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Ethanol Trade Policy and Global Biofuel Mandates

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Abstract

The impacts of the biofuel mandates in the EU and the US on agricultural markets and on the environment are assessed under three trade scenario assumptions using a global general equilibrium model. The study finds that while the biofuel mandates will result in important adjustments in global agricultural markets sector, it will generally be beneficial for the agricultural sector and farm producers, as well as on the environment in terms of reduced CO₂ emissions. These benefits are further enhanced if the mandate policies are accompanied by liberalization in ethanol trade.

Keywords: biofuel mandates, trade policy, ethanol

I. Introduction

Biofuel production increased sharply in the past decade and can be expected to grow more rapidly in the coming decade as country governments continue to seek greater energy independence through renewable energy sources. Many countries, notably the United States (US) and the European Union (EU), have adopted ambitious policies to reduce reliance on foreign oil and cut down greenhouse gas (GHG) emissions. International trade in biofuel and feedstock crops will also grow as countries seek to reach their renewable energy consumption targets through more cost-effective and environmentally efficient means.

A large expansion in biofuel production will be required to meet the EU and US biofuel consumption targets in the next decade. The EU adopted the Renewable Energy Directive (RED) which includes a 10% target for the use of renewable energy in road transport fuels by 2020. Under the 2007 Energy Independence and Security Act, the US set a target of 36 billion gallons of renewable fuels for road transportation by 2022. The renewable fuel standards are accompanied by environmental sustainability criteria. Renewable fuels in the US will be required to reduce GHG emissions by at least 20% with 58% of all renewable energy coming from cellulosic ethanol and other advanced biofuels by 2022. For the EU, the provisions are to reduce GHG emissions by 35% by December 2010 and by 50% from 2017, accompanied by restrictions on land where production of biofuel feedstock crops can be established.

The US and EU biofuel mandates will change the size and structure of global biofuel markets and its associated sectors, and will affect consumers and producers in developed and developing countries. The competition between biofuel crop sectors and other agricultural commodities will have implications for agriculture and land use, especially for net agricultural exporting countries of Latin America. Brazil, the largest ethanol producer and exporter in the region, has a competitive advantage with the lower production costs and environmental efficiency of sugarcane. The increased demand for biofuel around the world offers both opportunities and challenges for Brazil, as well as for other developing countries.

In this study, we seek to clarify the interactions between different biofuel policy scenarios and their potential impacts on global agricultural markets and on the environment, particularly on production, trade, welfare, land use, and CO₂ emissions. The primary goal of the study is to analyze the potential impacts of the EU and US biofuels mandates on world biofuels markets under different trade policy assumptions. This evaluation focuses on the impacts of the mandates on the following: (a) the distribution of global production, consumption and trade; (b) the prices of agricultural products and of fuel to consumers; (c) value-added, real income, and terms of trade ; (d) changes in land use ; and (e) the balance of emissions of greenhouse gases (GHG) associated with the liquid fuel market..

Although the study covers both the biodiesel and ethanol markets, the study provides greater emphasis to the evaluation of impacts of policies on the ethanol market. This emphasis on ethanol arises from the greater expansion in ethanol, relative to the biodiesel market, that results from both the US and EU mandates, and the concentration of initial high levels of trade protection in the sector. With the stronger slant towards ethanol and the acknowledged importance of Brazil in the global biofuel market, the study also analyses the hypothetical impacts of limited consumption of sugarcane ethanol on the US and EU markets, including the impacts of the biofuel consumption targets on GHG emissions.

This quantitative analysis of the global economic and environmental impact of first-generation biofuel development was conducted using an extensively modified version of the MIRAGE global, dynamic computable general equilibrium model (CGE) which captures domestic intersectoral relationships and interregional linkages in the global economy. Primary among the major methodological innovations introduced in the MIRAGE-BIOF model is the new modeling of energy demand which allows for substitutability between different sources of energy, including biofuels. This is facilitated by the extension of the underlying global Global Trade Analysis Project (GTAP) database which separately identifies ethanol with four subsectors, biodiesel, five additional feedstock crop sectors, four vegetable oils sectors, fertilizers, and the transport fuel sectors. The model was also modified to account for co-products generated in the ethanol and biodiesel production processes and their role as inputs to the livestock sector. Fertilizer modeling was also introduced to allow for substitution with land under intensive or extensive crop production methods. Also introduced is a land use module which allows for substitution between land classes, classified according to Agro-Ecological Zones (AEZs), land extension possibilities, and assessment of the greenhouse gas emissions (focusing on CO₂) associated with land use changes. The model was further improved with data for Brazil obtained from Brazil's Institute for International Trade Negotiations, including information from the Brazilian Land Use Model (BLUM)

A brief review of biofuel policies in the EU, US and Brazil is provided in the next section of the report. Section 3 includes an overview of the data development and model development involved in the study. The readers are referred to Al-Riffai et al. (2010) for more detailed discussions of the various components of the methodology. The baseline scenario and alternative trade policy scenarios analyzed in the study are presented in Section 4. Results and discussions are provided in Section 5 and concluding remarks are given in Section 6.

II. Biofuel Mandate and Trade Policies

In recent years, many countries have instituted biofuel programs due to the need to reduce reliance on foreign fossil fuels and achieve energy independence, to bolster farm incomes, and to reduce greenhouse gas emissions. This section provides a brief background about the biofuel policies in the three main biofuel markets: Brazil, the European Union, and the United States.

Brazil

Ethanol policies have been implemented in Brazil since the mid-70s and current blending obligations for ethanol are up to 20-25% for gasoline. More recently, Brazil has introduced biodiesel blending targets of 2% in 2008 and 5% in 2013, similar to the European Union. In order to reach these obligations, Brazilian federal and state governments grant tax reductions/exemptions. The level of advantage varies based on the size of the agro-producers and on the level of development of each Brazilian region.

The Common External Tariff (CET) of Mercosur also protects domestic biofuel production, with ethanol duties of 20% and biodiesel 14%. These tariffs could be eliminated or significantly reduced under the Doha and/or the EU-Mercosur negotiations. Furthermore, no non-tariff barriers constrain Brazilian imports of biofuels (e.g. no TRQ on biofuels in Mercosur).

Another important explanatory factor in the growth of the ethanol sector in Brazil is the role of foreign investment with recent investments coming from Europe and the United States. The investments include not only distillation plants but also sugarcane production. The competitive prices of raw materials and the high level of integration in the process explain the lower costs for ethanol production in Brazil and the motivation of the foreign investors.

EUROPEAN UNION

The adoption of targets for the use of biofuels in road transport fuels is a key component of the European Union's response to achieving its Kyoto targets of GHG emissions. In 2003 the European Union first set a target of 5.75% biofuels use in all road transport fuels by the end of 2010. The proposal to adopt a 10% target for a combination of first and second generation biofuels use in road transport fuels by 2020 was made in the Renewable Energy Roadmap (CEC, 2006) as part of an overall binding target for renewable energy to represent 20% of the total EU energy mix by the same date. On 23 April 2009, the European Union adopted the Renewable Energy Directive (RED) which includes a 10% binding target for renewable energy use in road transport fuels and also establishes the environmental sustainability criteria for biofuels consumed in the EU (CEC, 2008). A minimum rate of GHG emission savings (35% in 2009 and rising over time to 50% in 2017), rules for calculating GHG impact, and restrictions on land where biofuels may be grown are part of the environmental sustainability scheme that biofuel production must adhere to under the RED. The revised Fuel Quality Directive (FQD), adopted at the same time as the RED, includes identical sustainability criteria and it targets a reduction in lifecycle greenhouse gas emissions from fuels consumed in the EU by 6% by 2020. The adoption of the RED includes a requirement for the Commission to report, by 31 December 2010, on the impact of ILUC on GHG emissions and address ways to minimize that impact.

EU trade policies also affect domestic biofuel production as well as reduce production incentives and export opportunities for foreign biofuel producers (e.g. USA, Brazil, Indonesia, Malaysia, etc.). The

Most Favoured Nation (MFN) duty for biodiesel is 6.5%, while for ethanol tariff barriers are higher (€19.2 / hectolitre for the HS6 code 220710¹ and €10.2 / hectolitre for the code 220720). Even if tariffs for biodiesel were to be reduced, trade would still have to face more restrictive non-tariff barriers (NTBs) in the form of quality and environmental standards, which already mostly affect developing country exporters.

Nevertheless, some European partners already benefit from a duty-free access for biofuels under the Everything But Arms Initiative, the Cotonou Agreement, the Euro-Med Agreements and the Generalised System of Preferences (GSP) Plus. Many ethanol exporters, such as Guatemala, South Africa and Zimbabwe, use this free access opportunity. However, most ethanol imports come from Brazil and Pakistan under the ordinary European GSP without any preference for either since 2006. For European biofuel exports, the EU has a preferential access for ethanol in Norway through tariff-rate quotas (i.e. 164 thousand hectolitres for the code 220710 and 14.34 thousand hectolitres for 220720).

United States

USA biofuel policies date back to the 1970s and are as complex as those of the EU. Fiscal incentives and mandates vary from one state to another and differ from those at the federal level. The Energy Tax Act of 1978 introduced tax exemptions and subsidies for the blending of ethanol in gasoline. In contrast, biodiesel subsidies are more recent, and were introduced in 1998 with the Conservation Reauthorization Act.

Mandates on biofuel consumption were initiated under the Energy Policy Act of 2005 at the federal level, although obligations for biofuel use exist at the state level (e.g. Minnesota introduced a mandate on biofuels before the federal government, which it increased to 20% in 2013). This 2005 Act set the objective of purchasing 4 billion gallons of biofuels in 2006 and 7.5 billion gallons in 2012.

The US Renewable Fuel Standard (RFS-2) provides volume targets for different kinds of biofuel. The US mandate implies the consumption of 1 billion gallons of biodiesel (3.15Mtoe), 3.5 billion gallons of non-cellulosic advanced biofuels (7 Mtoe), and 15 billion gallons of conventional biofuels (30 Mtoe) by 2020.

The current biofuels policies in the USA consist of three main tools: output-linked measures, support for input factors and consumption subsidies. Tariffs and mandates benefit biofuels producers through price support. Tariffs on ethanol (24% in equivalent ad valorem) are higher than biodiesel (1% in equivalent ad valorem) which limit imports especially from Brazil. Moreover, producers benefit from tax credits based on biofuels blended into fuels. The Volumetric Ethanol Excise Tax Credit (VEETC) and the Volumetric Biodiesel Excise Tax Credit (VBETC) provide the single largest subsidies to biofuels, although there are additional subsidies linked to biofuel outputs.

