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# European Union and United States Biofuel Mandates

## Impacts on World Markets


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## Acknowledgments

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## FORWARD

Energy use, primarily from fossil fuels (including oil, natural gas, coal), is one of the largest contributors to global greenhouse gas emissions. Reducing or replacing fossil energy use with renewable fuels, including sustainable biofuels, is considered an important component of slowing climate change. Several countries worldwide, including many in the Latin America and Caribbean region, have begun to introduce institutional, policy and regulatory measures further increase the use of renewable energy and sustainable biofuels.

Under this framework, the European Union (EU) and the United States of America (US) have developed biofuels mandates that require a rising contribution within the transport sector over time. Especially in the case of the EU, the targets will likely be achieved through significant additions to the domestic supply. As a result, biofuels trading is becoming more important.

The Latin America and Caribbean Region has a large potential in this regard. Latin American countries already contribute a large portion of the ethanol consumed in the US and the EU. Brazil is by far the largest producer in the region, given its historic ethanol production and use for road transportation, as well as the competitive advantage given the presence of feedstock, land and good climate conditions.

Biofuels mandates pose opportunities and challenges for developing countries that export to the European Union and the United States (including Brazil). There is the potential that these new mandates will change the size and structure of biofuels markets with consequences that will not only affect consumers but also producers in both developed and developing countries.

In this study, the Inter American Development Bank has commissioned the International Food Policy Research Institute (IFPRI) to conduct a study that analyzes the potential impacts of the European Union and the United States biofuels mandates on world markets. The study also looks at the expected impacts of limited consumption of Brazilian ethanol in the US and EU markets, including greenhouse gas emission reduction commitments and biofuels consumption targets.

The IDB is committed to assisting Latin American and Caribbean countries to define sustainable biofuel policies. The partnership with IFPRI to deliver this study has also benefitted from the collaboration of the Instituto de Estudos do Comércio e Negociações Internacionais (ICONE), with additional support provided by the Federação das Indústrias do Estado de São Paulo (FIESP) and is a clear effort toward providing a sound economic analysis that will help assist policy makers to develop a strong biofuels agenda.

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## List of Acronyms and Abbreviations

| | |
|---|---|
| AEZ | agro-ecological zone |
| ASEAN | Association of Southeast Asian Nations |
| AVE | ad-valorem equivalent |
| BLUM | Brazilian Land Use Model |
| CEPII | Centre d'Etudes Prospectives et d'Informations Internationales |
| CES | constant elasticity of substitution |
| CET | constant elasticity of transformation |
| CGE | computable general equilibrium |
| $CO_2$ | carbon dioxide |
| DDA | Doha Development Agenda |
| DDGS | dried distillers grains with solubles |
| EPA | (US) Environmental Protection Agency |
| EU | European Union |
| FAPRI | Food and Agricultural Policy Research Institute |
| FIESP | Indústrias do Estado de São Paulo |
| FAO | Food and Agriculture Organization of the United Nations |
| GDP | gross domestic product |
| GHG | greenhouse gas |
| GSP+ | Generalised System of Preferences Plus |
| GTAP | Global Trade Analysis Project |
| HS | Harmonized System |
| ICONE | Instituto de Estudos do Comércio e Negociações Internacionais |
| IDB | Inter-American Development Bank |
| IEA | International Energy Agency |
| IFPRI | International Food Policy Research Institute |
| IPCC | Intergovernmental Panel on Climate Change |
| LCA | life cycle analysis |
| LES | linear expenditure system |
| MFN | most favored nation |
| MIRAGE | Modeling International Relationships in Applied General Equilibrium |
| Mtoe | million tons of oil equivalent |

| | |
|---|---|
| OECD | Organisation for Economic Co-operation and Development |
| PEM | partial equilibrium model |
| RED | Renewable Energy Directive |
| RFS-2 | United States Renewable Fuel Standard |
| SAM | social accounting matrix |
| SSA | Sub-Saharan Africa |
| T | tonne |
| TFP | total factor productivity |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNICA | União da Indústria de Cana-de-Açúcar |
| US | United States of America |

