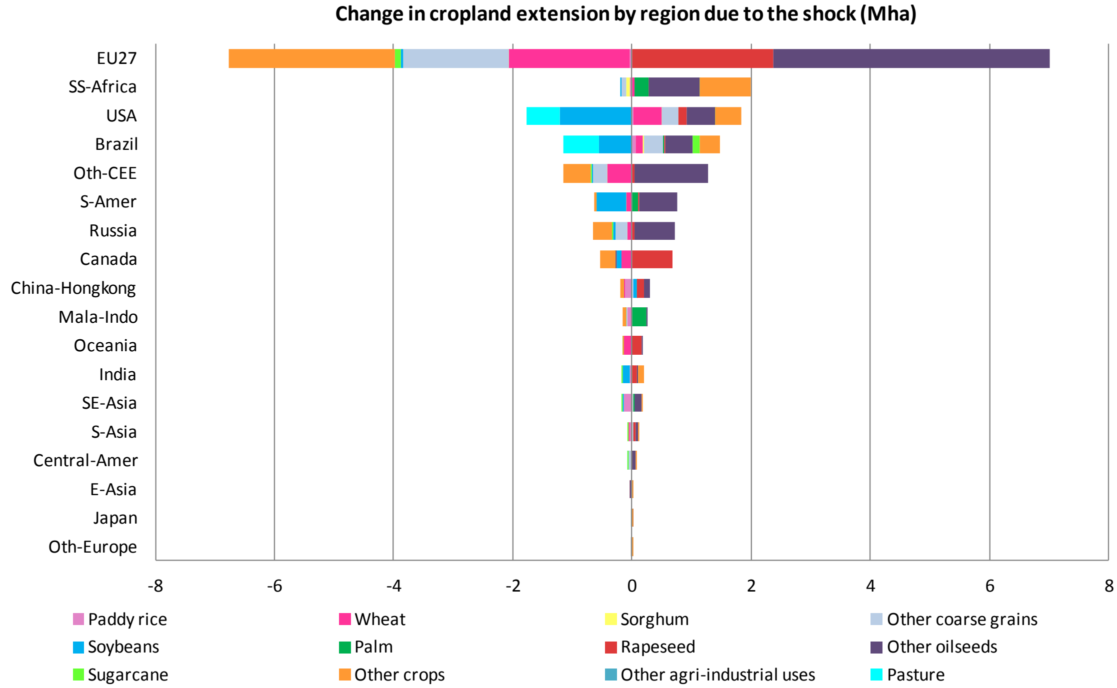

Figure 4. Changes in total agricultural land (Mha), by region, due to the shock on biodiesel consumption in the EU with the subsequent anti-dumping duties. Other countries than the main biodiesel exporters to the EU are affected by means of interactions among other agricultural commodities in the global market, triggered by changes across the biodiesel supply chain.

4. Conclusions

The results obtained show that establishing a 6% target for FGBs and a 4% target for advanced biofuels (with or without anti-dumping measures) is a great incentive for the biodiesel sector in the EU, since the market is filled with imported biodiesel but also with domestic product. Specifically, domestic production of *Biod_rape* and *Biod_oth* increases sharply. Despite the anti-dumping measures on biodiesel imports from Mala-Indo, the US and S-Amer, exports from these origins expand too, due to the huge increase in EU private demand for biodiesel, which obviously affects the leading exporting countries. When anti-dumping measures are introduced, *Biod_palm* imports from Mala-Indo into the EU are even higher due to price responses. In short, if EU has to increase demand for *Biod_palm*, the only source for it is Mala-Indo, therefore despite anti-dumping duties and huge tariff increases, EU continues depending on them. On the contrary, European consumers can choose between *Biod_soy* from the US and from S-Amer to meet the mandate targets. Hence, imports of the cheapest *Biod_soy* increase, which is the one from the US, due to lower anti-dumping duties as compared to the ones set for S-Amer.

