Economic and land use consequences of biofuel production and policy with application of US and EU sustainability criteria

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Introduction

In general, national biofuel programs, in particular in US and EU, have two major components. The first component defines a timeline to achieve certain levels of biofuel production over time. The second component defines sustainability criteria. In recent years several studies have examined the land use and economic consequences of national and multi-national biofuel targets(Ozdemir, Hardtlein et al. 2009) (Bringezu, Schutz et al. 2009; Ozdemir, Hardtlein et al. 2009; Hertel, Tyner et al. 2010; Smyth, O Gallachoir et al. 2010; Taheripour, Hertel et al. 2010). However, to the best of our knowledge, almost no one has examined the consequences of biofuel targets in the presence of sustainability criteria. The US and EU criteria are quite different in that the US criteria apply only to US biofuel production, but the EU criteria apply to land used for biofuels anywhere in the world.

While biofuel targets mandate certain levels of biofuel production, sustainability measures put restrictions on land-use changes induced by biofuel production. One can consider land restrictions defined in biofuel programs as a set of mandates which restrict land that can be used to produce biofuels. This means that biofuel programs impose two sets of mandates at the same time: 1) biofuel targets and 2) land restrictions. While several studies have examined the impacts of the biofuel targets, this research will explore the land restrictions imposed by the US and EU. That is, we will evaluate the sufficiency of sustainable land to meet biofuel targets and comply with land restrictions defined in biofuel programs globally. The main objective of this research is to determine the extent to which the US and EU sustainability criteria are binding. That is, do the results of the land use analysis change due to biofuel expansion in the presence of sustainability criteria. The previous research implicitly assumes the sustainability criteria are not binding. This research introduces sustainability criteria into the land use analyses due to biofuels.

Background and Literature Review

Currently, the world's leading producers of biofuels are the US, Brazil, and EU. The US is the world's largest biofuel producer producing 13.3 billion gallons (BGs) of ethanol and 1.1 BGs of biodiesel in 2012. In 2012 Brazil produced 5.6 BGs ethanol and 0.7 BGs biodiesel. Unlike the US and Brazil which mainly produce ethanol, the EU largely produces biodiesel. In 2012 the EU produced 1.3 BGs ethanol and 2.9 BGs biodiesel.

Brazil has defined land conservation programs and implemented land sustainability criteria (for example, see Galford et al. 2013). However, we were not been able to find clear links between these criteria and the Brazilian biofuel programs. Hence, while Brazil is a large biofuel producer, in this paper we do not include land sustainability criteria for this region.

The United States' biofuel programs go back over three decades. Ethanol production in the US has always been supported by the government in some form such as tax credit, trade barriers, and/or direct mandates (Tyner 2008). The most important renewable policy of the US to date is known the Renewable Fuel Standard (RFS). The Renewable Fuel Standard (RFS) was originally created under the Energy Policy Act in 2005 (U.S. Congress 2005) establishing the first mandate for renewable fuels in the US. The RFS program was later expanded in the Energy Security and Independence Act (EISA) of 2007 (U.S. Congress 2007). EISA expands the RFS program to include biodiesel, increases the total renewable fuel target to 36 billion gallons (BG) by 2022, and establishes new categories of renewable fuels, and introduces life-cycle greenhouse gas thresholds for renewable fuels. As explained in the next section of this paper, the US RFS bans using some certain types of land to produce feedstock for biofuel production.

The EU initiated its biofuel programs and policies in early 2000s, and the noteworthy document was the 2003 Biofuels directive. Then, the most updated policy that has the greatest impact is the Renewable Energy Directive (RED) 2009/28/EC, which is part of the EU Energy and Climate Change Package (CPP) (European Commission 2009). The RED mandates the 20/20/20 targets for biofuels in EU regions. The RED imposes some land sustainability criteria on the EU lands. It also imposes land sustainability criteria on biofuels produced outside the EU region. These restrictions are examined in the next section of this paper.