¹ Harmonized System (HS) code 220710 refers to undenatured ethyl alcohol, of actual alcoholic strength of => 80% and HS 220720 refers to denatured ethyl alcohol and other spirits.

III. Data and Methodology

The study uses extensively modified and enhanced versions of the MIRAGE model and the GTAP 7 Database. The model, MIRAGE-BIOF, and dataset were initially developed for the assessment of the global trade and environmental impacts of the EU biofuel mandate (Al-Riffai, et al., 2010a) and further modified for the study of the world market impacts of the EU and US biofuel mandates (Al-Riffai, et al., 2010b). The latter study included improved data for Brazil based information from the Brazilian Land Use Model (BLUM). This section provides a brief overview of the model and data. Further details are available in Al-Riffai, et al. (2010a, 2010b).

Global Database

The MIRAGE model relies on the Global Trade Analysis Project (GTAP) database for global, economy-wide data. The GTAP database combines domestic input-output matrices which provide details on the intersectoral linkages within each region, and international datasets on macroeconomic aggregates, bilateral trade flows, protection, and energy. We started from the latest available database, GTAP 7, which describes global economic activity for the 2004 reference year in an aggregation of 113 regions and 57 sectors (Narayanan and Walmsley, 2008). The market access data comes from the MacMap-HS6 version 2.1 database (Boumellassa et al., 2009), which measures protection in 2004 and includes all regional agreements and trade preferences existing to this date. The database was then modified to accommodate the sectoral changes made to the MIRAGE model.

Twenty-three new sectors were created from the GTAP sector aggregates -- the liquid biofuels sectors (an ethanol sector with four feedstock-specific ethanol sectors, and a biodiesel sector), maize, major biodiesel feedstock sectors (rapeseed, soybeans, sunflower, palm fruit, and their respective oils), co- and by-products of distilling and crushing activities, the fertilizer sector, and the transport fuels sector. Unlike other studies of the global biofuel economy, an original and complex procedure was employed to create the 23 new sectors from 9 parent sectors in the GTAP database. The resulting dataset, which is consistent in values and quantities, captures the volume and value relationships in the value chains between the various oilseed crops and the corresponding vegetable oil sectors that are inputs to biodiesel production. The biofuels sectors are constructed using a bottom-up approach that takes into account the production costs, input requirements, production volume, and the by-products from ethanol production. The specific data sources, procedures and assumptions made in the construction of the new sector are described in Al-Riffai et al. (2010a, Annex I; 2010b).

Global Model

The MIRAGE model, a computable general equilibrium model originally developed at CEPII for trade policy analysis, was extensively modified at IFPRI in order to address the potential economic and environmental impact of biofuels policies. The core features of the standard multi-country, multi-sector MIRAGE model are documented in Bchir et al. (2002) and Decreux and Valin (2007). The model operates in a sequential dynamic recursive set-up: it is solved for one period, and then all variable values, determined at the end of a period, are used as the initial values of the next one. In each country a representative consumer maximizes a CES-LES (Constant Elasticity of Substitution – Linear Expenditure System) utility function under a budget constraint to allocate income across goods. The origin of goods is determined by a CES (Constant Elasticity of Substitution) nested structure following the Armington

assumption.² On the production side, value-added and intermediate goods are complements under a Leontief hypothesis. The value added is a CES function of unskilled labor and a composite of skilled labor and capital: this allows for including less substitutability between the last two production factors. In agriculture and mining, production also depends on land and natural resources. New capital is perfectly mobile across sectors while installed capital is immobile. Skilled labour is perfectly mobile across sectors while unskilled labor is imperfectly mobile between agricultural sectors and non-agricultural sectors. Total employment is constant. Investment is savings-driven and the real exchange rate is adjusted (through price adjustments) such that the current account is constant in terms of world Gross Domestic Product (GDP). Macroeconomic closure is obtained by assuming that the sum of the balance of goods and services and foreign direct investments (FDIs) is constant in terms of share of the world GDP.

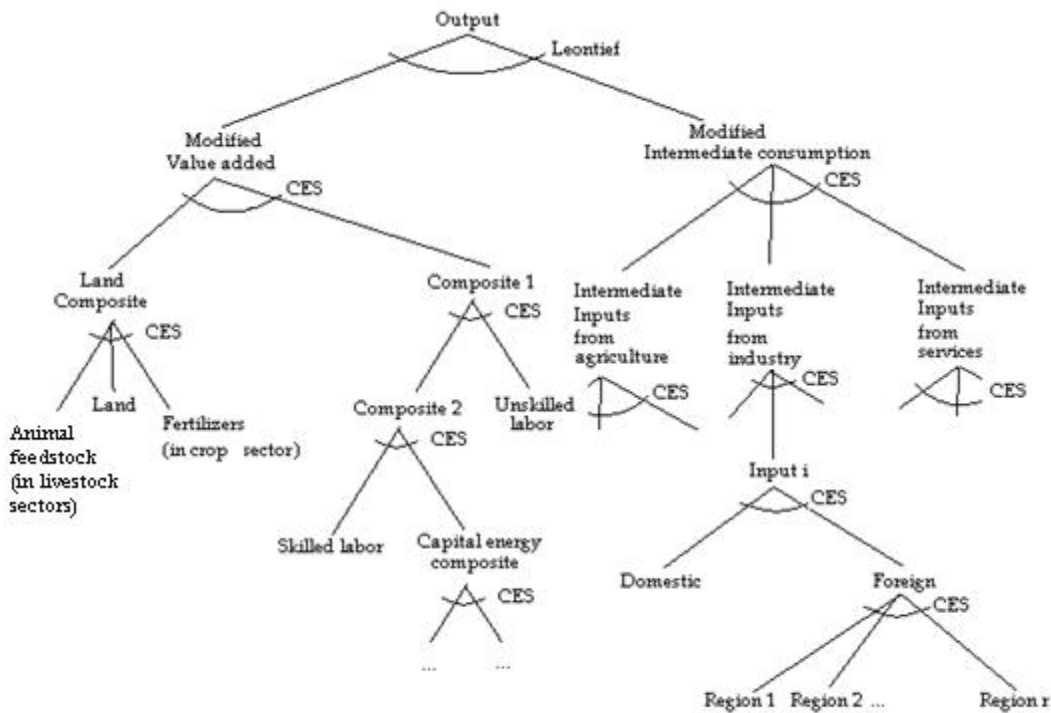
The key adaptations to the standard model are the integration of the biofuels sectors (ethanol and biodiesel) and biofuel feedstock sectors, improved modeling of the energy sector, the modeling of co-products and the modeling of fertilizer use. The land use module which includes the decomposition of land into different land uses, and the quantification of the environmental impact of direct and indirect land use change (ILUC), was introduced in the model at the Agro-Ecological Zone (AEZ) level. We provide brief descriptions of these model innovations in this paper. Further details are provided in Al-Riffai, et al. (2010b).

Energy Products. Energy products, including biofuels, were first introduced as components of value-added in the MIRAGE model in Bouet et al. (2008) and Valin et al. (2009). A top-down approach, similar to the GTAP-E model (Burniaux and Truong, 2002) was adapted. However, beyond what is in the GTAP-E model, the MIRAGE model was revised to include a better representation of agricultural production processes to better capture the potential impact of biofuels development on agricultural production (see Figure 1). Another distinctive feature of this new version of MIRAGE is in the grouping of intermediate consumptions into agricultural inputs/ industrial inputs/services inputs. This introduces greater substitutability within sectors. The demand function for final consumption, the Linear Expenditure System - Constant Elasticity of Substitution (LES-CES), was also modified through the introduction of new calibration to USDA income and price elasticities (Seale et al., 2003). Further details on the modification of the energy demand structure is provided in Annex III in Al-Riffai, Dimaranan, and Laborde (2010a).

Fertilizer Sector. A separate fertilizer sector is explicitly introduced in the global database and in MIRAGE-BIOF model to capture potential crop production intensification, i.e. the use of more fertilizers in response to increased demand for biofuel feedstock crops. Through improved modeling of fertilizers and their impact on crop yield, we introduce a more realistic representation of yield responses to economic incentives while taking into account the biophysical constraints and saturation effects using a logistic approach. The degree of crop intensification depends on the relative price between land and fertilizers. Further details on fertilizer modeling in MIRAGE-BIOF are provided in Al-Riffai, Dimaranan, and Laborde (2010, Annex IV).

² The MIRAGE model applies GTAP Armington trade elasticities which are low as compared to those used in other models, e.g. the World Bank's LINKAGE model(see Bouët, 2008, on this point).

Figure 1. Structure of the Production Process in Agricultural Sectors in the MIRAGE-BIOF Model



Biodiesel Production. Biodiesel production, which does not produce by-products, uses four kinds of vegetable oils (palm oil, soybean oil, sunflower oil and rapeseed oil) as primary inputs. These are combined with other inputs (mainly chemicals and energy) and value-added (capital and labor). Intermediate consumption is modeled using a CES nested structure with high substitutability assumed among the vegetable oils (an elasticity of substitution equal to 8). The initial dataset and the calibration of the model were set to allow for an initial marginal rate of substitution equal to 1 (e.g. one ton of rapeseed oil may be replaced by one ton of palm oil). The feedstock aggregate is then combined with a bundle comprised of the other components of intermediate consumption assuming complementarity (with elasticity of substitution equal to 0.001). As the only output of this sector, biodiesel can be exported or consumed locally. The shares of the different vegetable oils are given by initial data, but they evolve endogenously through the CES aggregate. However, in this framework, a country that does not produce biodiesel initially will never produce biodiesel and if a biodiesel sector in one country does not initially use a particular type of vegetable oil as feedstock, it will never switch to using it as a feedstock later on.

Ethanol Production. For the ethanol sector, we first model four subsectors, each one using only one of the following as specific feedstock -- wheat, sugarcane, sugarbeet, or maize. This main input is combined with other production inputs and value-added assuming complementarity. Each of these four subsectors, except for the sugarcane-based ethanol sector, produces a specific by-product (Distiller's Dried Grains with Solubles (DDGS) with different properties and prices), as well as the main output ethanol. These different types of ethanol are then blended into one homogenous good that is either exported or consumed locally. In addition, for Central America and the Caribbean regions, we allow for

the possibility of using imported ethanol from Brazil as an input into their own ethanol production sector.³ The rents generated by these preferences are shared between Brazilian exporters (represented as an additional export margin applied by Brazilian exporters on ethanol exports from Brazil to the Central America and Caribbean regions) and Central America and Caribbean agents (ad valorem margins on domestic production).

