Analysis of the Impacts of EU Biofuels Programs using a GTAP model

Monica Padella*

Adele Finco**

Wallace E. Tyner***

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* PhD, Department of Agricultural and Resource Economics, University Politecnica Marche, Ancona, Italy, m.padella@univpm.it.

** Professor, Department of Agricultural and Resource Economics, University Politecnica Marche, Ancona, Italy, a.finco@univpm.it.

*** James and Lois Ackerman Professor, Department of Agricultural Economics, Purdue University, West Lafayette, IN, USA, wtyner@purdue.edu.

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Abstract

Biofuels have the potential of playing an important role in the renewable energy sources panorama, ensuring the achievement of multiple goals such as security of supply, reduction of greenhouse gas (GHG) emissions and development of business opportunities in the agricultural and rural sectors. Subsidies to the sector were rationalized on this basis.

However, three potential impacts could offset any benefits biofuels may bring, and careful assessment and analysis of biofuels' impacts are necessary. These possible consequences involve food prices and food security; economic distortions of subsidies; and environmental and ecological impacts on land-use and global GHG emissions.

The present paper applies a general equilibrium model, an extended version of the GTAP model developed by Hertel, Tyner and Birur in 2010, to analyze the combined impacts of the US (US Energy Independence and Security Act of 2007) and EU (Renewable Energy Directive 2009/28/EC) biofuels programs with a particular emphasis on the effects in the European Union in 2015.

An alternative GTAP model closure has been used: unemployment in US and EU27 is introduced making endogenous the unskilled labor supply in both regions and fixing real wages.

The results of the paper are presented in terms of socio-economic (prices, welfare and employment), and environmental (land use change and Co_2 emissions) impacts.

1. Introduction

Skepticism about the positive impact of biofuels has escalated as the trade-offs between food, feed, and fuels and their impact on global agricultural markets lead to the debate over the extent of the role of biofuels in the 2007-08 food price crisis.

Although biofuels may provide new income opportunities for poor rural populations, they carry the risk of significant and hardly reversible environmental damages (Fonseca et al., 2010) and, in particular, it is likely to accelerate the expansion of land under crops.

Careful assessment of these trends has given rise to criticisms from economists, ecologists, NGOs and international organizations, who call for additional analysis of biofuels' effects.

The contribution of biofuels to the recent price boom, and especially the price spike of 2007/08, has been hotly debated. Several researchers sought to quantify the impact of biofuel polices on food prices[1] and determine which factors have contributed to the run-up in food commodity prices[2]. Although results vary, there is broad agreement from these studies that the price increases are due to several factors including but by no means restricted to biofuels (see, for example: Al-Riffai et al., 2010; Abbott et al., 2008; Abbott et al., 2009; Gerber et al., 2009; Baffes and Haniotis, 2010).

Current and future support of biofuels could have relevant consequences on global land-use, water, and global GHG emissions. Even if estimates of the savings in GHG emissions from cereal-based ethanol and of oilseed-based biodiesel diverge according to region, type of data, and methodological differences, so far, current biofuel support policies in the US, the EU and in Canada appear to reduce transport-related GHG emissions by between 0.5% and 0.8% of transport fuel related emissions in these regions projected for 2015 (OECD, 2008).

Most analyses continue to indicate that 1st-generation biofuels show at least some net benefit in terms of GHG emissions reduction and energy balances. However, with the exception of sugarcane ethanol, little improvement in these mitigation potentials can be expected in the short term (Sims et al., 2010).

Furthermore, one of the most critical issues in the biofuels debate involves the GHG emissions due to indirect land use changes (ILUC) (Searchinger et al., 2008), when land is converted from non-arable (e.g. forest or grassland) to arable use. Recent studies pay particular attention to the ILUC effects, and the associated emissions, of the main feedstocks used for first-generation biofuels production(see, for example: Al-Riffai et al., 2010; Tyner et al., 2010; Edwards et al., 2010).

Taking into account the current debate, a general equilibrium model, a version of GTAP developed by Hertel, Tyner and Birur in 2010, has been applied in order to evaluate socio-economic, (prices, welfare and employment) and environmental (land use change and CO2 emissions) impacts of US and EU biofuels programs.

The objective of the paper is to give relevant information regarding the effect of the two programs in order to have a complete view of their impact in particular in the European Union.

[1] See, for example, Banse et al. (2008), European Commission (2008), FAO (2008), Mitchell (2009), OECD (2008), Rosegrant (2008), Taheripour et al. (2008).

[2] See, for example, Gilbert (2010), Lipsky (2008), Sarris (2009), Trostle (2008).

2. GTAP Application

The biofuel program in US (US Energy Independence and Security Act of 2007) provides for 15 billion gallons of corn ethanol to be used by 2015, which corresponds to about 5.1% of project liquid fuels consumption in 2015 on an energy basis.

In the EU, the target is 10% of renewable fuel use in 2020 (Directive 2009/28) and for the analysis, the conservative mandate of 6.25% by 2015 has been adopted (Hertel et al., 2010).

The model by Hertel et al. is an extended version of the GTAP-E model, which incorporates the potential for intra-fuel substitution, as well as energy-capital-labor substitution (Burniaux and Truong, 2002).