Many papers have used partial and general equilibrium economic models in combination with biophysical data to analyze induced land use changes due to the expansions in the first generation biofuels produced in US, Brazil, and EU (Hertel 2010; Hertel, Tyner et al. 2010; Taheripour, Hertel et al. 2010; Taheripour, Hertel et al. 2011) on biofuels are produced from grains (e.g. corn ethanol in US and wheat ethanol in EU), sugar crops (e.g. sugarcane ethanol in Brazil and sugar beet ethanol in EU), and oilseeds (e.g. biodiesel produced from oilseeds such as soybean, rapeseed, palm, and sunflower seeds). Only few studies examined the induced land use changes due to the second generation biofuels (Taheripour, Tyner et al. 2011; Taheripour and Tyner 2013). For example, Taheripour, Tyner, and Wang (2011) and Taheripour and Tyner (2013) have introduced second generation biofuels in the GTAP-BIO model and examined the induced land changes due the production and consumption of the second generation biofuels produced from corn stover and two dedicated energy crops: switchgrass and miscanthus. None of these papers have studied the induced land use changes the EU region.

A common implicit assumption among all papers which evaluated the biofuel induced land use change is that the land sustainability criteria defined in US and EU biofuel programs do not impose constraints on the process of land conversion due to the expansions in biofuel production. This paper examines the validity of this implicit assumption. To accomplish this task we use the computation general equilibrium model developed by Tyner and Taheripour (2013). The model traces the production and consumption of the first and second generation biofuels an explained in the next section.

Biofuels Mandates and Sustainability Criteria

In the United States, the biofuels mandate is governed by the Renewable Fuel Standard (RFS) program under the Energy Independence and Security Act of 2007 (EISA) (U.S. Congress 2007). The objectives of the RFS are: 1) reducing the greenhouse gas emissions through the use of renewable fuels; 2) reducing imported petroleum, which brings about higher energy security; and 3) developing and expanding the nation's renewable fuels industry sector. These renewable fuels qualify to be counted in the target only if they meet the minimum greenhouse gas (GHG) reduction standard based on a lifecycle assessment specified in the program. The biofuels mandates announced in the RFS is a total of 36 billion gallons by 2022 with specific targets for different biofuels in each year from 2010 through 2022. RFS mandates biofuels including conventional renewable fuel (corn ethanol), advanced biofuels which are cellulosic biofuels, biomass-based biodiesel and other biofuels (that do not need to follow the sustainability criteria such imported biomass or biofuels) .

With respect to the European Union (EU), the Commission's most important document to date is the Renewable Energy Directive (RED) or Directive 2009/28 on the promotion of the use of energy from renewable sources. The Directive emphasizes the need to reduce the greenhouse gas emissions and comply with the Kyoto Protocol through the production and consumption of energy within the EU from renewable sources, energy savings, and increased energy efficiency. Above all, this directive launches the common framework for the promotion of renewable energy. It consists of the mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy and for the share of energy from renewable sources in transport. Each member state (MS) shall ensure that the share of energy from renewable sources in gross final consumption of energy in 2020 to be at least its national overall target, and these combined national targets must be at least 20% of the share of energy from renewable sources in the Community's gross final consumption of energy in 2020. Moreover, each MS must ensure that the share of energy from renewable sources in all forms of transport in 2020 is at least 10% of the final consumption of energy in transport in that MS (European Commission 2009).

Besides the biofuel targets mandates, RFS and RED also provide the descriptions of the land where biomass for biofuel production can be produced and harvested from, which is summarized in table 1.

Methodology

To examine whether the land sustainability criteria defined in the US and EU biofuel programs are binding or not, we follow two parallel activities. In the first activity we assess induced land use change due to the US and EU biofuel mandates, while we follow the literature and ignore the land sustainability criteria defined in the biofuel programs of these regions. This will help us to determine the global land requirements to meet the biofuel targets define in the US and EU biofuel programs. Then we impose the land sustainability criteria defined in the biofuel programs of these regions on the pool of available global land to exclude lands which are not eligible to be used for feedstock production for biofuels. Finally, we compare the results of these two activities to determine in what part of the world the eligible land for feedstock production is not enough to meet the demand for land conversion due to biofuel production. These activities are defined in the rest of this section.