Co-Products. This difference in the treatment of co-products of ethanol and biodiesel production is reflected in the modeling of co-products in this study. For ethanol, co-products are represented as a fixed proportion of ethanol production, with the shares based on cost shares data for co-products for selected ethanol feedstocks in the USA and EU.⁴ For biodiesel, we consider as co-products the oilcakes/meals that are produced in the crushing of oilseeds to produce vegetable oils that are then processed for biodiesel production. We rely on the cost share information for oilcakes in the vegetable oil production process. Co-products are then introduced in the model as substitutes for feedgrains in livestock production. Substitution between oilcakes, based on the protein content of the different oilcakes, is first introduced. The composite of oilcakes is then introduced as a substitute for animal feed and DDGS as feed inputs to the livestock sector based on their energy content. However, we do not model the co-products of the biodiesel trans-esterification process, i.e. glycerol and similar products that can be used as additives to the feeding process. With the introduction of co-products in the model, the modeling of livestock production was also significantly modified to allow for intensification through substitution of livestock feed, including ethanol and biodiesel co-products, with land. This is treated using a similar approach to our modeling of crop intensification through the substitution of fertilizer for land: land and feedstuffs are substitutable.

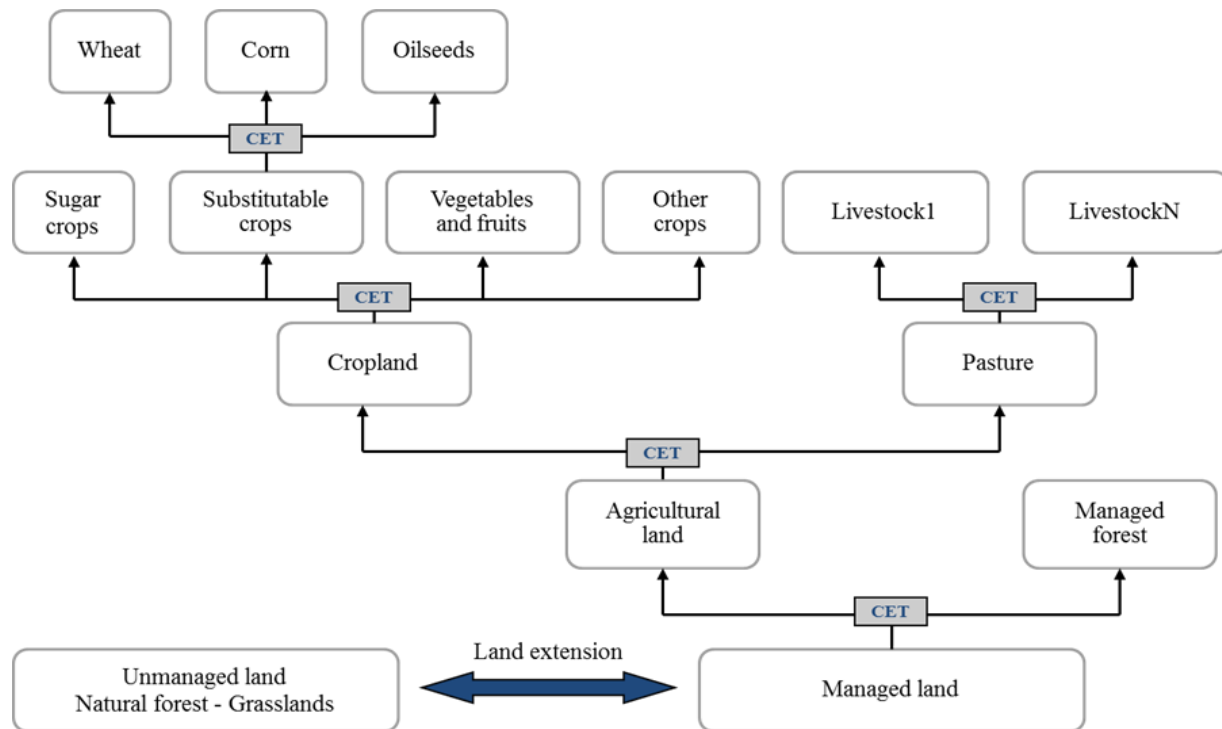
Land Use Module

To capture the interactions between biofuels production and land use change, we introduce a decomposition of land use and land use change dynamics. Land resources are differentiated between different agro-environmental zones (AEZ). The possibility of extension in total land supply to take into account the role of marginal land is also introduced. The modeling of land use change captures both the substitution effect involved in changing the existing land allocation to different crops and economic uses, and the expansion effect of using more arable land for cultivation (Figure 2). Detailed documentation of the land use module including data on AEZs and land use change modeling are available in Al-Riffai, et al. (2010a, see Annex V and VI).

³ The consumption of other inputs is corrected from the share of imported ethanol used in the processing of domestic ethanol under the assumption that transformation of processing of imported ethanol is performed at a low cost. However, only the existence of tariff preferences on the US and EU markets justify these indirect exports from Brazil.

⁴ For Brazil, the co-generation of electricity is taken into account but due to uncertainty on the evolution of the price of electricity, and the inadequacy of a global CGE to describe its evolution for Brazil, we assumed that co-generation generates a fixed percentage of income expressed as a percentage of production value for the ethanol producers.

Figure 2. Land Use Module



Land Allocation. Managed land includes cropland (cultivated land including permanent crops land and set aside land), pastureland, and managed forest. These different types of land are substitutes for each other. They are represented in the model in the form of economic rental values and the representative land owner can choose to allocate the land's productivity (homogenous to land rent values at initial year and defined as land surface adjusted by a productivity index) amongst the different land uses using different substitution levels. When demand for a crop increases, prices for the crop go up, and more land is allocated to this crop. This land is taken from other uses (pasture and managed forest) with respect to the respective prices of these two other categories. In the standard specifications, the price of pasture land is directly affected by the demand for cattle products (beef meat and dairy). Forest prices are affected by the demand for raw wood products. The magnitude of substitution follows the Constant Elasticity of Transformation (CET) specification. If the elasticity of transformation is high, the possibility for land replacement within managed land will allow for low prices when there is increased demand for crops and aggregated cropland price will not increase significantly. But if transformation possibilities inside managed land are smaller (for instance: simultaneous demand for competing products on the land market, a very homogenous use of the managed land, or a very small elasticity of transformation), then cropland prices will rise in response to the increased demand. Land use expansion will occur in response to the price increase (see below). Since we want to preserve the total physical surface in the model, we allow for adjustment in average productivity to keep consistency between the CET framework and this constraint. The elasticities of transformation used in the nested structured displayed in Figure 2 are drawn from the literature.

Land Extension. Land extension takes place at the AEZ level allowing the model to capture the different behavior across different regions of large countries (e.g. Brazil, Sub-saharan Africa). This behavior is described in the MIRAGE-BIOF model by a land extension equation that allows for the addition of new land to the amount of land available for crops in case of an increase in land prices. In this equation which defines a “land supply curve,” an important value is the expansion elasticity at the starting point. In the MIRAGE-BIOF model, the default value for land expansion has been set at the level of substitution value between managed forest and cropland-pasture aggregate in the substitution tree.

Although the historical trends for land use change are followed in the baseline, changes in land use allocation in the scenarios come from the endogenous response to prices through the substitution effects. Therefore, historical land use changes do not affect the distribution of land under economic use across their alternative uses (cropland, pasture, managed forest). In the scenario, to determine in which biotope cropland occurs, we followed the marginal land extension coefficients computed by Winrock International for the US EPA, wherein the extent of land use change over the period 2001 to 2004 was determined using remote sensing analysis. For Brazil, these coefficients are defined at the AEZ level, slightly modified the AEZ breakdown to be more consistent with the BLUM nomenclature, to capture the deforestation that occurs in specific regions. We assume that marginal land productivity in all regions is half the existing average productivity and will not change. This ratio is increased to 75% for Brazil.

GHG Emissions and LUC Measurement

A critical component of this study is the assessment of the balance in CO₂ emissions between: (a) direct emission savings induced by the production and use of biofuels and (b) possible increases in emissions as a result of land use changes (LUC) induced by biofuels production. Direct emissions savings for each region, are calculated primarily using the typical direct emission coefficients for various production pathways as specified in the EU Renewable Energy Directive. Additional sources were used for the relevant emissions coefficients data for other regions (EPA, 2009). We also assume that all biofuels will achieve a 50% direct saving target by 2020. The values of these CO₂ reduction coefficients are critical to the determination of direct emission savings and ultimately, the net emissions effects of biofuels.

In calculating the GHG emissions from land use change, the study considered emissions from (a) converting forest to other types of land, (b) emissions associated with the cultivation of new land and (c) below-ground carbon stocks of grasslands and meadows. We rely on IPCC coefficients for these different ecosystems. We also include two special treatments specific to EU and to Indonesia/Malaysia. For the EU, the carbon stock of forest is limited to 50% of the value for a mature forest. It is considered that no primary forest will be affected by the land extension in the EU and only the areas recently concerned by afforestation will be impacted. For Indonesia and Malaysia, in addition to the carbon stocks (above and below ground), we included the emissions from peatlands converted to palm tree plantations.

IV. Baseline and Trade Policy Scenarios

The impacts of the EU and US biofuel mandates are evaluated by comparing the policy scenarios against the baseline scenario. The baseline scenario provides a characterization of growth of the global economy up to 2020 without additional biofuel policy mandate by these two large economies. We then introduce the EU and US biofuel mandates as a policy scenario and examine the resulting changes compared to the baseline scenario. We then introduce two trade policy scenarios with the EU and US biofuel mandates – one with unilateral trade liberalization in ethanol in the EU and the US, and one where the EU and the US discontinue their imports of sugarcane ethanol.

Sectoral and Regional Aggregation

The study employs a rich 43-sector aggregation that separately includes the agricultural feedstock crops, feedstock processing sectors, biofuel processing sectors, energy sectors, and transport sectors. The regional aggregation is limited to the main players in the biofuel markets. Details are provided in Table 1 and Table 2.