The GTAP-E model has been augmented with a land use module, GTAP-AEZ, where AEZ stands for Agro-Ecological Zones (Hertel et al., 2009), which disaggregates land use into 18 AEZs that share common climate, precipitation and moisture conditions, and thereby capture the potential for competition among alternative land uses (Hertel et al., 2010). Moreover, Taheripour et al. (2008) show that ignoring the by-products of biofuels leads researchers to significantly overstate the impact of mandates. DDGS and vegetable oil cake (soybean meal in the US and rapeseed cake in EU) and substitution between biofuel by-products and other animal feed in livestock production are introduced.

An alternative GTAP model closure[3] is used in which unemployment in US and EU27 is introduced making endogenous the unskilled labor supply in both regions (the variables *qo (UnSkLab,US)* and *qo (UnskLab,EU)* which affect regional income and demand) and fixing real wages[4] (*pfactreal(UnSkLab,r)* which is wage relative to CPI[5]).

The biofuels mandates are treated as exogenous shocks: the subsidy on biofuel use is endogenous while the renewable fuel share is exogenous.

The database is the updated 2006 fuel economy which results from an historical analysis for the period 2001-2006 (Hertel et al., 2010). The dataset is composed by 18 regions, 22 endowment commodities and 22 sectors (see Appendix for more details). Three biofuels sectors have been considered: corn-based ethanol, sugarcane-based ethanol, and oilseed-based biodiesel (Taheripour et al., 2007).

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[3] The standard closure imposes equilibrium in all the markets, firms earn zero-profits, the regional household is on its budget constraint, and global investment equals global savings.

[4] Unemployment is introduced adding these two lines in the closure:
swap qo(“unsklab”,”USA”)=pfactreal(“unsklab”,”USA”);
swap qo(“unsklab”,”EU27”)=pfactreal(“unsklab”,”EU27”).

[5] In formula: pfactreal(i,r) = pm(i,r) - ppriv(r) where i=endowment and r=region; pm is the market price of commodity i in region r and ppriv is the price index for private consumption expenditure in region r.

The land cover types include forest, pastureland and cropland. Other land uses are assumed to be invariant to biofuels policies.

The model by Hertel et al., 2010 introduces a new parameter, the constant elasticity of substitution amongst liquid fuel products consumed which measures the change in the intensity of ethanol use in total liquid fuels in response to a change in the relative price of ethanol. Since these elasticities are likely to vary greatly by country, Hertel et al. utilize historical data to develop general equilibrium estimates of these parameters over the period 2001-2006. For Brazil, USA and EU, they estimate the parameter obtaining these values: Brazil = 1.35, EU = 1.65 and USA = 3.95, which are the elasticities considered in the present simulation.

The reason for a relatively low elasticity in Brazil derives from the fact that large percentage changes become more difficult as ethanol becomes more dominant and ethanol already commands a large share of that market. The estimated elasticity of substitution in the US is high, relative to Europe, because the EU renewable fuel share grew by a much larger percentage over this period, the share of US ethanol going to the price inelastic additive market was quite high in 2001 (base period) and the economic "power" of the US ethanol subsidy diminished as the prices of gasoline and ethanol rose (Hertel et al., 2010).

The model is implemented using GEMPACK (Harrison and Pearson, 1994).

3. Results

3.1 Socio-economic impacts

The shocks in renewable fuel share correspond to a percentage increase in biodiesel and ethanol production of 530% and 515% respectively in the EU27 and of 1,959% and 183% in the United States, while ethanol from sugarcane rises almost 60% in Brazil (Table 1).

Table 1 - Percentage change of biofuels production from 2006 to 2015

	Biodiesel	**Ethanol1**	**Ethanol2**
United States	1,959.1	183.4	0.3
Canada	-6.7	5.4	8.7
European Union 27	529.9	514.7	5.8
Brazil	-5.4	0.2	59.7
Japan	-7.4	3.2	-0.4
China, Hong Kong	-4.8	-1.9	-0.3
India	-8.4	-2.6	-0.6
Latin American Energy Exporters	-12.3	-3.8	-2.6
Rest of Latin America+Caribbean	-10.4	-3.5	-7.3
EE and FSU Energy Exp	-3.4	-1.5	-0.2
Rest of Europe	-7.2	-0.5	-1.5
Middle Eastern N Africa E Exp	-8.6	-0.2	-2.5
Sub Saharan Energy Exporters	-8	-3.4	-1.4
Rest of North Africa & SSA	-5.4	2.9	-1.3
South Asian Energy Exporters	-27.7	1.8	-1.9
Rest of High Income Asia	-14.1	13.9	0
Rest of Southeast & South Asia	-7	0.9	-1.7
Oceania countries	-5.3	-1.8	-1.7

Note: Ethanol1 is corn based ethanol, and Ethanol2 is sugarcane based ethanol.

In terms of raw materials' production (Table 2), in order to meet the renewable fuel share target, the EU requires massive amounts of oilseeds, and the production in the EU rises by 59% while outputs of other crops fall.

It is interesting to note how oilseed production registers relevant increases in all regions, especially in the European countries (Member and not Member States), in Africa, and Asia. That means that the European mandate stimulates production of the feedstock also outside the European Union.