The expansion in demand for biodiesel creates in turn an increased demand for feedstock, not only in the EU but also in the main exporters of both vegetable oils (such as Mala-Indo, S-Amer, Brazil or India) and oilseeds (such as USA, Brazil, S-Amer, China or Canada). Feedstock exporting countries are generally those exporting biodiesel too, since they produce oilseeds and oils for export or for domestic firms' consumption, depending on the world market prices of each commodity. It has to be pointed out that, whereas the US and specially S-Amer export both oilseeds and oils, Mala-Indo only exports palm oil, due to high transportation costs of the fresh palm fruit bunches; this helps to promote the domestic crushing industry. Anyhow, the increased demand for biofuels due to European mandates will be only met with domestic biofuel feedstock partially, and the region will incur an agricultural trade deficit, as Banse et al. (2008) concluded. LUC will thus take place globally mainly because of the increased production of rapeseed, palm and other oilseeds, while production of soybean will decrease in major producing countries since the shock in *Biod_soy* consumption is the lowest (relative to 2009 consumption levels, when *Biod_soy* was the second most used in the EU, after *Biod_rape*). In addition, in many countries such as S-Amer, the expansion of these other oilseeds will even occur at the expense of soybean. As has been addressed, European biofuel policies can have strong consequences outside the EU in terms of LUC and GHG emissions, mainly in regions such as the US, Brazil, S-Amer but also SS-Africa, Russia or Canada, by means of market mediated responses. Banse and Grethe (2008) found that increasing EU biofuel demand –due to the RED– will be satisfied by imports for a substantial share, either in the form of biofuels or biofuel inputs. These effects will also lead to changes in the agricultural structures worldwide, which can have other effects than only environmental, for example of social nature. In these sense, analyzing welfare effects will be useful to estimate the cost of these policies for the society.

It should be recalled, however, that the present results are only based on bilateral trade flows of biodiesel between the EU and the regions Mala-Indo, S-Amer and the US. As a result, LUC effects are mainly transferred to other countries via interaction among agricultural markets (ILUC). In order to get a more realistic picture, the same experiment should be performed by introducing other biofuel trade flows with all the EU partners. However, current results can be considered reasonably representative because only Malaysia, Indonesia, Argentina and the US accounted for more than 94% of the total extra-EU27 biodiesel imports in 2012 (European Commission, 2013). It has to be said that biodiesel production in the US has slowed down in recent years, and exports to the EU have dramatically declined since 2011, hardly representing 0.03% of the imports share in 2012. Other countries to be thus considered to improve the reliability of the analysis should be Norway, South Korea, United Kingdom or Canada, according to these very data. Similarly, although most of the advanced biodiesel in the EU is currently produced from domestic used cooking oil (Ecofys et al., 2013), some trade flows of *Biod_oth* should be included if consumption of advanced biofuels is expected to increase sharply as a consequence of policies such as the COM 595, driving demand for imported biodiesel and/or for feedstock (algae, bagasse, crude glycerin, nut shells, etc). Additionally, it must be noted that for the present experiment, it has been assumed that the commodity *Biod_oth* corresponds entirely to advanced biofuels, when in reality it can be manufactured from other oilseeds such as sunflower, thus competing with food production. Disaggregating these other FGBs from the *Biod_oth* commodity would lead to zero LUC values associated to the increased feedstock production, providing a better analysis of the COM 595 effects. Therefore, current GHG emissions from LUC are overestimated, due to the enormous increase in the land diverted to other oilseeds. Finally, performing the same experiment by shocking only the demand for an aggregated first generation biodiesel commodity (including *Biod_soy*, *Biod_rape* and *Biod_palm*) instead of three independent shocks may provide additional insights, since this will let the market adjust according to consumers preferences (based on price changes) instead of according to current consumption shares. Results will then depict projected biodiesel consumption in 2020 through market mediated responses, and expected LUC and GHG effects may be slightly different in that case.