Table 1. Regional Aggregation

Region	Description
Brazil	Brazil
CAMCarib	Central America and Caribbean countries
China	China
CIS	Commonwealth of Independent States (inc. Ukraine)
EU27	European Union (27 members)
IndoMalay	Indonesia and Malaysia
LAC	Other Latin American countries (inc. Argentina)
RoOECD	Rest of OECD (inc. Canada & Australia)
RoW	Rest of the World
SSA	Sub Saharan Africa
USA	United States of America

Assumptions in the Baseline

The underlying GTAP 7 database that is used in the study is first updated from the 2004 data reference year to 2008. This update is undertaken through a simulation that uses external macroeconomic variables (GDP, population, labor force) over that period, as well as by targeting observed biofuel production and consumption data for 2008. Endogenous variables (mandate) are used to reach these levels. After 2009, we let the model evolve freely in the baseline except for the macroeconomic variables and oil prices that are still targeted. Economic growth projections, taking into account the effects of the economic crisis, were updated with projections data from the World Economic Outlook (April 2009) of the International Monetary Fund. The oil prices in the baseline were obtained from the International Energy Agency forecasts (2008), with oil prices reaching \$120 a barrel in 2030 current prices.

Table 2. Sectoral Aggregation

Sector	Description	Sector	Description	Sector	Description
Rice	Rice	SoybnOil	Soy Oil	EthanolW	Ethanol – Wheat
Wheat	Wheat	SunOil	Sunflower Oil	Biodiesel	Biodiesel
Maize	Maize	OthFood	Other Food sectors	Manuf	Other Manufacturing activities
PalmFruit	Palm Fruit	MeatDairy	Meat and Dairy products	WoodPaper	Wood and Paper
Rapeseed	Rapeseed	Sugar	Sugar	Fuel	Fuel
Soybeans	Soybeans	Forestry	Forestry	PetrNoFuel	Petroleum products, except fuel
Sunflower	Sunflower	Fishing	Fishing	Fertiliz	Fertilizers
OthOilSds	Other oilseeds	Coal	Coal	ElecGas	Electricity and Gas
VegFruits	Vegetable & Fruits	Oil	Oil	Construction	Construction
OthCrop	Other crops	Gas	Gas	PrivServ	Private services
Sugar_cb	Sugarbeet or cane	OthMin	Other minerals	RoadTrans	Road Transportation
Cattle	Cattle	Ethanol	Ethanol - Main sector	AirSeaTran	Air & Sea transportation
OthAnim	Other animals (inc. hogs and poultry)	EthanolC	Ethanol - Sugarcane	PubServ	Public services
PalmOil	Palm Oil	EthanolB	Ethanol – Sugarbeet		
RpSdOil	Rapeseed Oil	EthanolM	Ethanol – Maize		

The average total factor productivity (TFP) in the economy is computed endogenously to reach the real GDP target in the baseline. In agriculture, we introduce country and sector specific TFP rates based on estimates from Ludena et al. (2006). Farm policies are not modified in the baseline except for the case of EU sugar market reform. It means that we do not consider changes in the US Farm Bill or the CAP reform of 2013 in the EU. In the case of the EU sugar market, we do not explicitly model the existing sugar policy tool, but instead we mimic the sugar market reform by reducing the EU MFN tariff on sugar and sugarbeet to reproduce the price decrease.

Since the study evaluates the impacts of the “incremental” mandate (the additional effort needed to reach the 2020 targets starting from 2008 levels) and not the full mandate in the US and the EU, we freeze the biofuel policies of these two regions in 2008 in the baseline scenario. All tax credits/subsidies remain constant. For Brazil, ethanol consumption is not modeled through an explicit mandate but is driven by the relative price of oil vs. ethanol. This mechanism will determine the overall consumption of ethanol in the economy which is estimated to be 34.90 Mtoe, equivalent to a blending rate of 52%. For biodiesel, we implement a 5% mandate on diesel consumption. Based on projections provided by ICONE, we calculated that it will represent 4.21 Mtoe by 2020. For the other regions in the world, we assume a 5% mandate in China, Indonesia and Malaysia and a 10% mandate in the rest of the OECD.

The baseline scenario includes the trade policies that were in place by the end of 2008⁵. Negotiations on trade agreements that were not finalized by the end of 2009 are not included⁶. For the US, the Caribbean Basin Initiative and its preferences are maintained during the period. For Brazil, the removal of its ethanol tariff is implemented, however, it has no effect due to the non-existence of ethanol imports in our baseline for this country.⁷ For the EU, the baseline scenario includes the full ad-valorem equivalent (AVE around 48%) of the prevailing EU MFN duty bioethanol imports from countries that do not benefit from bilateral or unilateral (GSP) preferential schemes. The anti-dumping duties imposed by the on US exports of biodiesel in March 2009 are also included in the baseline.

Baseline Evolutions

Within the context of the assumptions in the baseline, there will be no significant increase in EU and US demand for ethanol but there will be a larger demand from the rest of the OECD, the first market for Brazilian exports (80%) in 2020 in the baseline. In 2020, biofuel consumption in the EU will reach 11 Mtoe, of which 9.1 will be provided by biodiesel (3.3% average blending rate). For the US, biofuel consumption will be about 19 Mtoe (average blending rate of 6.4%) of which 17.8 Mtoe is ethanol. The overall world consumption of biofuels will reach 98.8 Mtoe for ethanol (mainly based on sugarcane and sugarbeet) and 26.2 Mtoe for biodiesel (of which half is produced from soybean oil). Sugar cane will be the main feedstock for ethanol (61%) but maize, driven by the US market will also be quite significant (34%), at the global level. Soybeans will be the main feedstock used for biodiesel (53%), while sunflower, rapeseed and palm fruit contribute 10%-20% each.

In the baseline, oil prices follow trends identified by the IEA in the recent World Energy Outlook with oil prices stabilizing at \$83.8 a barrel by 2010, increasing slowly up to \$96.4 in 2015, and reaching \$109 in 2020 (values are given in 2004 constant dollars). Oil production is forecast to experience constraints with an increase of only 32% on the period 2010-2020.

Demand for all crops increases only marginally (35% in world production) over the 2010-2020 period. The largest increases in demand are for palm fruit (57%) and for sugarcane, sugarbeet (57%) and soybeans (49%). Demand for cereals face smaller increases (17% for wheat and 24% for maize). These figures are above the FAO-Aglink projections and are mainly driven by a relatively inelastic demand for agricultural products by other sectors (services, agri-business, chemicals) and are intrinsic to the CGE exercise. With the sugar market reform in the EU, sugar production declines by 10% between 2008 and 2020. The effects of the reform are slightly absorbed by the ethanol industry since sugarbeet production declines by only 7.5%.

Along with the forecasted changes in crop production, cropland expansion is expected to reach 1.47 Mios of km² between 2008 and 2020 (12%). The largest expansion takes place in Brazil (350,000 km², half of them extracted from previous pasture land) and in Sub-Saharan Africa (550,000 km²). Cropland surface will increase moderately between 2008 and 2020 in the EU (1%) and the US (3%).

⁵ The Economic Partnership Agreements (EPAs) between the EU and the African, Caribbean, and Pacific (ACP) countries, negotiated in 2008, are implemented either as ratified interim agreements or a complete EPA (e.g. with the Caribbean Community and Common Market (CARICOM)), depending on the status of the agreement.

⁶ E.g. the Doha Development Agenda, an EU-ASEAN agreement, and an EU-Ukraine agreement

⁷ Even if due to special conditions (poor sugarcane harvest, exchange rate) there were some ethanol imports in Brazil in 2009, this is not captured in our base year and baseline.

Scenarios

Against the baseline scenario, we evaluate the impact of the full implementation of ongoing EU and US first generation biofuel policies with three different trade policy scenarios. In each case, the US and the EU mandates are implemented to reach the consumption targets by 2020. The Renewable Fuel Standard (RFS-2) of the US provides volume targets for the different kinds of biofuel. The US mandate implies the consumption of 1 billion gallons of biodiesel (3.15Mtoe), 3.5 billion gallons of non-cellulosic advanced biofuels (7 Mtoe), and 15 billion gallons of conventional biofuels (30 Mtoe) by 2020. Ethanol will remain dominant and biodiesel will play only a marginal role in the US market. We assume that only sugarcane ethanol is eligible to meet the non-cellulosic advanced biofuels category.

In the EU, although the Renewable Energy Directive defines a 10% target for renewable energy in fuel used for road transportation by 2020, different sources of energy can be used: electric cars, second and third generation biofuels, first generation biodiesel made from wastes, etc. In addition, the ratio between ethanol and biodiesel will strongly depend on the evolution of the car fleet and the different tax incentives that member states will implement. We assume that the incorporation rate of land-based, first-generation biofuels (ethanol from grains and sugar crops, and biodiesel from vegetable oils) will total 6% of an overall fuel consumption of 316 Mtoe (million tons of oil equivalent), of which 40% will be ethanol (approximately 4.4 billion gallons).

The mandate scenarios are combined with different trade policy assumptions:

- **Scenario 1: Mandate policy** - Implementation of the EU and US biofuel mandates of targeted consumption of ethanol and biodiesel in 2020, under a business as usual trade policy assumption (i.e. same trade policy as in baseline)
- **Scenario 2: Mandate policy with trade liberalization** - Implementation of the EU and US biofuel mandates with full, unilateral trade liberalization in the biofuels sectors (not feedstocks) in the US and EU. Starting in 2010, all import duties and charges are removed, including the tax credit compensation in the US even if it is not a tariff, starting in 2010.
- **Scenario 3: Mandate policy without sugarcane ethanol imports** - Implementation of the EU and US biofuel mandates, without US and EU imports of sugarcane ethanol, under a business as usual trade policy assumption.

V. Results and Discussion

In this section, we present the potential impacts of the EU and US biofuel mandates on biofuel and crop production and prices; bilateral trade; employment, agricultural value-added, and welfare impacts; land use changes; and environmental impacts in terms of GHG emissions from land use changes. The results are presented as variations of the three mandate and trade policy scenarios relative to the 2020 baseline levels.

Production and Prices

In this section, we present the impacts of the scenarios on production on ethanol, biodiesel, and of feedstock crops. We also report the impacts on world commodity prices, on commodity aggregates, and oil and fuel prices in major regions.

Biofuel Production

Across all scenarios, global production of biodiesel and ethanol increases to reach the mandated biofuel consumption levels. Because the US policy remains effectively just an ethanol mandate and that in the EU favors faster growth in ethanol production, biodiesel production will enjoy a much smaller boost compared to ethanol under the mandate scenario. World biodiesel production will reach 32 Mtoe in 2020 while ethanol production will reach 123 Mtoe (Figure 3). The EU and US mandates will lead to a 44.3% expansion of biodiesel production in the EU against the 2020 baseline level of 7.9 Mtoe. In the US, biodiesel production is projected to increase by 115.6%, totaling 3.3 Mtoe, in 2020. Trade liberalization will have no significant impact on biodiesel production since the initial protection is quite low. The production of biodiesel in Brazil will remain stable due to the biodiesel mandate in the country.