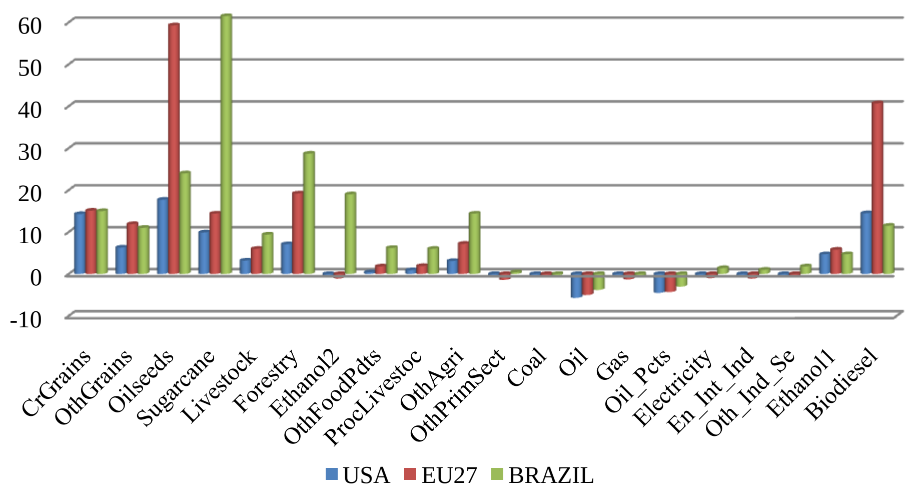
Table 2 - Percentage change of raw materials production from 2006 to 2015

	CrGrains	OthGrains	Oilseeds	Sugarcane	OthAgri
United States	10.5	-5.4	12.9	-1.1	-1.1
Canada	1.1	-1	22.5	-1	-0.7
European Union 27	-6.3	-12.9	58.6	-3.7	-4.4
Brazil	-7.9	-16	10.8	32.2	-9.1
Japan	6.3	1.5	9.1	0.1	0.1
China, Hong Kong	1.4	0.6	9	0.1	0.1
India	0	1.2	2	0	0.3
Latin American Energy Exporters	2.1	2	15.9	-0.3	0.2
Rest of Latin America+Caribbean	1.6	0.9	16.4	-0.1	0.6
EE and FSU Energy Exp	0.9	0.8	21.1	0.2	0.2
Rest of Europe	1.9	2.8	13.5	1	1
Middle Eastern N Africa E Exp	2.8	3.1	10.2	0.3	0.1
Sub Saharan Energy Exporters	-0.1	3.4	16.6	0.6	1.6
Rest of North Africa & SSA	1.3	2.5	18.2	0.9	1.7
South Asian Energy Exporters	0.7	0.8	4.5	0.5	0.5
Rest of High Income Asia	3.3	0.7	9.3	0.2	0.2
Rest of Southeast & South Asia	0.5	1	4.7	0.3	0.5
Oceania countries	2.9	-0.3	23.1	0.8	0.9

The impacts on prices are presented in Figures 1, 2 and 3.

As we can see from the graphs, the greater percentage changes involve US, EU27 and Brazil in the grain, oilseed, sugarcane and forestry sectors.

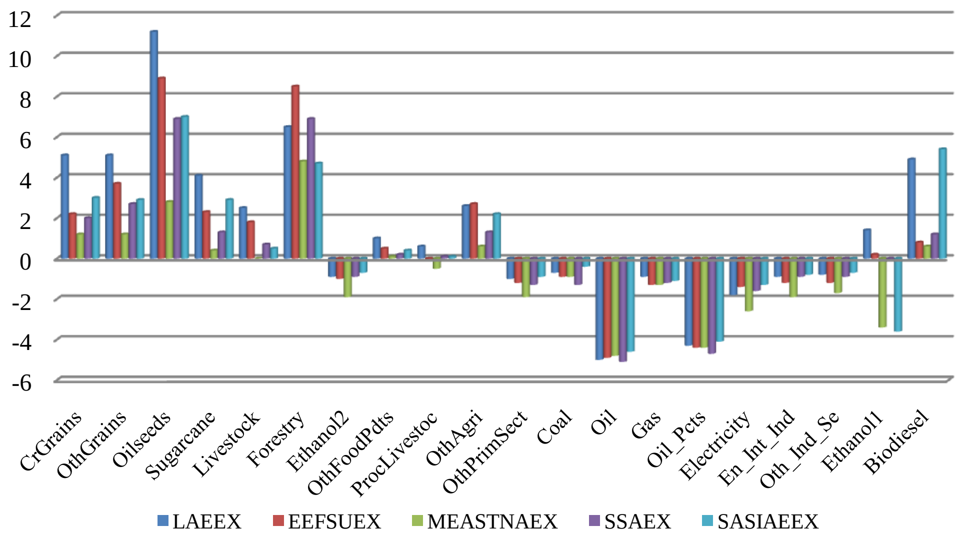
Figure 1 - Impact on prices (% change) in US, EU27 and Brazil



In all the other regions, the greater change occurs in the oilseed sector, in which the price increases and in the oil and oil products sectors, in which price decreases as a consequence of the substitution with biofuels.