Table 1: Summary of the US and EU Sustainability Criteria

US Sustainability Criteria	EU Sustainability Criteria
Qualifications of land ***permitted*** for biomass production	Qualifications of land ***prohibited*** for biomass production
1. Planted crops or crop residues harvested from existing agricultural land and nonforested	1. Land with high biodiversity value
	1.1 Primary forest and other wooded land
	1.2 Areas designated for nature protection purpose (listed by IUCN)
	1.3 Highly biodiverse grassland; natural and non-natural grassland
2. Planted trees and tree residues from actively managed tree plantation on non-federal land	2. Land with high carbon stocks
	2.1 Wetlands
	2.2 Continuously forested area
	2.3 Peatland
(Effective date certifying land status: December 19, 2007)	(Effective date certifying land status: January 2008)

We begin with development of sustainable land. In order to rule out all the non-sustainable lands prohibited to be used for biomass production for both the EU and the US, we will use ArcGIS, which is a geographic information system developed by the Economic and Social Research Institute (ESRI). It is a program designed for working with maps and geographic information. The GTAP global grid-cell land database (GGCD) is firstly converted into the ArcGIS geodatabase with specified geographical coordinate system (GCS-WGS-1984). It will be the first layer of geographic data layer waiting for the overlays of other prohibited lands that will later be removed from the overall land area.

The US limits the policy enforcement to only the biomass produced within its border, henceforth; the GTAP-GGCD is bounded to display only the US, the area of our concern. As dictated in the RFS that biofuels can be produced from crop and crop residues from existing agricultural land and planted trees and tree residues from nonfederal and nonforested lands; consequently federal land, primary forest, protected areas (including rangeland), and wetlands need to be removed from the land for biofuel production. The US Federal land data layer is overlain on top of the US GGCD layer; using the combined techniques equipped in the ArcGIS to remove the Federal land from the total US land. These techniques only remove the specified lands of the same geographic locations of the two layers. As each grid cell of the GTAP-GGCD can contain all types of land; hence the removal of federal land can be to any types of land-use of the same geographic location grid-cell. Similar steps are repeated for the protected areas and wetlands layers. As a result, we have a map of US land permitted for biomass production by AEZ and land-use types including the land areas of each category of AEZ and land-use type.

With respect to the potential land used for biomass production of the European Union, we also begin with the GTAP-GGCD map as the primary layer. However, the EU renewable policy is applied to all feedstock regardless of the place of origin; thus, the (combined) global data layers are required for the construction of the sustainable land for biomass production. Similar to the approach used with the US, all prohibited land layers are removed one by one by the combined ArcGIS techniques. These prohibited lands are, as indicated in the sustainability criteria of the Directive, primary forest, IUCN protected areas, and wetland/peatland. The IUCN protected areas layer is the first, followed by the primary forest (GSW frontier forest), and finally the Ramsar site wetlands layers. The final map layer we get is the potential map layer indicating the area for biomass production under the sustainability criteria of the EU's directive.

Simulations Undertaken

The analytical framework of this research is designed to demonstrate the extent to which direct application of land sustainability criteria changes the economic and land-use implications of biofuels programs in the US and EU. In this research we will conduct the following main experiments:

US-I: Expansion in biofuel production (including first and second generation biofuels) according to the targets defined in the RFS with no land constraints,

US-II: Expansion in biofuel production (including first and second generation biofuels) according to the targets defined in the RFS in the presence of the US land sustainability criteria and identifies the AEZs of the US and other regions in world being impacted by the sustainability criteria,

EU-I: Expansion in biofuel production (including first and second generation biofuels) according to the targets defined in Directive 2009/28 with no land constraint,