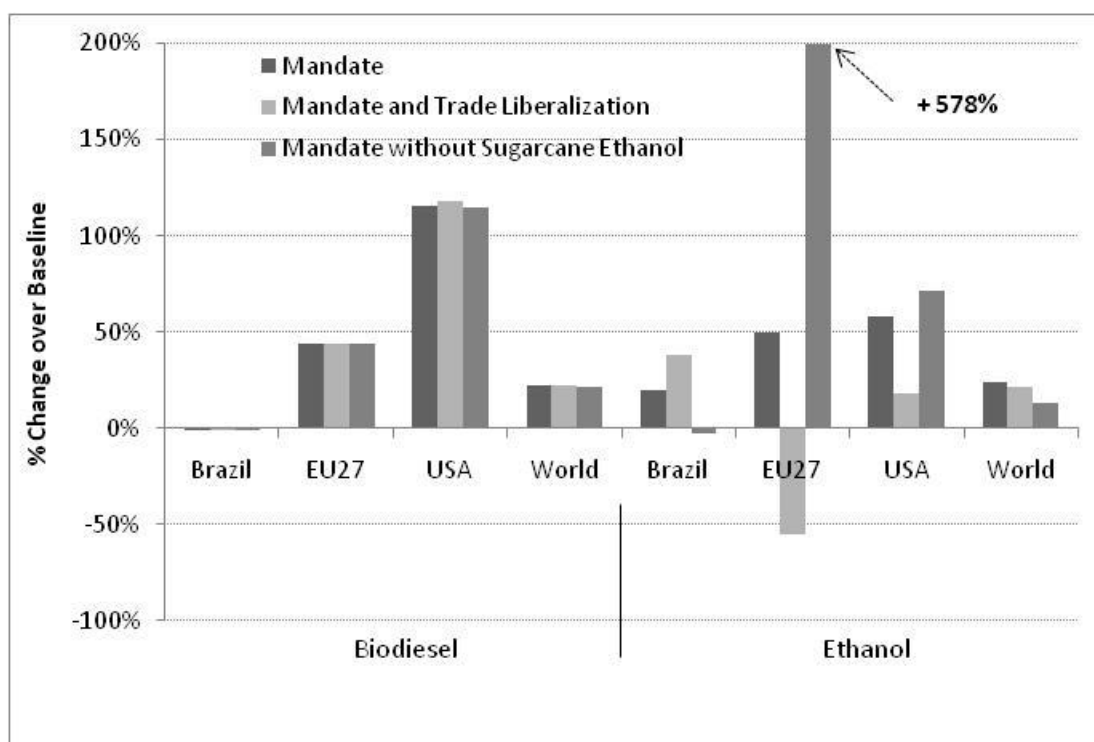
Due to current large production and consumption of biodiesel in the EU, the 6.6% mandate with a 40% ethanol component will require an increase in ethanol consumption by 250% compared to 45% for biodiesel. The EU and US mandates will increase Brazilian ethanol production by 19.9% against the projected 2020 baseline level of 52.9 Mtoe. US ethanol production will increase by 58.1% to reach 24.7 Mtoe while that in the EU will increase by 49.8% to reach 1.2 Mtoe. When combined with trade liberalization, the US and EU mandate will boost Brazilian ethanol production by 38.4% as the US and EU open their markets to Brazilian ethanol exports. The EU and US ethanol industries will benefit more from restrictive trade policies. Trade liberalization corresponds to a much smaller increase in US ethanol production, but it still grows by 18% compared to the baseline. For the EU, the removal of trade protection will result in a 55% decline in ethanol production even with the mandate.

Under the third scenario, if the EU and US mandates are to be achieved without sugarcane ethanol imports, domestic ethanol production in the EU will shoot up by 578% to 5.6 Mtoe while that in the US will rise by 72% to 26.8 Mtoe. With the reduction in export demand, Brazilian ethanol will decline by 2.3% in 2020. In this case, the fall in production is limited since the domestic market will absorb a part of the production and alternative export markets (Japan and the rest of the OECD) will be tapped.

Feedstock Crop Production

The mandate and trade policy scenarios have significant implications on crop production, particularly for feedstock crops used in the production of ethanol and biodiesel. As shown in Table 3, the wheat sector in the EU declines slightly (-0.40%) due the competition of other sectors (sugarbeet, maize) for land and other inputs in the pure mandate scenario. With trade liberalization, the decline is deeper (-0.50%) with the fall in domestic ethanol production. However, this effect remains limited since the demand for wheat for ethanol remains small with respect to the total market (1% of EU wheat production). However, the end of sugarcane ethanol imports will boost drastically the demand for ethanol feedstock in the EU. It will stop the decline of wheat production in this region and will be associated with a redirection of existing wheat production to the ethanol sector (the market share of ethanol will reach 5% of the EU wheat market).

Figure 3. Domestic Biofuel Production, 2020



Source: Authors' simulations with the MIRAGE-BIOF model

Global production of sugarcane and sugarbeets will increase by 7.9% in 2020 to support the EU and US mandate. Brazilian sugarcane production will grow by 15% under the mandate. A larger boost in sugarcane production, 32%, will be needed to support the increase in Brazilian ethanol production under the trade liberalization scenario. Brazilian production of other feedstock crops experience slower growth or actually decline (e.g. maize, wheat) as resources are pushed into sugarcane production in this scenario⁸. When the EU and US markets are closed to sugarcane ethanol, sugarbeet production in the EU expands

⁸ The projected decline in maize and wheat production may be partly mitigated if second cropping had been taken into account in the model. Indeed, if maize production in Brazil has declined as a first crop, it has expanded as a second crop in recent years.

by 13% and maize production rises in both regions to meet ethanol feedstock demand. Conversely, Brazilian sugarcane production will decline by 1.7% while maize production will increase by 6.1% due to the incremental demand for maize in the US. Production of biodiesel feedstock crops such as palmfruit, soybeans, and sunflower seeds also experience a larger boost in Brazil under this scenario as resources become available from sugarcane production.

Table 3. Feedstock Crop Production, 1000T and % Change over Baseline, 2020

Feedstock Crop	Region	Reference Level	Mandate	Mandate and Trade Liberalization	Mandate without Sugarcane Ethanol
Maize	Brazil	88,685	2.46%	-1.39%	6.07%
Maize	EU27	87,044	0.79%	0.17%	1.46%
Maize	USA	400,734	1.92%	0.72%	2.51%
Maize	World	975,446	1.55%	0.38%	2.32%
Sugarcane	Brazil	1,382,179	14.95%	31.78%	-1.67%
Sugarbeet	EU27	126,305	4.26%	0.42%	13.00%
Sugarcane\beet	USA	63,841	1.13%	-0.14%	-0.35%
Sugarcane\beet	World	3,020,917	7.87%	14.60%	-0.02%
Wheat	Brazil	11,319	-0.99%	-1.94%	0.72%
Wheat	EU27	188,110	-0.40%	-0.50%	-0.04%
Wheat	USA	68,791	-0.74%	-0.54%	-0.70%
Wheat	World	782,356	-0.30%	-0.37%	-0.04%
PalmFruit	Brazil	4,905	13.04%	10.32%	15.65%
PalmFruit	World	278,538	2.66%	2.51%	2.72%
Rapeseed	Brazil	149	6.82%	6.61%	7.26%
Rapeseed	EU27	25,930	3.45%	3.63%	2.81%
Rapeseed	USA	1,744	1.23%	1.65%	0.95%
Rapeseed	World	66,304	2.66%	2.79%	2.29%
Soybeans	Brazil	119,307	1.82%	1.57%	2.34%
Soybeans	EU27	1,317	0.28%	0.70%	-0.51%
Soybeans	USA	101,770	-0.54%	0.20%	-0.96%
Soybeans	World	342,119	1.12%	1.43%	1.00%
Sunflower Seed	Brazil	178	5.78%	5.33%	6.41%
Sunflower Seed	EU27	8,370	2.84%	2.95%	2.27%
Sunflower Seed	USA	1,065	1.45%	1.72%	1.16%
Sunflower Seed	World	44,392	3.85%	3.89%	3.46%

Source: Authors' simulations with the MIRAGE-BIOF model

COMMODITY PRICES

As shown in Table 4, the EU and US biofuel mandates will result in a small increase in real world prices of agricultural commodities, especially for feedstock crops. World prices of oilseeds for biodiesel such as

rapeseed, sunflower seeds, palm fruit, and palm oil increase by close to 5% while those of ethanol feedstocks such as maize and sugarcane will rise more modestly at 2 to 3%. Ethanol and biodiesel prices will increase by 3.9% and 5.9%, respectively, under the mandate scenario. The removal of trade barriers will result in smaller increases in world commodity prices, thereby benefiting consumers. Indeed, it will help to distribute the impacts of increasing demand of biofuels in a more efficient way. The much lower change in world trade price of ethanol under the third scenario, 0.31%, reflects the sharp fall in trade in ethanol when sugarcane ethanol is no longer exported to the US and EU. Producer prices for ethanol in the domestic US and EU markets still rise by 7% and 20%, respectively, owing to increased demand under the mandate. For biodiesel, since trade policy options have limited (trade liberalization of biodiesel) or no direct (sugarcane restriction) impacts, the price changes remain constant across scenarios. Even if the overall demand of biofuels is more concentrated in ethanol, the price of biodiesel is more reactive. This is due to the incremental tensions in the vegetable oil markets and in the fact that most of the biodiesel traded will come from Southeast Asia and will rely on palm oil.

Table 4. World Commodity Prices in International Markets, % Change over Baseline, 2020

Commodities	Mandate	Mandate and Trade Liberalization	Mandate without Sugarcane Ethanol
Maize	2.96%	1.53%	3.69%
Meat and Dairy	0.16%	0.15%	0.11%
PalmFruit	7.27%	6.83%	7.34%
Palm Oil	4.92%	4.63%	4.89%
Rapeseed	5.18%	4.99%	5.08%
RapeSeed Oil	3.81%	3.67%	3.72%
Soybeans	1.97%	2.08%	1.70%
Soybean Oil	1.61%	1.71%	1.38%
Sugar	2.21%	1.65%	0.20%
Sugarcane/Beet	2.06%	0.35%	1.32%
Sunflower Seed	5.26%	4.88%	5.20%
Sunflower Oil	4.43%	4.13%	4.39%
Wheat	0.90%	0.44%	1.61%
Ethanol	3.87%	3.92%	0.31%
Biodiesel	5.92%	5.56%	5.19%

Source: Author's calculations with the MIRAGE-BIOF Model, 2010

As shown in Table 5. , the rise in domestic prices agricultural commodities in response in increased global demand for biofuels under the mandate is limited mostly to Brazil. Much smaller prices increases can be expected for the commodity aggregates (all crops, animal products, and primary food products) in the US and EU. Marginal price impacts can also be expected for third countries such as Sub-saharan Africa (SSA). Trade liberalization with the mandate policy will lead to smaller price increases for commodity aggregates in all countries.