The fact is that increasing demand for biofuels due to European policies will require the use of a significant amount of biomass, and the global economy is expected to be affected in several ways, with the subsequent LUC effects not only in the EU but also in very distant regions. Although these effects are difficult to predict due to their global dimension, addressing LUC is not temporary, and most of the latest bioenergy policies (such as the Renewable Fuel Standard -RFS2-, RED, etc) urge countries to reduce overall GHG emissions generated by increasing biofuel consumption. This paper is an example of the application of the GTAP model to estimate the environmental consequences (regarding to GHG emissions and ILUC) of different market instruments affecting the biodiesel sector in the EU. When analyzing public policies, these market mediated responses cannot be neglected, and CGE models are the best tool to estimate the potential global effects from these decisions since international trade is crucial.

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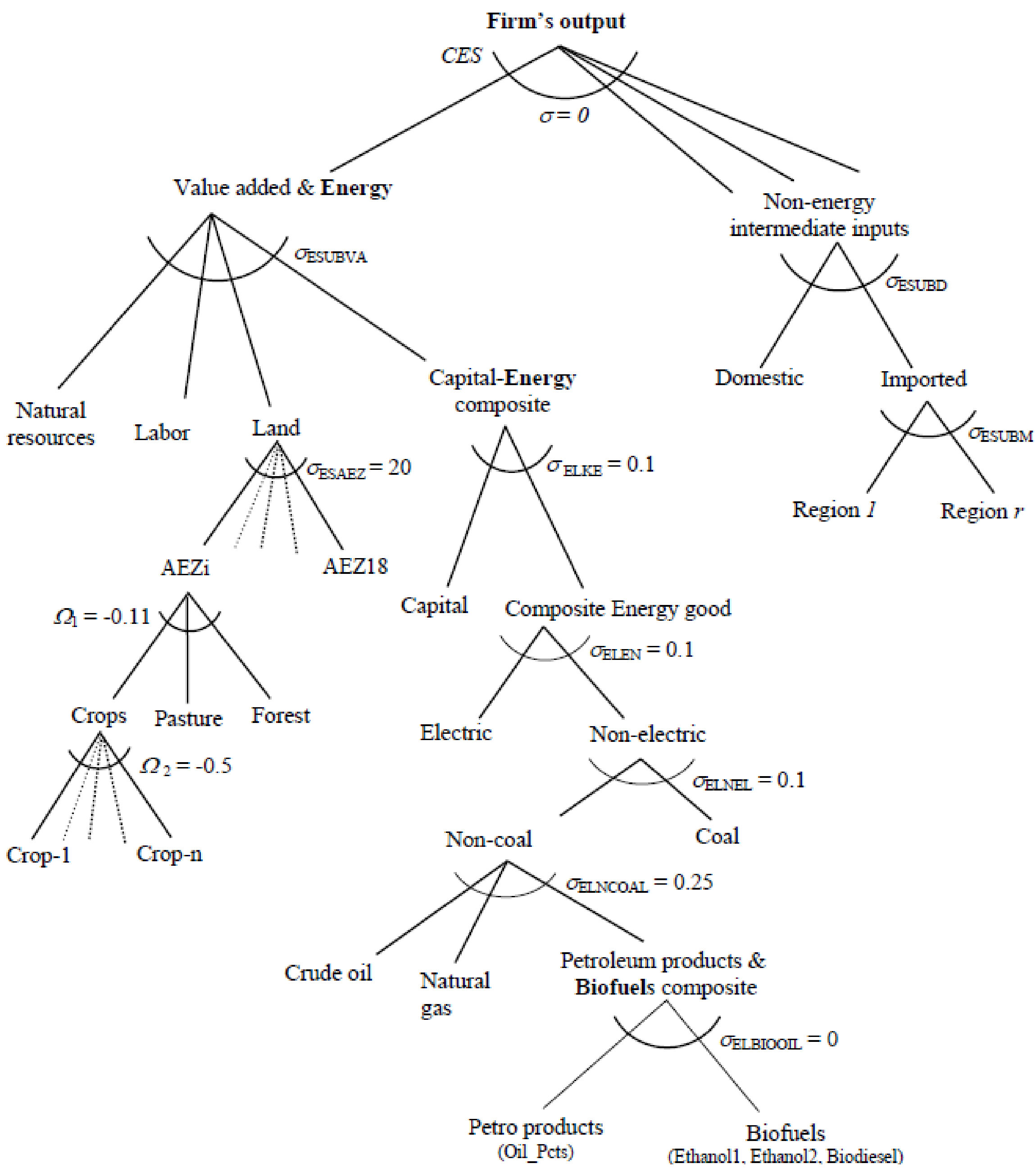
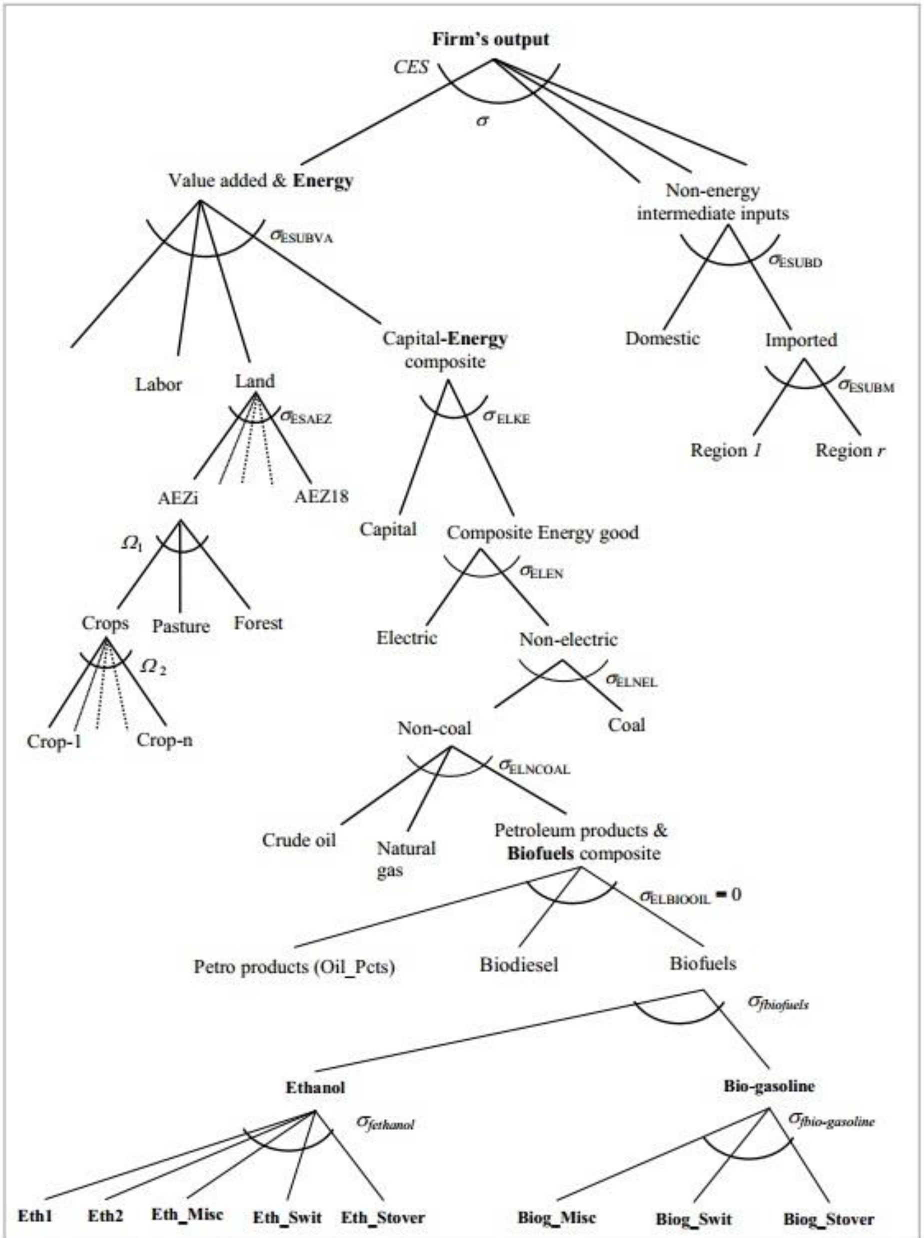
Annex A. Production nest in the GTAP-E model.