EU-II: Expansion in biofuel production (including first and second generation biofuels) according to the targets defined in Directive 2009/28 in the presence of the EU land suitability criteria, and identifies AEZs of any regions of the world being impacted by the sustainability criteria,

US-EU-I Expansion in biofuel production (including first and second generation biofuels) according to the targets defined in the RFS and Directive 2009/28 with no land constraint,

US-EU-II Expansion in biofuel production (including first and second generation biofuels) according to the targets defined in the RFS and Directive 2009/28 in the presence of the US and

EU land sustainability criteria, and identifies AEZs of any regions of the world being impacted by the sustainability criteria,

US-EU-Food-I Expansion in biofuel production (including first and second generation biofuels) according to the targets defined in the RFS and Directive 2009/28 in the presence of the US and EU land sustainability criteria and with food consumption fixed for the low-middle income countries,

US-EU-Food-II Expansion in biofuel production (including first and second generation biofuels) according to the targets defined in the RFS and Directive 2009/28 in the presence of the US and EU land sustainability criteria and with food consumption fixed across the world, and identifies AEZs of any regions of the world being impacted by the sustainability criteria.

For the experiments involving the US biofuel mandate, the 2022 targets of 15 billion gallons (BG) of conventional biofuel (or corn ethanol), 16 BG ethanol equivalent of cellulosic biofuel, and 1 BG of biodiesel which are the maximum targets of each biofuels type will be implemented. The other biofuel, mostly sugarcane ethanol, does not need to meet the RFS sustainability requirement, and will not be covered in this research. Hence, three different cellulosic drop-in fuels, namely AdvfB_Misc, AdvfB_Swit, and AdvfB_Stover (cellulosic drop-in fuel produced from miscanthus, switchgrass and corn stover respectively) are used to represent the RFS cellulosic biofuel targets. The energy content of cellulosic drop-in fuel is assumed to be the same as that of conventional gasoline, while the energy content of ethanol is two-third of that of conventional gasoline (Taheripour, Tyner et al. 2011).

The experiments involve the EU biofuels mandates is slightly more complicated. The EU renewable energy consumption for road transportation based on the Directive 2009/28 is estimated at 316 Million ton of oil equivalent (Mtoe) in 2020. We adopt the 5.6 percent first-generation land-using biofuels share in the overall EU renewable energy target of 10 percent for road transportation of Al-Riffai et al. (2010). This 5.6 percent translates into 17.696 Mtoe for biofuels for road transportation. In the absence of any estimates of the likely breakdown among renewable biofuels, we have assumed 50 percent of this being biodiesel from oilseeds, 25 percent from cellulosic biofuel, and 25 percent from conventional ethanol. Our assumption is based on the 2011 GAIN report of USDA-FAS that 70 percent of renewable fuel in transport was biodiesel(Flach, Bendz et al. 2012), and coupled this with European Commission document on EU energy trends to 2030 projection indicating the future growth of biodiesel(Capros, Mantzos et al. 2009). The cellulosic biofuel of 25 percent for the EU is likely to be biodiesel; therefore, cellulosic drop-in fuel from miscanthus is used to represent this. With this assumption, the biodiesel together from oilseeds (rapeseed and palm oil) and cellulosic drop-in fuel accounts for 75 percent of the total renewable fuel mix. Hence, 17.696 Mtoe for biofuels for road transportation is broken down into 8.848 Mtoe for biodiesel from oilseeds, 4.424 Mtoe from miscanthus cellulosic drop-in fuel, and 4.424 Mtoe from wheat ethanol. To implement these targets in the model, they need to be converted into billion gallons as for the US targets. With the energy contents of 21 mega joule per liter (Mj/l) and 33 Mj/l respectively for (bio) ethanol from biomass and methyl-ester biodiesel from vegetable oil from Annex III of the Directive 2009/28, it is translated into the targets of 1.481 BG for the rapeseed and palm oil biodiesel, 2.328 BG for cellulosic drop-in fuel and 2.328 BG conventional ethanol. The EU Directive applies to all biomass regardless of origin. Land in the EU is limited and all existing land is already allocated for primary purposes of crop production, pasture, conservation, and living. Therefore, we expect widespread impact on land practice in the EU and also the rest of the world.