Table 5. Food Prices of Commodity Aggregates (2004=1), % Change over Baseline

Commodity Aggregates	Region	Reference Year 2020	Mandate	Mandate and Trade Liberalization	Mandate without Sugarcane Ethanol
All crops	Brazil	1.02	1.25%	2.01%	0.38%
Animal	Brazil	1.06	1.43%	2.31%	0.48%
PrimFood	Brazil	1.04	1.32%	2.13%	0.42%
All crops	EU27	1.09	0.50%	0.29%	0.78%
Animal	EU27	1.02	0.11%	0.10%	0.07%
PrimFood	EU27	1.06	0.36%	0.22%	0.53%
All crops	USA	1.00	0.59%	0.38%	0.64%
Animal	USA	1.02	-0.15%	-0.06%	-0.23%
PrimFood	USA	1.01	0.27%	0.19%	0.26%
All crops	SSA	1.26	0.36%	0.17%	0.54%
Animal	SSA	1.10	0.06%	0.04%	0.17%
PrimFood	SSA	1.25	0.33%	0.16%	0.50%

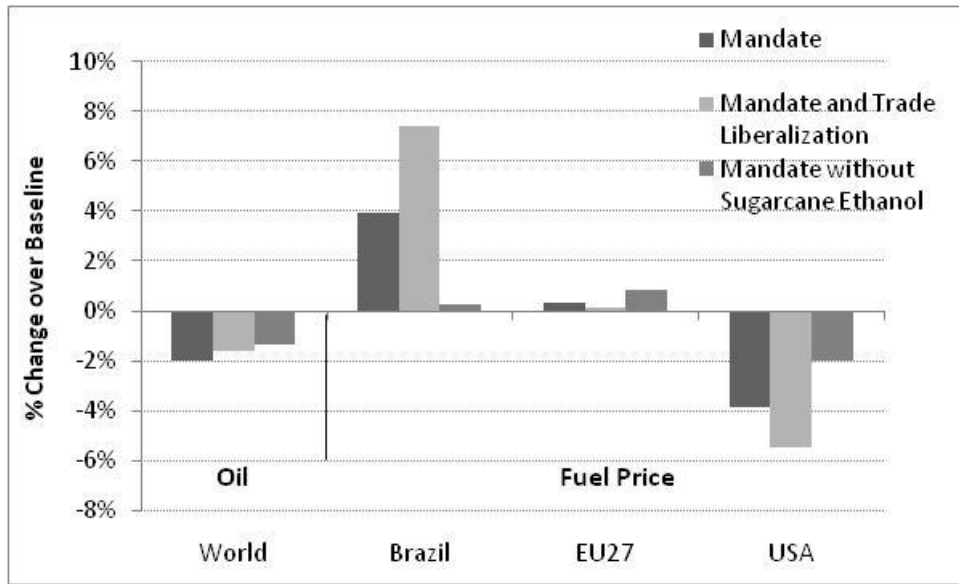
Source: Author's calculations with the MIRAGE-BIOF Model

FUEL PRICES

Increased consumption of biofuels under the EU and US mandates will lead to a reduction in demand for oil and thus a slight decline in world oil prices by 2020 (Figure 4). The mandate scenario has favorable impacts in terms of transport fuel prices in the US, with a 3.9% decline against the 2020 baseline price⁹. One of the biggest benefits of the trade liberalization scenario is the reduction of fuel prices for consumers especially in the US. Transport fuel price for US consumers will drop by 5.5% while EU consumers will face a smaller increase in fuel prices. This result is reversed when the US and EU mandates are met without sugarcane ethanol imports. The EU consumers will suffer from a larger price increase at the pump. In the US, the price reduction will be lower with sugarcane ethanol than without it. With the mandate, the increased demand of ethanol in the world markets will raise fuel prices in Brazil by 3.9% due the increase in ethanol price. This mechanism is magnified when trade liberalization occurs in the US and the EU: the increase in fuel prices in Brazil reaches 7.4%.

⁹ It should be noted that under the pure mandate scenario the tax credit is still implemented meaning that the gain for consumers is compensated by a cost for taxpayers.

Figure 4. Oil and Fuel Prices, 2020



Source: Authors' calculations with the MIRAGE-BIOF Model

Trade Impacts

The production and price impacts reported in the previous section are linked to the trade impacts of the mandate and trade policy scenarios. In this section, we focus of the impacts on imports of biodiesel and ethanol and on bilateral trade of selected feedstock crops.

BIOFUEL IMPORTS

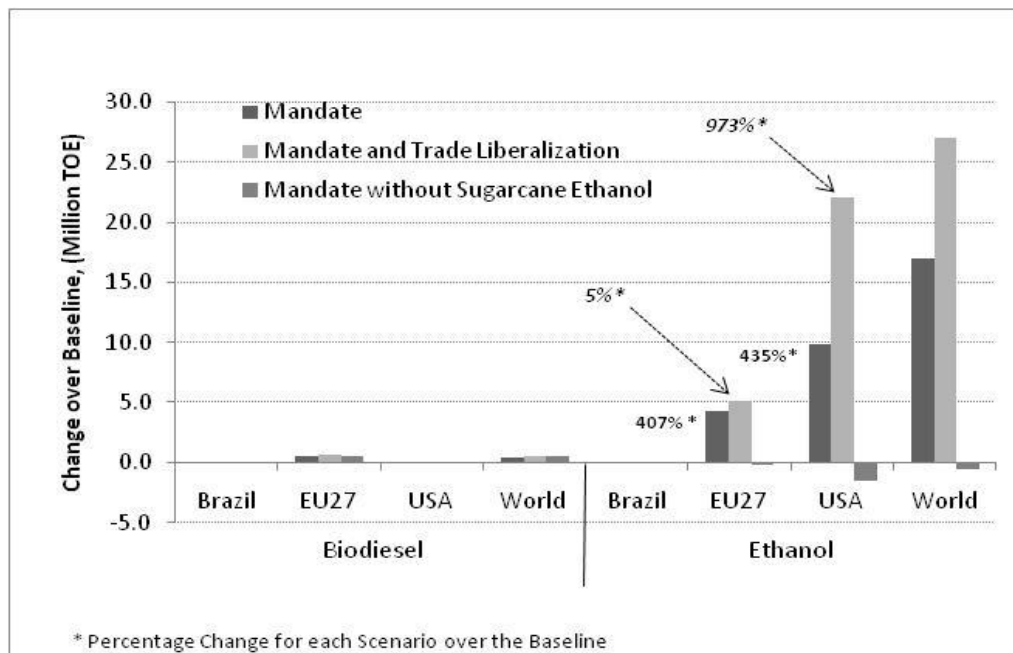
The EU and the US biofuel mandates will lead to a 35% increase in global trade of biodiesel and an 88% increase in global trade of ethanol in 2020 (Figure 5). Increased trade in biodiesel arises from increased imports of the EU from Indonesia\Malaysia and the Rest of Latin America (LAC). Since EU protection for biodiesel is low, the trade impacts under the two trade liberalization scenarios will not differ from the first scenario.

EU ethanol imports are expected to increase by 407% against baseline levels to reach 5.3 Mtoe in 2020 under the mandate scenario. This is supplied largely by Brazil and the Central America/Caribbean region which will see ethanol exports to the EU rise by 506% and 25%, respectively. Similarly, ethanol exports from Brazil, the Central America\Caribbean region, and the rest of Latin American will rise by 600%, 553% and 63%, respectively, to supply the 435% increase in US ethanol imports in 2020. Trade liberalization will lead to a greater increase in EU and US imports of ethanol and this will come largely from stronger growth in Brazilian ethanol. Since the Central America\Caribbean region and the rest of Latin American already enjoy preferential access to the US market, the benefits of the removal of significant tariff protection in these markets accrue largely to Brazil.

The EU and the US will rely mostly on domestic ethanol production under the third scenario wherein the mandate is met without sugarcane ethanol imports. EU and US imports of ethanol fall by 8% and 64%, respectively, under this scenario. Ethanol exports of Brazil to these markets collapse but are

slightly offset by increased exports to the rest of the OECD region (including Japan) and by increased domestic consumption. Ethanol exports from the LAC region to the US and from US to the EU (of maize ethanol) will rise marginally under this scenario.

Figure 5. Biofuel Imports, (Mtoe), 2020



Source: Authors' calculations with the MIRAGE-BIOF model

FEEDSTOCK TRADE

Aside from their impacts on trade in biofuels, the EU and US mandates also significantly affect trade in biofuel feedstocks. Table 6 shows selected figures for bilateral trade in feedstocks, focusing on imports of the EU and the US. Under the mandate scenario, Brazil's export of vegetable oils (palm oil and soybean oil) to both the US and EU rise significantly. US imports of maize from both Brazil and the EU also grow by more than 60% compared to 2020 baseline levels. With the removal of trade protection on ethanol and biodiesel, and hence increased imports of these biofuels, EU and US imports of the biofuel feedstock crop do not grow as much as in the mandate scenario. This situation is reversed under the third scenario where sugarcane ethanol is not exported to the EU and US. Under this scenario, EU and US imports of maize from Brazil rise by 33% and 84%¹⁰, respectively, to augment their domestic feedstocks for ethanol production.

¹⁰ The initial level of US imports of corn from Brazil is very low.