Figure A.1. Production nest in the GTAP-BIO (Birur et al., 2008), based on the improvements made by McDougall and Golub (2007) to facilitate addition of levels within the consumption and production structures of the GTAP-E model (Burniaux and Truong, 2002).



Annex B. Production nest in the GTAP-BIO-ADV model.

Figure B.1. Production nest in the GTAP-BIO-ADV model (Taheripour et al., 2011).



In the latest GTAP-BIO version, the *biofuels composite* is only disaggregated between *Ethanol1* (from grains, mainly corn), *Ethanol2* (from sugarcane) and *Ethanol3* (from other feedstock: miscanthus, switchgrass and corn stover). The biodiesel composite is disaggregated between *Biod_soy, Biod_rape, Biod_palm* and *Biod_oth* (from other feedstock than soy, rape or palm). The version in the Figure B.1. was especially created to study the ILUC effects from the penetration of advanced biofuels (in this case, ethanol from non-food feedstock) into the US market. Besides ETA, there are two parameters, ETL1 and ETL2 (*elasticity of transformation for land cover at bottom of supply tree* and *elasticity of transformation for crop land in supply* tree) which distribute the sluggish endowment "cropland" across sectors.

Annex C. Regions, industries and commodities included in the GTAP-BIO version.

Table C.1. Regions, industries and commodities considered for the GTAP-BIO version to analyze biofuel policies in depth.

Regions	Industries	Commodities
1 USA	1 Paddy_Rice	1 Paddy_Rice
2 EU27	2 Wheat	2 Wheat
3 Brazil	3 Sorghum	3 Sorghum
4 Canada	4 Oth_CoarseGrains	4 Oth_CoarseGrains
5 Japan	5 Soybeans	5 Soybeans
6 China-Hongkong	6 Palm	6 palmf
7 India	7 Rapeseed	7 Rapeseed
8 Central-Amer	8 Oth_Oilseeds	8 Oth_Oilseeds
9 S-Amer	9 Sugar_Crop	9 Sugar_Crop
10 E-Asia	10 Oth_Crops	10 Oth_Crops
11 Mala-Indo	11 Forestry	11 Forestry
12 SE-Asia	12 Dairy_Farms	12 Dairy_Farms
13 S-Asia	13 Ruminant	13 Ruminant
14 Russia	14 NonRuminant	14 NonRuminant
15 Oth-CEE	15 Proc_Dairy	15 Proc_Dairy
16 Oth-Europe	16 Proc_Rumiants	16 Proc_Rumiants
17 ME-Asia-N-Africa	17 Proc_NonRumiants	17 proc_NonRumiants
18 SS-Africa	18 Vol_Soy	18 Bev_Sug
19 Oceania	19 Vol_Palm	19 Proc_Rice
	20 Vol_Rape	20 Proc_Food
	21 Vol_Oth	21 Proc_Feed
	22 Bev_Sug	22 Oth_PrimarySectors
	23 Proc_Rice	23 Ethanol_sugarcane
	24 Proc_Food	24 Biod_Soy
	25 Proc_Feed	25 Biod_Palm
	26 Oth_PrimarySectors	26 Biod_Rape
	27 Ethanol_grains	27 Biod_Oth
	28 Ethanol_sugarcane	28 Coal
	29 Ethanol_Oth	29 Oil
	30 Biod_Soy	30 Gas
	31 Biod_Palm	31 Oil_Products
	32 Biod_Rape	32 Electricity
	33 Biod_Oth	33 Energy_Int_Ind
	34 Coal	34 Oth_Ind_Services
	35 Oil	35 NTrdServices
	36 Gas	36 Pasturecrop
	37 Oil_Products	37 Ethanol_grains
	38 Electricity	38 DDGS
	39 Energy_Int_Ind	39 Vol_Soy
	40 Oth_Ind_Services	40 VOBPS
	41 NTrdServices	41 Vol_Palm
	42 Pasturecrop	42 VOBPP
		43 Vol_Rape
		44 VOBPR
		45 Vol_Oth
		46 VOBPO
		47 Ethanol_Oth
		48 DDGSS