Beyond the pure land use issue, another issue that sometimes arises is to what extent biofuels could be sustainably produced while at the same time not reducing food availability. We are not attaching any judgment on the merits of this case, but are simply including it to provide information on the role of food consumption changes in the analysis. Our intention is simply to explore the possibility and its consequences.

The GTAP model captures comprehensive and extensive conditions of production, consumption, and trade in both domestic and international markets. However, the GTAP model does not conveniently allow direct modification to the consumption or the demand side of the economy. Thus, any experiments dealing with consumption or the demand need to be done through a proxy. The proxy used in this research is maintaining food production at the level as the base year (base data) coupled with the assumption of the model that all of food production will be consumed. These steps practically impose an additional constraint to the model on top of the biofuels targets; that is, the model is now set to deliver both the biofuels targets (as indicated in the policy) and food production target. In order to do so, some modifications are made to the model. First of all, a creation of new food subset (FOOD) under the tradable commodities (TRAD_COMM) to separate out food crops and food related commodities from other tradable commodities. Second is the creation of subsets of countries of interest. There are two groups of countries, lower-to-middle income countries (with GDP per capita less than 10,000 US dollars, or NDEV in the model) and high income countries (with GDP per capita higher than 10,000 US dollars, or DEV in the model).

The fixing of food consumption is separated into two cases; the global food consumption fix and food consumption fix for the lower-to-middle income (LTMI) countries. The first case is to represent the assumption that the world will likely maintain its original food consumption, while the latter is to represent the case when lower-to-middle income countries are shielded from the impacts from the biofuels targets that could drive the food crops and food related commodities outputs down. The lower-to-middle income countries are Brazil, CHIHKG (China and Hong Kong), India, East Asia, Southeast Asia, MsiaINDO (Malaysia and Indonesia), Russia, Eastern Europe, Central America and Caribbean, South America, Middle Eastern and North Africa, and Sub-Saharan Africa; and the high income countries are the US, EU27, Canada, Non-EU27 (that do not belong to Eastern Europe), Oceania (Australia and New Zealand) and Japan.

Results

The sustainable land result is the crucial information required for the sustainable land practice analysis. Hence, we will begin with the sustainable land result and then we will present the impact analysis due to the biofuel mandates. The combined targets of US and the EU biofuel expansions have a greater impact on land-use than the case of only the US or the EU biofuel expansion. Table 2 is used to depict the additional cropland requirement in comparison to the available sustainable land in each biofuel expansion case, and table 3 is used to show the result of changes in land-use allocation. In the case of the US biofuel expansion, the total biofuel mandate of 16 BG requires additional cropland of 1.3 Mha. Nonetheless, according to the sustainable land resulted from ArcGIS technique, there are 228.6 Billion hectares (Bha) of sustainable land from managed forest and pasture available to be converted to cropland. The US biofuel expansion not only impacts the land-use in the US but also other regions of the world. In total, the world requires additional cropland of 3.3 Mha, 0.7 Mha comes from the conversion of managed forest, and 2.6 Mha comes from conversion of pasture land. Clearly, in the case of the EU biofuel expansion, the EU requires more of the additional cropland than the case of on the US biofuel expansion. Two main causes drive this event; the EU has limited land area and most of the land is fully utilized; and lack of cropland-pasture that can partly serve in the production of the dedicated energy crop.