Table 6. EU27 and US Feedstock Imports by Trading Partner, % Change over Baseline

Biofuel Feedstock	Importer	Exporter	Reference Year (1000T)	Mandate Policy	Mandate and Trade Liberalization	Mandate without Sugarcane Ethanol
Maize	EU27	Brazil	817	0.60%	-5.65%	33.08%
Maize	USA	Brazil	3	63.64%	20.97%	84.30%
Maize	USA	EU27	95	64.98%	28.35%	51.57%
Palm Oil	EU27	Brazil	42	36.66%	29.76%	43.91%
Palm Oil	USA	Brazil	10	108.46%	84.70%	124.48%
Soybeans	EU27	Brazil	3,354	1.69%	3.42%	0.05%
Soybean Oil	EU27	Brazil	1,244	45.89%	41.15%	51.69%
Soybean Oil	USA	Brazil	79	54.87%	42.44%	64.08%

Source: Authors' calculations using the MIRAGE-BIOF model

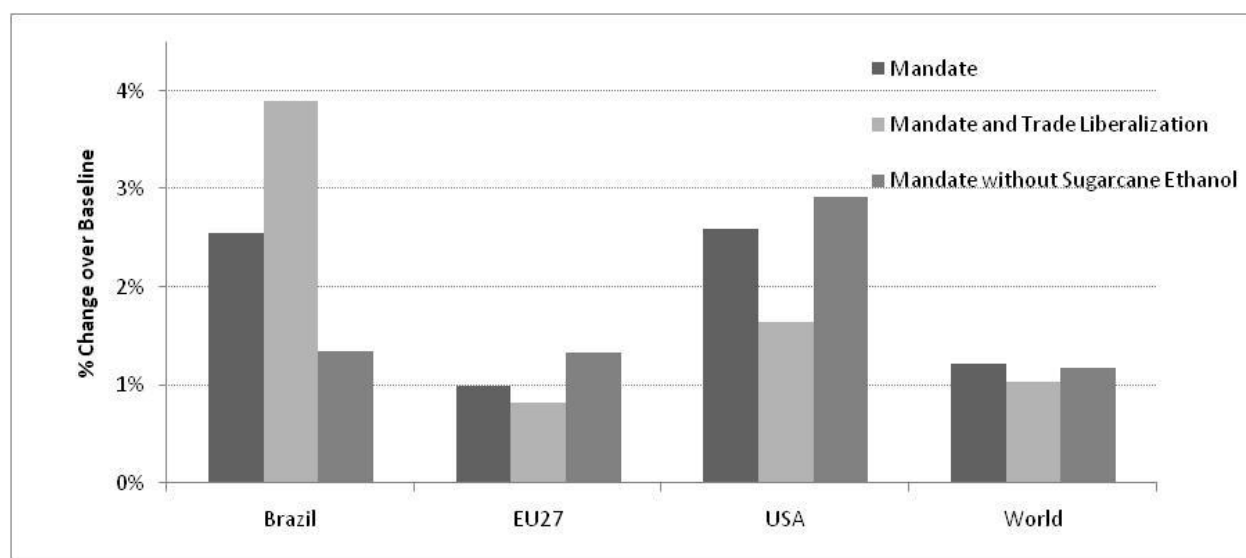
Macroeconomic Impacts

The mandate and trade policy scenarios affect agricultural value-added, and real income and terms of trade. These macroeconomic impacts are reported in this section.

AGRICULTURAL VALUE-ADDED

Figure 6 shows the impact of the different scenarios on agricultural value-added. The biofuel mandate and trade policies create increased activity in the agricultural sector and the potential impact on agricultural value-added is positive in almost all countries/regions throughout the world, and particularly for Brazil, the EU, and the US. It will increase by more than 1% at the world level with peaks at 4% in Brazil under trade liberalization and 3% in the US when sugarcane ethanol imports are restricted. Consistent with the results regarding feedstock crop production, the mandate will boost agriculture production in all three countries but trade liberalization will further enhance agricultural value-added in Brazil, while also slowing down growth in agricultural value-added in the EU and the US. This result is reversed when the EU and US markets are closed to sugarcane ethanol imports. Since increased domestic production of feedstock crops will be required to replace sugarcane ethanol imports to reach the mandate, the expansion of agricultural value-added in the EU and US is greatest under this scenario.

Figure 6. Agricultural Value-Added, 2020



Source: Authors' calculations with the MIRAGE-BIOF Model,

REAL INCOME EFFECTS

The real income effects of the EU and US mandates shown in Table 7 indicate that the mandates have negative global effects, on average (-0.04% under all scenarios). As a net agricultural exporter, Brazil is positively impacted in all cases due to increased agricultural prices in world markets (see terms of trade effects) and increased demand for its products. The real income effects for the US and the EU are very limited (smaller than 0.05%). Since both countries implement distortive policies, the mandates have an efficiency cost that can be compensated only by the terms of trade effects (evolution of the export prices vs. import prices), the latter being driven by the fall in demand and prices of oil. Aside from these countries, oil producing countries such as those in the CIS and the SSA¹¹ region suffer losses due to reduction of oil prices (up to -1.8%) led by the shift in demand toward biofuels, thereby reducing aggregate world real income. However, the real behavior of oil producers to the increase of biofuels market share is difficult to assess due to the lack of perfect competition in this sector. The price/quantity response of a cartel of oil producers may be different from the model projections and therefore the real income effects driven by the terms of trade effects have to be taken carefully.

For the EU and the US, the best outcome is the mandate with the status quo on trade policies since trade restrictions will lead to greater inefficiency and more liberalization will erode the terms of trade gains. For the US, trade liberalization leads to a deterioration of the terms of trade that are stronger than in the EU since the starting point for the US is a large trade deficit (which implies higher marginal real income costs of any deterioration of its real exchange rate (needed to compensate increased imports)).

¹¹ Due to existing difficulties related to a fair distribution of oil rents in many developing countries, the real income loss at the macro level may not lead to a deterioration of the situation for most of their population.

Table 7. Real Income and Terms of Trade, % Change over Baseline

Indicator	Region	Reference Year 2020 (US\$ Billion)	Mandate Policy	Mandate and Trade Liberalization	Mandate without Sugarcane Ethanol
Real Income	Brazil	835	0.34%	0.42%	0.12%
Real Income	CAMCarib	406	0.13%	0.01%	0.01%
Real Income	China	4,194	0.00%	0.01%	-0.01%
Real Income	CIS	1,030	-0.65%	-0.55%	-0.46%
Real Income	EU27	13,857	0.05%	0.03%	0.02%
Real Income	IndoMalay	537	0.01%	0.05%	0.08%
Real Income	LAC	1,491	-0.14%	-0.11%	-0.08%
Real Income	RoOECD	7,754	0.00%	-0.01%	-0.02%
Real Income	RoW	5,254	-0.42%	-0.35%	-0.31%
Real Income	SSA	863	-0.48%	-0.40%	-0.34%
Real Income	USA	13,868	0.04%	-0.01%	0.02%
Real Income	World	50,089	-0.04%	-0.04%	-0.04%
Terms of Trade	Brazil		1.36%	2.34%	0.39%
Terms of Trade	CAMCarib		0.51%	0.08%	0.03%
Terms of Trade	China		0.19%	0.17%	0.11%
Terms of Trade	CIS		-0.92%	-0.77%	-0.64%
Terms of Trade	EU27		0.13%	0.10%	0.10%
Terms of Trade	IndoMalay		0.23%	0.23%	0.23%
Terms of Trade	LAC		-0.20%	-0.18%	-0.07%
Terms of Trade	RoOECD		0.09%	0.09%	0.06%
Terms of Trade	RoW		-0.54%	-0.45%	-0.39%
Terms of Trade	SSA		-0.85%	-0.72%	-0.59%
Terms of Trade	USA		0.36%	0.21%	0.32%

Source: Authors' calculations with the MIRAGE-BIOF Model

Land Use Impacts

Changes in crop production, particularly due to the increased demand for feedstock crops used as inputs in biofuels, will have different implications on the expected patterns of land use under the mandates and trade liberalization scenarios. Most of the environmental debate around biofuels is now focused on changes in land use and the role of biofuel policies on agricultural expansion, which leads to deforestation and increases in GHG emissions.

Table 8 indicates the variation in land use by type of land which could be expected from the policy scenarios. The amount of cropland is significantly affected in Brazil (+2.7% under the mandate scenario, 3.9% with trade liberalization, and 1.7% without sugarcane ethanol – see also Figure 7). This result is due

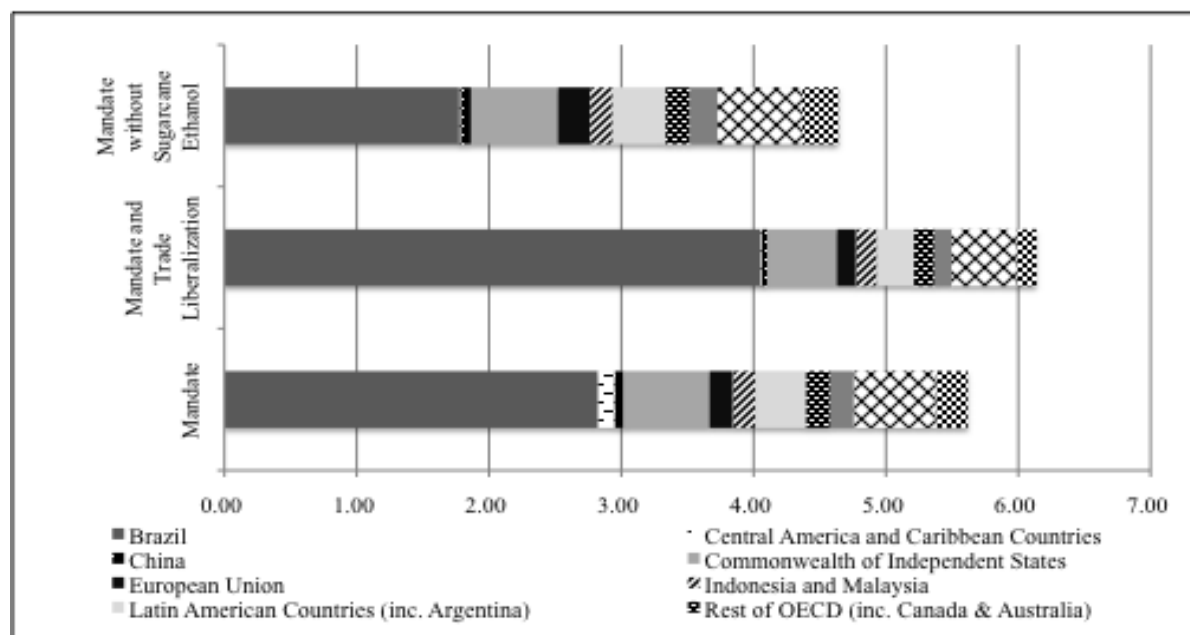
to the combination of the demand for ethanol (sugarcane) and oilseeds (soya). However, our detailed modeling of land extension and land reallocation indicates that primary forests, e.g. Amazonia, are not the main source of cropland. More than half of the land will be released by the livestock sectors (-1.8% to -2.6% of pasture), followed but Savannah/Grassland (Cerrado in southeastern Brazil). It is clear that our assumption about intensification of livestock production can play a critical role here and should be considered carefully. At the same time, it is also critical that ranchers pay the price of the land they use; otherwise they will have no incentives to intensify production and may continue with deforestation. The other regions that are affected are the EU, the CIS region, the rest of Latin America and Indonesia/Malaysia.