Annex D. Market mediated responses.

Table D.1. Market responses as a consequence of the blending mandate in the new COM 595, as combined with import tariffs on biodiesel imports from Mala-Indo, S-Amer and the US.

	Mandate shock	Mandate + tariff shock
Parameters	**% change in individual variable**	**% change in individual variable**
tms(biod_soy,S-Amer,EU27)	0.00	24.60
tms(biod_palm,Mala-Indo,EU27)	0.00	18.90
tms(biod_soy,USA,EU27)	0.00	10.80
pim(biod_soy,EU27)	4.87	24.50
pim(biod_palm,EU27)	5.49	24.91
pim(biod_rape,EU27)	5.16	5.17
pim(biod_oth,EU27)	2.15	2.20
pm(biod_soy,EU27)	8.49	8.51
pm(biod_palm,EU27)	4.02	4.03
pm(biod_rape,EU27)	11.43	11.46
pm(biod_oth,EU27)	12.30	12.33
qim(biod_soy,EU27)	45.02	48.59
qim(biod_palm,EU27)	32.79	34.19
qim(biod_rape,EU27)	188.46	188.55
qiw(biod_soy,EU27)	43.92	49.39
qiw(biod_palm,EU27)	32.79	34.19
qiw(biod_rape,EU27)	181.03	181.10
qxs(biod_soy,S-Amer,EU27)	67.29	24.91
qxs(biod_soy,USA,EU27)	2.70	93.20
qxs(biod_palm,Mala-Indo,EU27)	32.79	34.19
qpm(biod_soy,EU27)	45.02	48.59
qpm(biod_palm,EU27)	32.79	34.19
qpd(biod_soy,EU27)	45.70	36.37
qpd(biod_palm,EU27)	867.59	852.94
qpd(biod_rape,EU27)	685.00	685.00
qpd(biod_oth,EU27)	16,313.87	16,313.78
qo(biod_soy,EU27)	45.70	36.37
qo(biod_palm,EU27)	867.59	852.94
qo(biod_rape,EU27)	685.00	685.00
qo(biod_oth,EU27)	16,313.85	16,313.78
qo(biod_soy,S-Amer)	67.29	24.91
qo(biod_soy,USA)	2.70	93.20
qo(biod_palm,Mala-Indo)	32.49	33.88
qfd(vol_soy,biod_soy,EU27)	43.22	34.22
qfd(vol_rape,biod_rape,EU27)	667.33	667.33
qfd(vol_palm,biod_palm,EU27)	756.60	743.40