Table 2: Additional Cropland Requirement vs. Available Sustainable Land for each Biofuel Expansion (in million hectares)

	Additional Cropland Needed	Sustainable Mng. Forest for Conversion	Sustainable Pasture for Conversion	Total Sustainable Land for Conversion
US Biofuel Expansion				
US	1.3	114.6	114.0	228.6
EU Biofuel Expansion				
US	0.7	177.8	211.4	389.2
EU	2.3	125.7	49.3	175.0
World	7.7	1,129.4	2,389.6	3,519.0
US-EU Biofuel Expansion w/o Food Consumption Fix				
US	1.8	114.6	114.0	228.6
EU	2.5	125.7	49.3	175.0
World	10.8	1,065.6	2,292.2	3,358.5
US-EU Biofuel Expansion w/ LTMI Food Consumption Fix				
US	1.8	114.6	114.0	228.6
EU	2.5	125.7	49.3	175.0
World	12.5	1,065.6	2,292.2	3,358.5
US-EU Biofuel Expansion w/ Global Food Consumption Fix				
US	2.2	114.6	114.0	228.6
EU	3.0	125.7	49.3	175.0
World	14.2	1,065.6	2,292.2	3,358.5

In the case of the US-EU biofuel expansion, the additional cropland requirements in the US and in the EU for the cases of the absence of food consumption fix and LTMI food consumption fix are not much of the difference. The US requires approximately 1.8 Mha, while the EU requires approximately 2.5 Mha. Nonetheless, the additional cropland requirements for the world of the two cases are different. The biofuel expansion with LTMI food consumption fix requires slightly more of additional cropland at the global level. The EU cropland conversion is unique from others in that majority of cropland is converted from managed forest, not pasture land. As the biofuel expansion cause a higher demand in cropland, it also induces the return on land (rent) of cropland. This causes the cropland conversion from other land-use types. This conversion comes from land with abundance and/or land with the best return. In the EU case, cropland conversion occurs to the land with greater abundance, which is managed forest.

The US-EU biofuel expansion with global food fix has the greatest land-use implication. It requires an additional cropland of 14.2 Mha globally. The US and the EU also require slightly more of additional cropland than in the case of partial food consumption fix or in the absence of food consumption fix. Nonetheless, in all biofuel expansion cases, the additional cropland induced by the biofuels mandates does not exceed the available sustainable land for cropland conversion. No region or AEZs is binding in any of the biofuel expansion cases. Therefore, the sustainable land practice complying with the US and the EU sustainability criteria is possible in order to deliver the national biofuel targets.

In all biofuel expansion cases, besides the US and the EU, there are other regions who are noticeably affected. Canada, the important trading partner of the US, cannot avoid the impacts. In fact, when we look closely at the pattern of the land-use and cropland allocation, it is found that Canada picks up the production of crops and other commodities especially livestock and dairy industries which are replaced by the biofuels crops. Brazil is the other country worth highlighting. Brazil is an important producer of sugar cane and oilseeds. Despite the lack of the cane ethanol target in this research, oilseeds biodiesel targets affect the soy production and cane production in Brazil. With significant biodiesel mandates, world demands for oilseeds rise for biofuel production on top of existing food demand. Consequently, oilseeds become the dominating crops in many regions and of the world as a net cropland area. Brazil as one of important oilseeds producers (i.e. soy) also expands oilseeds harvested area. This expansion comes at a price of other crops including cane. Sub-Saharan Africa is the other region with substantial changes in the land-use allocation. Large portion of the cropland conversion comes from pasture land. However, this cropland conversion is not for the biofuel crops but rather for other agricultural crops.

The analysis of change in economic welfare is also interesting. The equivalent variation is used to measure the economic welfare in the GTAP model. The result shows that in all biofuel expansion cases, the total welfare falls. The countries/regions with the greatest loss in welfare are always the biofuel policy implementers, i.e., the US and the EU. These losses are mainly due to the negative term of trade effects. Biofuel mandates cause the changes in the land-use cropland allocations to serve the higher demand for cropland for biofuel production. As the US and the EU dedicate more cropland for biofuel crops, they have to find other sources to meet the demand of others being replaced by biofuel crops. These do not only refer to the crops but also other commodities using land as a production factor such as the livestock industry. This makes them to be more reliable on the imports of those commodities and results in the negative term of trade effect.