Table 8. Land Use, % Change over Baseline

		Reference Year 2020 (1000 Hectares)	Mandate	Mandate and Trade Liberalization	Mandate without Sugarcane Ethanol
Pasture	Brazil	119,021	-1.84%	-2.64%	-1.11%
Pasture	EU27	68,823	-0.02%	-0.02%	-0.03%
Pasture	USA	61,453	0.02%	0.01%	0.02%
Pasture	World	1,045,634	-0.29%	-0.36%	-0.21%
Cerrado	Brazil	183,839	-0.16%	-0.24%	-0.10%
Grassland	EU27	20,520	-0.33%	-0.27%	-0.45%
Grassland	USA	282,403	-0.04%	-0.03%	-0.05%
Savannah/Cerrado/Grassland	World	2,986,028	-0.04%	-0.03%	-0.03%
Cropland	Brazil	104,851	2.69%	3.87%	1.69%
Cropland	EU27	93,765	0.19%	0.16%	0.26%
Cropland	USA	103,735	0.23%	0.14%	0.26%
Cropland	World	1,392,942	0.40%	0.44%	0.33%
Managed Forest	Brazil	16,925	-1.04%	-1.53%	-0.98%
Managed Forest	EU27	148,354	-0.03%	-0.02%	-0.04%
Managed Forest	USA	143,542	-0.04%	-0.03%	-0.05%
Managed Forest	World	1,093,845	-0.08%	-0.07%	-0.08%
Primary Forest	Brazil	420,048	-0.02%	-0.03%	-0.02%
Primary Forest	EU27	6,780	0.00%	0.00%	0.00%
Primary Forest	USA	161,001			
Primary Forest	World	2,669,467	-0.01%	-0.01%	-0.01%

Source: Authors' calculations with MIRAGE-Biof Model

Figure 8. Agricultural Land Extension MHa, 2020



Source: Authors' calculations with the MIRAGE-BIOF Model

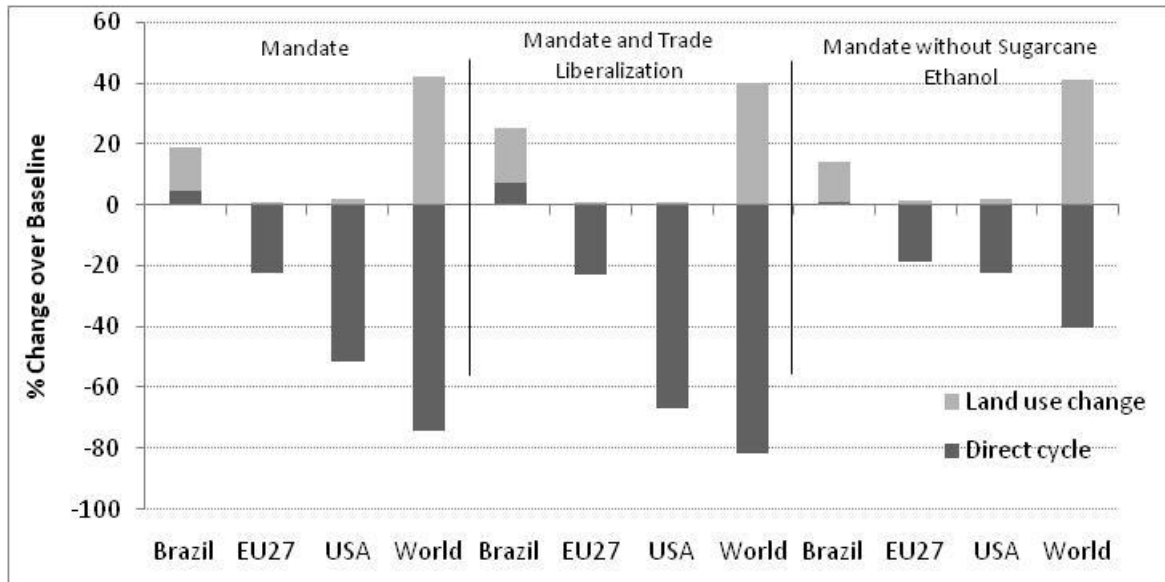
Greenhouse Gas Emissions

GHG emissions balance accounts for direct emissions savings in the biofuel production cycle and the emissions associated with changes in land use. As shown in Figure 8, the sum of direct emissions reductions¹² generated by the substitution of fossil fuel by biofuels and implied by the mandate at -74 million tons of CO₂ equivalent in 2020 is slightly less than the sum of direct emissions when liberalization of trade in ethanol and biodiesel is combined with the mandate: -81 million tons of CO₂ equivalent in 2020. Direct emissions reductions are significantly less (-41 mtCO₂eq) when sugarcane ethanol is eliminated. This result is driven by the efficiency of sugarcane ethanol. The net emissions balance (land use emissions minus direct emission savings) is positive and slightly larger under the liberalization case (-41 mtCO₂eq) than under the pure mandate scenario (-32 mtCO₂eq). Even if the liberalization leads to more emissions through indirect land use effects, using efficient imported biofuels delivers a net emissions reduction in a 20 year period. However, when sugarcane ethanol is not allowed in the mandate, the direct emissions savings are cancelled out by land use emissions at the world level. Under this scenario, the decline in sugarcane production in Brazil and the increased demand for feedstock crops for biofuels and food in the EU and US, encourages increased production of less environmentally efficient crops (oilseeds for biodiesel, maize) in Brazil. These results indicate that the biofuel mandates can lead to positive net GHG emissions reductions¹³, but further reductions can be achieved when the trade barriers are removed along with the mandate.

¹² Each MJ of fossil fuel is assumed to generate 25gr of carbon, i.e. about 92 gr. of CO₂.

¹³ Without considering the effects of fertilizers.

Figure 9. Emissions Balance, 2020, MTCO₂eq



Source: Authors' Calculations with the MIRAGE-BIOF Model

Note: The emissions credit is attributed to the country that consumes the biofuel. Land use change emissions are attributed to the region where the expansion took place.

Table 9 displays the carbon balance sheet of the EU and US mandates and the trade policy scenarios. The upper part of the table displays the total carbon release (from forest biomass and soil contents) due to the change in land use from 2008-2020 following the implementation of the mandate. The lower part shows *average* LUC effect computed with our model which is equal to the sum of carbon release from forest biomass and soil carbon content. All annual coefficients take the stock value of the upper table and divide them by 20 years. This is then divided by the increase in EU consumption of biofuels. The results indicate a reduction in GHG emissions under the US and EU mandates, with the net emission balance over a 20-year period of about -20.8gCO₂/MJ under the US and EU mandates, and -28gCO₂/MJ if the mandates are not associated with an open trade policy. However, the GHG emissions balance turns positive at +7.9 gCO₂/MJ when sugarcane ethanol imports are not allowed in the mandate. These coefficients are average values since they are based on the full mandate increase in both EU and US and take into consideration all the direct and indirect effects in the CGE framework in terms of income and substitution effects. CO₂ variations, which are not directly related to biofuel policies (such as the income effects on the steel industry), are excluded.

VI. Concluding Remarks

This study shows that the incremental expansion of the biofuel consumption under the US and EU biofuel mandates will be beneficial at the global level in terms of value-addition in the agricultural sector, in the expansion of global trade, and in the reduction of GHG emissions. The biofuel mandates will have limited impacts on real food prices. However, there will also be global costs driven mainly by the decline in income of oil exporting countries.

Table 9. Carbon Balance over a 20 Year Period

	Mandate	Mandate and Trade Liberalization	Mandate without Sugarcane Ethanol
Total carbon release from forest biomass (MtCO ₂ eq)	268.28	231.17	283.26
Total carbon release from carbon in soil (MtCO ₂ eq)	576.95	570.69	535.16
Marginal carbon reimbursement rate (MtCO ₂ per year)	-74.27	-81.37	-40.55
Carbon debt payback time (years)	11.38	9.85	20.18
EU+US Consumption of biofuel in 2020 (million GJ)	2502	2524	2069
Annual carbon release from forest biomass (gCO ₂ eq/MJ)	15.64	13.69	24.89
Annual carbon release from below ground (gCO ₂ eq/MJ)	23.16	22.51	32.92
Annual direct savings (gCO ₂ /MJ)	-59.63	-64.19	-49.89
Total emission balance on a 20 years period (gCO ₂ /MJ)	-20.83	-27.98	7.92

Source: Authors' Calculations with the MIRAGE-BIOF Model

Since both the US and EU mandates favor greater ethanol consumption, it is the ethanol sector that will expand more compared to biodiesel. Brazil will benefit from increased production and exports of sugarcane ethanol to supply these markets, especially when the EU and US biofuel mandates are combined with trade liberalization in biofuels in both countries since higher ethanol production and exports will be accompanied by higher real income gains and agricultural value-added. Use of cropland in Brazil will increase, with land coming mostly from pasture. Unilateral biofuel trade liberalization will dampen the positive economic impacts of the mandate for the EU and the US but will enhance the reduction of GHG emissions as these countries increase imports of the more environmentally-efficient sugarcane ethanol.

Although Brazil will still experience real income gains when the US and the EU discontinue their use of imports of sugarcane ethanol, the gains will be sharply lower. However, Brazil will be able to tap other markets for ethanol while also allowing production and exports of other agricultural sectors (e.g. oilseeds and vegetable oils for biodiesel production) to expand. The exclusion of sugarcane ethanol imports will require a significant expansion of domestic ethanol production in the US and the EU. Production of feedstock crops, and thus cropland use, will also increase in these countries. Although more beneficial for the agricultural sector and for real income in these countries, the mandate policy without sugarcane ethanol has more adverse implications for the environment in terms of positive net CO₂ emissions.

This study indicates that the US and EU biofuel mandates have generally beneficial impacts on the agricultural markets and on the environment in terms of reduced CO₂ emissions. These benefits are further enhanced if the mandate policy is accompanied by liberalization in biofuels trade. Trade liberalization will bring greater benefits to consumers in terms of lower fuel prices and greater reductions in CO₂ emissions, when sugarcane ethanol is traded. While it will result in important adjustments in the agricultural sector, it will generally be beneficial for the agriculture sector and farm producers.

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