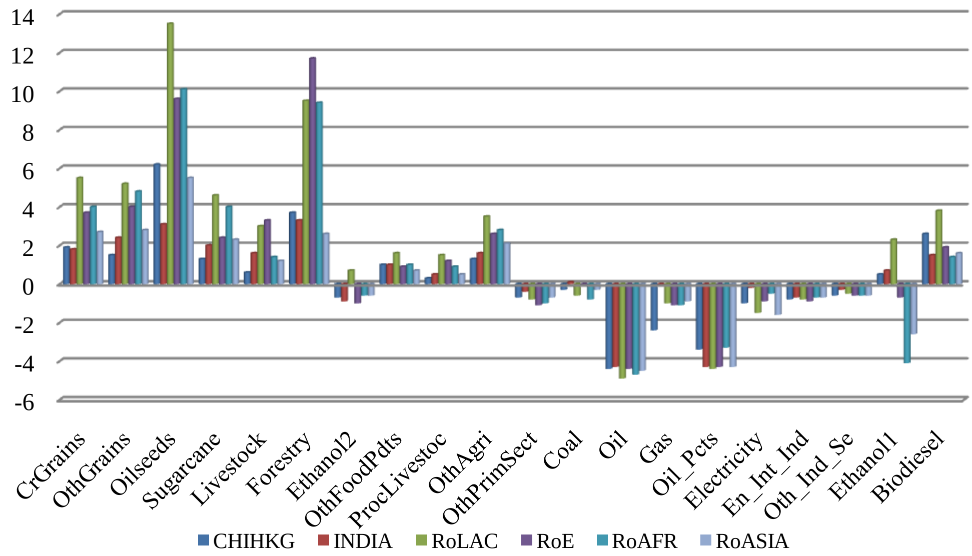
The impact of the mandates on food prices can be analyzed through the percentage changes in the “other food products” and “livestock products” sectors in Figures 1, 2 and 3. Biofuels mandates determine increases in prices of both sectors in all the considered regions. In particular, the main increases are registered in the European Union (1.8% and 1.9% in prices of other food products and livestock products respectively), in Brazil (6.2% and 6% in prices of other food products and livestock products respectively) and in the Latin American countries (1.6% and 1.5% in prices of other food products and livestock products respectively). Less relevant increases occur in all the other regions. That means that the impact of biofuels mandates on food prices is confirmed by the model.

Figure 2 - Impact on prices (% change) in Oil Exporters areas



Where: LAEEX= Latin American Energy Exporters; EEFSUEX= EE and FSU Energy Exp; MEASTNAEX=Middle Eastern N Africa E Exp; SSAAEX= Sub Saharan Energy Exporters; SASIAEEX= South Asian Energy Exporters

Figure 3 - Impact on prices (% change) in the Rest of the World



Where: CHIHKG= China, Hong Kong; RoLAC= Rest of Latin America+Caribbean; RoE= Rest of Europe; RoAFR= Rest of North Africa & SSA; RoASIA= Rest of Southeast & South Asia

In terms of trade, Table 3 reports the change in trade volumes (exports and imports) for all products and the percentage change in trade as a result of the combined mandates. As can be seen from the first row of entries, EU27 exports of coarse grains, oilseeds and other food products are sharply reduced, holding all other changes in the world economy constant. Turning to imports, the largest volume changes arises in the oilseed sector with an increase of 81%.

Table 3 - Impacts on trade: export and import in EU27 expressed in $ million and in percentage change

	$ million		% change	
	Export	**Import**	**Export**	**Import**
Cereal grains	-313	-83	-9.5	-2.5
Paddy and Wheat	-1,248	313	-26.8	6.7
Oil seeds	-774	4,965	-56.6	80.9
Sugar cane, sugar beet	-1	6	-9.7	22.6
Cattle,Animal pdts,Milk,Wool	-513	158	-6	1.5
Forestry	-444	440	-19.7	11
Ethanol2	0	-11	274.8	-36
Other Food Products	-1,662	-1,194	-2.8	-1.8
Meat, Dairy products	-1,219	-552	-2.6	-1.2
Other agriculture goods	-5,415	388	-8.4	0.5
OtherPrimary:Fishery & Mining	3	-157	0	-0.8
Coal	1	-42	0.1	-0.6
Crude Oil	-207	-1,366	-1	-1
Natural gas	21	-288	0.3	-1.1
Petroleum, coal products	-324	-652	-0.7	-1
Electricity	-51	-108	-0.4	-0.9
Energy intensive Industries	1,424	-2,536	0.3	-0.5
Other industry and services	687	-17,286	0	-0.9
Ethanol produced from corn	-25	-26	-48.1	-48.1
Byproduct of corn ethanol	33	710	577.6	429.1
Biodiesel from oilseeds	0	-4	-84.3	-89.7
Byproduct of biodiesel	0	0	2,44.5	486

A useful measure of the combined impact of changes in production, trade and policies is given by the "welfare" that corresponds to the Equivalent Variation (EV).

The aggregate welfare impacts of the biofuel mandates on both the EU and US economies, as well as the rest of the world expressed as a money metric value of these changes in US$ millions (measured as equivalent variation) and the decomposition into the portion attributable to changes in allocative efficiency[6], endowments[7] and terms of trade[8] are shown in Table 4.

[6] Allocative efficiency effect: welfare may increase or decrease due to reallocation of the existing resources. e.g. moving labor from the one sector to another.

[7] Endowment Effect: welfare may change as a result of a change in the amount of resource endowments.