## Executive Summary

Biofuel production increased sharply in the past decade and can be expected to grow more rapidly in the coming decade as national governments continue to seek greater energy independence through renewable energy sources. A large expansion in biofuel production will be required to meet the European Union (EU) and United States (US) biofuel consumption targets in the next decade. These biofuel mandates will change the size and structure of global biofuel markets and their 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 the net agricultural exporting countries of Latin America. Brazil, the largest ethanol producer and exporter in the region, has a competitive advantage due to 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 analyzed the potential impacts of EU and US biofuels mandates on world biofuels markets. The evaluation focused on the impacts of the mandates on (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, counting both the direct reduction of GHG emissions from the replacement of fossil fuels with biofuels, as well as emissions from land-use change. Special emphasis was given to Brazil because of the country's importance in international ethanol markets, accounting for more than 95% of ethanol exports in Latin America.

Building on an earlier study carried out by the International Food Policy Institute (IFPRI) on the impacts of possible changes in EU biofuel and trade policies on global agricultural production, trade and the environment, the impacts of EU and US biofuel and trade policies are assessed using a global dynamic computable general equilibrium (CGE) model, which captures domestic intersectoral relationships and interregional linkages in the global economy. The Modeling International Relationships in Applied General Equilibrium (MIRAGE) CGE trade model was extensively modified by IFPRI to incorporate specific features of energy demand and ethanol and biodiesel production, including different technologies based on different feedstocks and generation of co-products. A land supply module was also introduced, along with data on

sub-national land allocation between different economic activities (forestry, pasture, different crops) based on agro-ecological zones (AEZs). The Global Trade Analysis Project (GTAP) 7 database was modified to disaggregate key biofuel and feedstock commodities, and to ensure consistency of the dataset in terms of prices and quantities. Instituto de Estudos do Comércio e Negociações Internacionais (ICONE) datasets and information from the Brazilian Land Use Model (BLUM) model were used to improve the data for Brazil.

The 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.

Since both 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, as 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 EU and US discontinue their use of imports of sugarcane ethanol, the gains will be sharply lower. The exclusion of sugarcane ethanol imports will require a significant expansion of domestic ethanol production in the US and the EU. 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 $CO_2$ 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 $CO_2$ emissions. These benefits are further enhanced if the mandate policy is accompanied by liberalization in biofuel trade. Trade liberalization will bring greater benefits to consumers in terms of lower fuel prices and greater reductions in $CO_2$ emissions, when sugarcane ethanol is traded. While it will result in important adjustments in the agricultural sector, it will generally be beneficial for the agricultural sector and farm producers.

## 1 Introduction

Biofuel production increased sharply in the past decade and can be expected to grow more rapidly in the coming decade as national 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. The use of renewable fuels in the US will be required in order to reduce GHG emissions by at least 20% by 2022, with 58% of all renewable energy coming from cellulosic ethanol and other advanced biofuels. 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 $CO_2$ emissions. The primary goal of the study is to analyze the potential impacts of the EU and US biofuels mandates on world biofuels markets.

We focus on Brazil, and not on other developing countries in Latin America or other regions, because of the importance of Brazil in international ethanol markets. For example, within Latin America, Brazil accounts for more than 95% of ethanol exports. This is amplified in some countries in the region, especially those in Central America and the Caribbean, where most of the ethanol exports are re-exports from Brazil.

This evaluation focuses on the impacts of the mandates on (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 GHGs associated with the liquid fuel market, counting both the direct reduction of GHG emissions from the replacement of fossil fuels with biofuels, as well as emissions from land-use change.

Although the study covers both the biodiesel and ethanol markets, the study provides greater emphasis on 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, this study also analyses the hypothetical impacts of limited consumption of sugarcane ethanol on the US and EU markets, including the impacts of biofuel consumption targets on GHG emissions.