Despite of the overall global welfare loss, some regions show positive welfare gains; these regions are Brazil, Malaysia-Indonesia, and Oceania (Australia-New Zealand). These regions benefit from oilseeds production and trade as the result shown that oilseeds become highly demanded due the biofuel targets. Brazil benefits from soy, while Malaysia-Indonesia benefits from palm oil. The positive welfare gain of Australia-New Zealand is different from the cases of Brazil and Malaysia-Indonesia. They benefit from the unchanged significance of the livestock and dairy products including their exports. In fact, their livestock and dairy products become more expensive due to the shrinkage of production in other regions, consequently, the positive term of trade for these products cause the total positive welfare gain.

Table 3: Changes in Land-Use Allocation due to Different Biofuel Expansion

	Changes in Land-Use Allocation (in thousand hectares)		
	Forest	**Crop**	**Pasture**
US Biofuel Expansion			
US	(726)	1,309	(583)
EU	(147)	226	(78)
World	(702)	3,313	(2,610)
EU Biofuel Expansion			
US	250	668	(918)
EU	(1,944)	2,310	(366)
World	318	7,751	(8,070)
US-EU Biofuel Expansion w/o Food Consumption Fix			
US	(669)	1,801	(1,131)
EU	(1,998)	2,411	(414)
World	(501)	10,767	(10,266)
US-EU Biofuel Expansion w/ LTMI Food Consumption Fix			
US	(611)	1,851	(1,239)
EU	(2,008)	2,463	(454)
World	(1,684)	12,455	(10,771)
US-EU Biofuel Expansion w/ Global Food Consumption Fix			
US	(644)	2,195	(1,551)
EU	(2,821)	3,047	(226)
World	(1,142)	14,218	(13,076)

Table 4: Summary of Economic Welfare Analysis by Region of each Biofuel Expansion

Region	US Expansion	EU Expansion	US-EU Biofuel Expansion		
			No Food Fix	LTMI Food Fix	Global Food Fix
USA	(48,170)	1,650	(47,857)	(48,094)	(47,214)
EU27	(69)	(29,316)	(30,721)	(32,255)	(38,103)
Brazil	242	955	1,312	1,458	1,721
Canada	(711)	57	(622)	(580)	(612)
Japan	(247)	(395)	(782)	(995)	(1,463)
CHIHKG	(24)	(528)	(627)	(705)	(1,052)
India	513	91	582	458	401
C.America	(1,429)	(215)	(1,647)	(1,775)	(2,124)
S.America	(615)	902	432	653	830
E.Asia	311	(129)	115	(9)	(234)
MsiaIndo	61	277	388	400	442
SE.Asia	233	183	420	388	338
S.Asia	59	(60)	(13)	(69)	(124)
Russia	(1,353)	(897)	(2,237)	(2,236)	(2,422)
E.Europe	(11)	181	193	177	119
Oth Europe	(648)	(520)	(1,165)	(1,205)	(1,628)
ME&N.Afr	(4,658)	(1,891)	(6,460)	(6,632)	(7,394)
SSAfr	(1,041)	335	(609)	(542)	(584)
Oceania	90	435	576	598	781
Total	**(57,465)**	**(28,886)**	**(88,722)**	**(91,021)**	**(98,322)**

Conclusions and Discussion

The utmost important question at the beginning of this research is the sufficiency of sustainable land for biofuel production. Based on the results of this research, the world has sufficient sustainable land to meet the biofuel mandates in all cases of biofuel expansion regardless of only individual country targets or of the combined targets of the US and the EU. In other words, the sustainability are not binding in any case. Nonetheless, it is important to point out that this result is based on many assumptions. The data on some of the sustainability critieria is incomplete, so we cannot be sure all non-sustainable lands have been excluded.

Although, the economic welfare analysis indicates the total welfare loss of the world, this loss is only considered from the stand point of the biofuel production alone, which is the only shock to the model. The benefits of the biofuels to the environment, to a potential new job creation, or national energy security are not captured in the shown welfare analysis.

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