[8] Terms of Trade (TOT) Effect: Welfare may change as a result of more/less favorable prices of exports/imports of a region due to trade policy reforms, or changes in supply and demand conditions.

Table 4 - Welfare change (summary)

WELFARE ($ millions)	Allocative Efficiency	Endowments	Terms of trade	Total Welfare Change
USA	-23,801	-18,409	6,726	-34,816
EU27	-55,787	-26,976	2,959	-80,018
Brazil	827	0	4,344	5,288
Oil Exporters	-1,719	0	-22,353	-23,832
RoW	1,980	0	8,187	9,355
Total	-78,499	-45,385	-138	-124,023

USA and EU both experience a loss in welfare due to biofuel programs, as do oil exporting countries, while Brazil and the rest of the world experience an increase in welfare.

In dollar terms, the equivalent variation measure of these welfare changes are $34 billion and 80 billion for USA and EU respectively, while oil exporters lose $23 billion.

By the term "welfare decomposition", a given change in the welfare of consumers (or the consumer that represents the entire region) is decomposed into its various constituent parts. Welfare decomposition is important to explain the sources of welfare changes due to trade policy reforms, or other shocks to the economy. Changes in welfare in the model are therefore attributed to the interactions between taxes (both pre-existing and newly introduced taxes) and quantity changes taking place over the course of the simulation, as well as the added effect of changes in regional terms of trade and changes in the relative prices of savings and investment.

Columns 2-4 of Table 4 break down the total EV into component parts.

The efficiency loss largely explains the global welfare loss from EU-US mandates. This component amounts to $23 billion in the US and $55 billion in the EU reflecting the cost of mandating producers to boost biofuel production from 2006 levels to 2015 mandated amounts in the absence of higher oil prices.

There is also an endowment effect due to the introduction of unemployment in the model. It contributes for a relevant amount to the total welfare loss both in US and in the EU (-$18 billion and -$27 billion respectively) showing that the mandates have no benefits in term of employment in both the economies. This is an important conclusion as employment gains are a common argument given by biofuel supporters.

For the terms of trade component, the oil exporters' loss becomes the importers' gain. This benefits the US most, offsetting a part of the adverse efficiency and endowments effects in that region while in the EU, the terms of trade gain is smaller ($3 billion).

Tables 5-10 provide a decomposition of the allocative efficiency effects, by commodity and by tax focusing on the European Union. Each of these effects results from summing by commodity, the products of distortions in individual markets and quantity changes for transactions under each distortion.

Table 5 - Allocative efficiency effect by commodity ($ millions)

	EU27
UnSkLab	-23,684
SkLab	-257
Capital	248
Cereal grains	114
Paddy and Wheat	239
Oil seeds	-1,764
Sugar cane, sugar beet	1
Cattle,Animal pdts,Milk,Wool	-6
Forestry	14
Ethanol2	-1
Other Food Products	-123
Meat, Dairy products	-122
Other agriculture goods	-360
Other Primary: Fishery & Mining	2
Coal	-7
Crude Oil	-1
Natural gas	-330
Petroleum, coal products	-9,986
Electricity	-884
Energy intensive Industries	-72
Other industry and services	-3,587
Ethanol produced from corn	-2,195
Biodiesel from oilseeds	-11,237
Total	**-55,787**

The largest figure in Table 5 is a loss to welfare in EU of $23 billion from transactions involving labor sector and $11 billion for biodiesel sector. These losses result from the reduction of employment in the first case and from the combination of the increase in output

(530%) of the subsidized biodiesel sector and a decrease in imports and exports in the second one.

Table 6 decomposes the allocative efficiency effects by tax instrument.

Table 6 - Allocative efficiency effect by tax instruments ($ millions)

	EU27
Primary Factor Taxes	-16,017
Output Taxes	-20,476
Input taxes	1,532
Taxes on final demand	-21,356
Govtax	-18
Export taxes	388
Import taxes	160
Total	**-55,787**

Taxes or subsidies on final demand, output and primary factor taxes contribute the most to the total efficiency loss. It is hardly surprising that final demand taxes represent the most important tax instrument, since this is where the policy acts.

In particular, Table 7 shows that welfare change due to the tax on final demand derives from welfare change in the oil products sector (-12$ billion), which registers a decrease in the volume demanded by the private sector (-2,806) due to an increase in tax rate after the simulation (from 836 to 972). A relevant welfare change is also visible in the biodiesel sector in which the demand increases (+7,010) due, in this case, to the decrease in the tax rate (subsidy in the sector) from 0 to -63.

Table 7 - Tax on final demand in EU27, decomposition ($ millions)

	welcnt	dvol	taxrateb	taxrateu
CrGrains	-1	-24	10	10
OthGrains	0	-28	7	7
Oilseeds	-2	-22	11	11
Sugarcane	0	-4	14	14
Livestock	-23	-509	10	10
Forestry	-22	-254	16	16
Ethanol2	-1	-11	6	33
OthFoodPdts	-155	-2,814	11	11
ProcLivestoc	-172	-3,046	12	12
OthAgri	-361	-4,771	14	14
OthPrimSect	-2	-113	7	7
Coal	-6	-14	104	104
Oil	0	0	7	7
Gas	-311	-345	183	183
Oil_Pcts	-11,936	-2,806	836	972
Electricity	-846	-2,173	84	84
En_Int_Ind	-47	-800	12	12
Oth_Ind_Se	-1,773	-33,081	11	11
Ethanol1	-1,124	2,043	0	-57
Biodiesel	-4,573	7,010	0	-63
Total	**-21,356**	**-41,762**	**1,352**	**1,396**

A relevant part of the total welfare loss can be also explained by the tax on the production side (Table 8): it derives in particular from the welfare loss occurred in the labor sector (-$9 billion) in which the demand decreases (-36,424) and in the biodiesel sector (-$7 billion) in which the volume increases (+7,014).