	Mandate shock	Mandate + tariff shock
Parameters	**% change in individual variable**	**% change in individual variable**
pm(vol_soy,EU27)	11.00	10.99
pm(vol_palm,EU27)	8.94	8.94
pm(vol_rape,EU27)	14.80	14.83
pm(vol_oth,EU27)	17.02	17.07
qxs(vol_soy,USA,EU27)	-3.08	-12.10
qxs(vol_soy,rest of regions,EU27)	[3.78-68.71]	[1.48-67.69]
qxs(vol_palm,Mala-Indo,EU27)	85.35	84.39
qxs(vol_palm,rest of regions,EU27)	[98.20-144.46]	[97.68-143.53]
qxs(vol_rape,rest of regions,EU27)	[317.67-606.83]	[313.18-608.15]
qxs(vol_oth,rest of regions,EU27)	[244.66-531.72]	[244.88-531.51]
qo(vol_soy,EU27)	6.89	5.89
qo(vol_palm,EU27)	18.49	18.63
qo(vol_rape,EU27)	158.71	158.77
qo(vol_oth,EU27)	173.75	173.78
qfd(soybean,vol_soy,EU27)	0.95	0.04
qfd(soybean,vol_soy,S-Amer)	1.70	1.68
qfd(soybean,vol_soy,USA)	-7.50	-5.72
qfd(rapeseed,vol_rape,EU27)	150.82	150.87
qfd(palm,vol_palm,Mala-Indo)	18.76	18.80
qfd(palm,vol_palm,EU27)	31.50	31.61
qfd(oth_oilseeds,vol_oth,EU27)	158.55	158.57
ppd(soybeans,EU27)	3.07	3.05
ppd(rapeseed,EU27)	14.97	14.96
ppd(palm,EU27)	1.87	1.85
ppd(oth_oilseeds,EU27)	14.46	14.45
qfm(soybean,vol_soy,EU27)	7.04	6.04
qfm(soybean,vol_soy,S-Amer)	2.75	2.69
qfm(soybean,vol_soy,USA)	-8.49	-6.44
qfm(rapeseed,vol_rape,EU27)	172.58	172.64
qfm(palm,vol_palm,Mala-Indo)	22.76	22.84
qfm(palm,vol_palm,EU27)	18.15	18.30
qfm(oth_oilseeds,vol_oth,EU27)	193.92	193.95
ppm(soybeans,EU27)	0.62	0.62
ppm(palm,EU27)	6.41	6.38
ppm(rapeseed,EU27)	11.13	11.12
ppm(oth_oilseeds,EU27)	9.58	9.56

	Mandate shock	Mandate + tariff shock
Parameters	**% change in individual variable**	**% change in individual variable**
qfd(vol_oth,biod_oth,EU27)	15,422.42	15,423.05
ppd(vol_soy,EU27)	11.00	10.99
ppd(vol_palm,EU27)	8.94	8.94
ppd(vol_rape,EU27)	14.80	14.83
ppd(vol_oth,EU27)	17.02	17.07
qfm(vol_soy,biod_soy,EU27)	48.17	38.50
qfm(vol_palm,biod_palm,EU27)	867.59	852.94
qfm(vol_rape,biod_rape,EU27)	703.11	703.08
qfm(vol_oth,biod_oth,EU27)	17,234.96	17,234.12
ppm(vol_soy,EU27)	9.87	9.94
ppm(vol_palm,EU27)	4.96	4.98
ppm(vol_rape,EU27)	13.22	13.25
ppm(vol_oth,EU27)	13.17	13.22

	Mandate shock	Mandate + tariff shock
Parameters	**% change in individual variable**	**% change in individual variable**
pm(soybeans,EU27)	3.07	3.05
pm(palm,EU27)	1.87	1.85
pm(rapeseed,EU27)	14.97	14.96
pm(oth_oilseeds,EU27)	15.46	15.45
qiw(soybean,EU27)	-0.41	0.82
qiw(palm,EU27)	8.56	8.65
qiw(rapeseed,EU27)	79.57	79.59
qiw(oth_oilseeds,EU27)	92.03	92.04
qxs(soybean,S-Amer,EU27)	-1.54	-1.81
qxs(soybean,USA,EU27)	3.41	2.59
qxs(palm,Mala-Indo,EU27)	-5.08	-5.16
qo(soybean,EU27)	-7.60	-7.76
qo(rapeseed,EU27)	61.09	61.10
qo(oth_oilseeds,EU27)	61.49	61.48