Table 8 - Output Tax in EU27, decomposition ($ millions)

	welcnt	**dvol**	**taxrateb**	**taxrateu**
UnSkLab	-9,538	-36,424	26	26
SkLab	0	0	26	26
Capital	0	0	7	7
NatRes	0	0	9	9
CrGrains	5	-1,210	0	0
OthGrains	18	-2,401	-1	-1
Oilseeds	-1,745	4,952	-29	-29
Sugarcane	1	-193	0	0
Livestock	5	-3,395	0	0
Forestry	35	-1,383	-2	-2
Ethanol2	0	0	0	0
OthFoodPdts	-42	-8,414	0	0
ProcLivestoc	-2	-5,185	0	0
OthAgri	-512	-13,973	4	4
OthPrimSect	4	-275	-1	-1
Coal	0	-20	0	0
Oil	-1	-225	1	1
Gas	-9	-183	5	5
Oil_Pcts	-6	-2,319	0	0
Electricity	-45	-926	5	5
En_Int_Ind	2	1,478	0	0
Oth_Ind_Se	-913	-79,816	1	1
Ethanol1	-1,071	2,044	-51	-51
DDGS	0	743	0	0
Biodiesel	-6,663	7,014	-81	-81
BDBP	0	3,435	0	0
CGDS	0	-14,884	0	0
Total	**-20,476**	**-151,558**	**-21**	**-21**

Finally, the decomposition for primary factors (Table 9) confirms that most of the welfare change derives from the labor sector (-$14 billion) due to the same decrease in volume (-36,424).

Table 9 - Primary Factor Tax in EU27, decomposition ($ millions)

	Welfare change
UnSkLab	-14,146
SkLab	-257
Capital	248
NatRes	0
Total	**-16,017**

Decomposing for unskilled labor in which most of the welfare changes occurred, Table 10 shows that most of the decrease in employment derives from "Other industries and services" sector, while only in the biodiesel, oilseeds and ethanol sectors an increase in the volume of unskilled labor employed is registered after the mandates.

Table 10 - Primary Factor Tax in EU27, decomposition for UnSkLab ($ millions)

	welcnt	**dvol**	**taxrateb**	**taxrateu**
CrGrains	-70	-198	35	35
OthGrains	-153	-407	37	37
Oilseeds	555	1,583	35	35
Sugarcane	-14	-32	43	43
Livestock	-189	-482	39	39
Forestry	-4	-12	37	37
EthanolC	1	74	2	2
Ethanol2	0	0	40	40
Biodiesel	7	281	2	2
OthFoodPdts	-369	-971	38	38
ProcLivestoc	-199	-539	37	37
OthAgri	-729	-1,830	40	40
OthPrimSect	-17	-67	25	25
Coal	-2	-6	38	38
Oil	-2	-8	20	20
Gas	-4	-18	24	24
Oil_Pcts	-37	-89	41	41
Electricity	-100	-305	33	33
En_Int_Ind	-729	-1,853	39	39
Oth_Ind_Se	-12,091	-31,545	38	38
CGDS	0	0	0	0
Total	**-14,146**	**-36,424**	**643**	**643**

The same results can be obtained considering the percentage change in employment in EU27. As Table 11 shows, the European biofuel mandate determines an increase in labor employed in the biofuel sector (both ethanol and biodiesel) and in the oilseed sector while employment declines in all the other sectors of the economy with a consequence decline in the overall employment of 2%.

Table 11 - Percentage change in employment in EU27

	Labor
CrGrains	-5.7
OthGrains	-12.4
Oilseeds	62.5
Sugarcane	-3.1
Livestock	-2.2
Forestry	-0.9
EthanolC	506.0
Ethanol2	3.6
Biodiesel	521.8
OthFoodPdts	-3.4
ProcLivestoc	-2.7
OthAgri	-4.2
OthPrimSect	-0.9
Coal	-0.4
Oil	-1.8
Gas	-1.1
Oil_Pcts	-6.6
Electricity	-2.1
En_Int_Ind	-1.8
Oth_Ind_Se	-2.1
CGDS	-3.0
Total	**-2.0**

This is an important result which leads to some important considerations regarding the effect of the biofuel policies in the European Union. As we argued before, one of the arguments in favor of the subsidy to the biofuel sectors in Europe is represented by the possibility to create jobs.

The results of the model show that employment is created only in the biofuels and in the oilseed sector but not in the rest of the economy and, as a global result, there is a reduction of employment (2%). This is reasonable, since the mandate is pushing the economy away from the more efficient allocation of resources.

The reason for the employment's result can be found in the *REALRETURN* equation which defines the real rate of return to primary factor i (labor) in region r (EU27).

Eq. 1) *pfactreal(labor,EU) = pm(labor,EU) - ppriv(EU)*

Since the left side term of the equation has been fixed in the closure, its value is 0.

As a consequence: *pm(labor,EU) = ppriv(EU)* which value is 0.15%. That means that wages and the price index for private consumption expenditure increase after the biofuel mandates in the European Union.

Considering the price index for private consumption expenditure equation *(PHHLDINDEX)*, it shows that the increase depends on the private consumption price (*pp*) in EU which rises in most of the sectors of the economy after the mandates (Table 12).

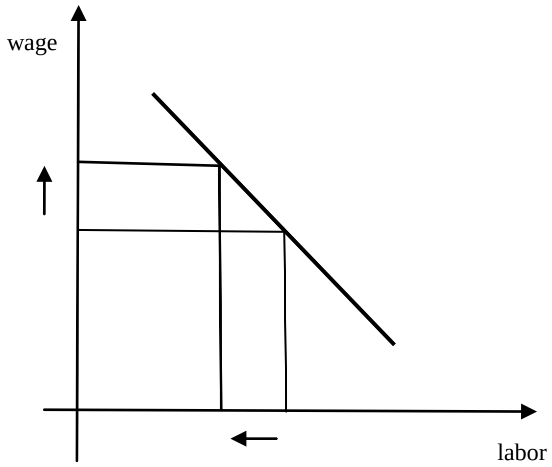
Eq. 2) *Ppriv(EU) = sum(i,CDE_COMM, CONSHR(i,EU) * pp(i,EU))*

Table 12 - Private consumption price in EU27 (% change)

i	*pp (i,EU)*
henergy	4,41
CrGrains	14,2
OthGrains	11,08
Oilseeds	28,51
Sugarcane	14,13
Livestock	5,78
Forestry	17,25
OthFoodPdts	1,73
ProcLivestoc	1,84
OthAgri	6,68
OthPrimSect	-1,34
En_Int_Ind	-1,03
Oth_Ind_Se	-0,75
DDGS	6,59
BDBP	0,6
Total	109,71

The increase in wages drives the increase in unemployment (Figure 4).

Figure 4 - Labor supply



3.2 Environmental impacts

From the environmental results, three impacts have been considered in the analysis.

The impact on land use changes in crop harvested area owing to the biofuel mandates in the US and EU for all regions shows an overall increase in land area under oilseeds (215%) from 2006 to 2015, which occurred not only in the European Union but also in the rest of Europe, Canada and Latin America countries (Table 13).

Oilseed acreage in EU27 derives from contribution of land from other land-using sectors such as grains and sugarcane.

Table 13 - Land use change (%)

	CrGrains	Oilseeds	Sugarcane	OthGrains	OthAgri
United States	6.0	7.5	-4.4	-7.6	-2
Canada	-0.8	18.9	-3.2	-2.9	-1.7
European Union 27	-9.5	47.6	-7.0	-15.4	-5.8
Brazil	-10.8	6.1	21.6	-18.1	-10.6
Japan	5.2	7.5	-0.6	0.6	-0.1
China, Hong Kong	0.8	6.8	-0.5	-0.2	-0.5
India	-0.7	0.8	-0.7	0.3	-0.2
Latin AmericanEnergy Exporters	0.2	11.9	-2.1	0	-0.8
Rest of LatinAmerica+Caribbean	-0.3	11.9	-1.6	-0.9	-0.5
EE and FSU Energy Exp	0.2	18.2	-0.6	-0.3	-0.5
Rest of Europe	0.5	10.6	-0.2	1.3	0.2
Middle Eastern N Africa E Exp	2	8.9	-0.5	2.3	-0.5
Sub Saharan Energy Exporters	-1	14.1	-0.1	2.3	1.1
Rest of North Africa & SSA	-0.2	15	-0.6	0.9	0.9
South Asian Energy Exporters	-0.7	2.6	-0.8	-0.5	-0.1
Rest of High Income Asia	2.3	6	-0.2	-0.2	-0.1
Rest of Southeast & South Asia	-0.4	2.7	-0.8	-0.1	-0.1
Oceania countries	1	18.4	-0.7	-1.9	0
Total	-6.6	215.5	-3	-40.4	-21.2

From an environmental point of view, the big issue is not which crops are grown, but how much cropland is demanded overall, and how much (and where) forestlands and pasturelands are converted to cropland (Hertel et al., 2010).

Table 14 reports the percentage changes in different land cover areas as a result of the EU and US mandates. From the first group of columns, we can see that crop cover is up in nearly all regions and it comes from pastureland and accessible forest lands, since idle lands are not considered. The largest net reduction in land cover tends to be in forestry. For example, in EU27, forestry could decline by 5% as a result of this global push for biofuels followed by smaller changes in Brazil, rest of Europe and Africa. In most of the regions, the percentage decline in pasture land cover is rather small. This result is different from the one obtained by Hertel et al., 2010 and it can be related to the different parameter file and the introduction of the unemployment in this version of the model.

Table 14 - Land cover change (%)

	Forestry	Crops	Livestock
United States	-1.3	2.6	-0.1
Canada	-0.5	3.8	0.0
European Union 27	-5.1	5.9	-0.4
Brazil	-2.2	7.3	-0.2
Japan	-0.2	0.9	0.6
China, Hong Kong	0.1	0.1	-0.1
India	-0.1	0.0	-0.1
Latin AmericanEnergy Exporters	-0.8	1.1	-0.1
Rest of LatinAmerica+Caribbean	-0.1	0.8	-0.2
EE and FSU Energy Exp	-0.2	0.8	-0.1
Rest of Europe	-1.1	1.3	-0.4
Middle Eastern N Africa E Exp	-0.9	0.6	-0.1
Sub Saharan Energy Exporters	-0.4	1.5	-0.3
Rest of North Africa & SSA	-2.4	0.9	-0.1
South Asian Energy Exporters	0.1	-0.2	0.4
Rest of High Income Asia	0.1	-0.3	-0.4
Rest of Southeast & South Asia	-0.1	0.0	0.0
Oceania countries	-0.7	0.9	0.0

Finally, in term of CO_2 emissions, the global carbon dioxide emission is the only one that matters.

The variable *gco2tw* in AnalyzeGe is the total world emissions expressed in percentage change and it is derived from the equation:

Eq. 3) *sum(r, REG, CO2T(r)) * gco2tw = sum(r, REG, CO2T(r) * gco2t(r))*

where *CO2T(r)* is the carbon dioxide emission in millions of tons of carbon and *gco2t(r)* is the variable carbon dioxide emission in percentage change for different regions[9].

Taking into account the results for each sector and each region, the global result is a reduction of CO_2 emission equal to 0.5% as a consequence of the mandates (Table 15).

[9] The variable *gco2t(r)* is obtained from the equation:
*CO2T(r)*gco2t(r)=sum(i,CTAX_COMM, CO2(r,i)*gco2(r,i))*; where *CTAX_COMM* are the commodities subject to carbon tax (coal, oil, gas, oil_pdcts).

Table 15 - CO_2 emission per region and global (% change)

gco2t (r)	%
United States	-2.0
Canada	0.5
European Union 27	-0.9
Brazil	1.4
Japan	0.1
China, Hong Kong	0.2
India	-0.2
Latin AmericanEnergy Exporters	0.6
Rest of LatinAmerica+Caribbean	0.7
EE and FSU Energy Exp	0.0
Rest of Europe	0.3
Middle Eastern N Africa E Exp	0.3
Sub Saharan Energy Exporters	0.4
Rest of North Africa & SSA	0.2
South Asian Energy Exporters	0.5
Rest of High Income Asia	0.4
Rest of Southeast & South Asia	0.3
Oceania countries	0.2
gco2tw	**-0.5**

4. Conclusion

The urgent need to diversify energy sources, the increased energy demand and the international policy debate on climate change have led to growing attention on renewable energy resources and biofuels among them.

However, a number of issues fuel the debate over the real benefits of a steady development of biofuels, at least first generation biofuels. It concerns the range of increase in agricultural prices to high production costs, from competition for land to achievable environmental benefits.

The work highlights that the increase in production of first generation biofuels owing to US and EU policies will have important economic and environmental consequences in terms of welfare, food prices, employment and land use change in the European Union and in the rest of the world.

In particular, the model shows how for the European Union mandates in the biofuel sector drive an increase in the biodiesel, ethanol and oilseed production over the period 2006-2015 and a consequent increase in the employment only in these sectors. But the welfare change is negative, showing a loss in the welfare for the total society which might be justified by relevant environmental benefits. The model shows that from the environmental point of view, the mandates lead to a decline especially in forestry but at the same time a global reduction of CO_2 emission of 0.5 percentage points.

Therefore, policy makers should take into account these impacts during the decision process and, at the same time, consider alternative investments such as second generation biofuels.

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APPENDIX

VERSION

Database: updated database for 2006 fuel economy which results from the historical analysis (2001-2006).

18 Regions

1	United States
2	Canada
3	European Union 27
4	Brazil
5	Japan
6	China, Hong Kong
7	India
8	Latin American Energy Exporters
9	Rest of Latin America+Caribbean
10	EE and FSU Energy Exp
11	Rest of Europe
12	Middle Eastern N Africa E Exp
13	Sub Saharan Energy Exporters
14	Rest of North Africa & SSA
15	South Asian Energy Exporters
16	Rest of High Income Asia
17	Rest of Southeast & South Asia
18	Oceania countries

22 Endowment commodities

1	AEZ1
2	AEZ2
3	AEZ3
4	AEZ4
5	AEZ5
6	AEZ6
7	AEZ7
8	AEZ8
9	AEZ9
10	AEZ10
11	AEZ11
12	AEZ12
13	AEZ13
14	AEZ14
15	AEZ15
16	AEZ16
17	AEZ17
18	AEZ18
19	UnSkLab
20	SkLab
21	Capital
22	NatRes

22 TRAD_COMM (sectors)

1	Cereal grains
2	Paddy and Wheat
3	Oil seeds
4	Sugar cane, sugar beet
5	Cattle,Animal pdts,Milk,Wool
6	Forestry
7	Ethanol2
8	Other Food Products
9	Meat, Dairy products
10	other agriculture goods
11	OtherPrimary:Fishery & Mining
12	Coal
13	Crude Oil
14	Natural gas
15	Petroleum, coal products
16	Electricity
17	Energy intensive Industries
18	Other industry and services
19	Ethanol produced from corn
20	Byproduct of corn ethanol
21	Biodiesel from oilseeds
22	Byproduct of biodiesel