This study builds on an earlier International Food Policy Research Institute (IFPRI) study by Al-Riffai, Dimaranan, and Laborde (2010) that analyzes the impact of possible changes in EU biofuel and trade policies on global agricultural production and the environmental performance of the EU biofuel policy as concretized in the RED. The quantitative analysis of the global economic and environmental impact of first-generation biofuel development was conducted using an extensively modified version of the Modeling International Relationships in Applied General Equilibrium (MIRAGE) global, dynamic computable general equilibrium (CGE) model[1], which captures domestic intersectoral relationships and interregional linkages in the global economy. Primary among the major methodological innovations introduced in this new MIRAGE model (MIRAGE-BIOF) is the new modeling of energy demand, which allows for

[1] The MIRAGE model was initially developed at the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). Documentation of the standard model is available in Bchir et al. (2002) and Decreux and Valin (2007).

substitutability between different sources of energy, including biofuels. This is facilitated by the extension of the underlying 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. Finally, another major innovation is the introduction of a land use module, which allows for substitution between land classes, classified according to AEZs and land-extension possibilities. This land-use module enables assessment of the GHG emissions (focusing on $CO_2$) associated with land-use changes.

In this study commissioned by the Inter-American Development Bank (IDB), the MIRAGE-BIOF 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)[2].

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. Readers are referred to Al-Riffai et al. (2010) for more detailed discussions on 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.

## 2 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 to achieve energy independence, to bolster farm incomes, and to reduce GHGs. This section provides a brief background about the biofuel policies in the three main biofuel markets: Brazil, the EU, and the US.

[2] Technical discussions with, and data support from, Andre Nassar of the Instituto de Estudos do Comércio e Negociações Internacionais (ICONE) are gratefully acknowledged.

## 2.1 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 EU. 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 of Mercosur also protects domestic biofuel production, with ethanol duties of 20% and biodiesel duties of 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 tariff-rate quota 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.

## 2.2 European Union

The adoption of targets for the use of biofuels in road transport fuels is a key component of the EU's response to achieving its Kyoto targets of GHG emissions. In 2003, the EU 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 EU adopted the 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, adopted at the same time as the RED, includes identical sustainability criteria and it targets a reduction in lifecycle GHG 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 indirect land-use change on GHG emissions and ways to minimize that impact.

EU trade policies also affect domestic biofuel production and reduce production incentives and export opportunities for foreign biofuel producers (e.g. US, Brazil, Indonesia, Malaysia, etc.). The most-favored-nation (MFN) duty for biodiesel is 6.5%, while for ethanol tariff barriers are higher (€19.2 / hectolitre for the HS6 code 220710[3] 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 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 Plus (GSP +). 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 code 220710 and 14.34 thousand hectolitres for 220720).

## 2.3 United States

US 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

[3] Harmonized System (HS) code 220710 refers to undenatured ethyl alcohol, of actual alcoholic strength of 80%; HS 220720 refers to denatured ethyl alcohol and other spirits.

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 consumption of 1 billion gallons of biodiesel (3.15 Mtoe [million tons of oil equivalent]), 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 US 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 ad-valorem equivalent [AVE]) are higher than biodiesel (1% in AVE), which limit imports, especially from Brazil. Moreover, producers benefit from tax credits based on biofuels blended into fuels. The Volumetric Ethanol Excise Tax Credit and the Volumetric Biodiesel Excise Tax Credit provide the single largest subsidies to biofuels, although there are additional subsidies linked to biofuel outputs.

## 3 Data and Methodology

This study uses the MIRAGE-BIOF model and the dataset developed for the study entitled "Global Trade and Environmental Impact Study of the EU Biofuels Mandate" (Al-Riffai, Dimaranan, and Laborde, 2010). Several changes in parameter values and in the dataset have been performed in this study thanks to the contribution of the Instituto de Estudos do Comércio e Negociações Internacionais (ICONE) and information from the Brazilian Land Use Model (BLUM), which improved the data for Brazil. In the description of the database and model used in this study, we emphasize the main changes from the previous study.

### 3.1 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, 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 database was then modified to accommodate the sectoral changes made to the MIRAGE model.

Twenty-three new sectors were carved out of the GTAP sector aggregates – the liquid biofuels sectors (an ethanol sector with four feed-stock specific sectors, and a biodiesel sector), major feedstock sectors (maize, rapeseed, soybeans, sunflower, palm fruit and the related oils), co- and by-products of distilling and crushing activities, the fertilizer sector and the transport fuels sector. For the last two sectors, we split the existing GTAP sectors with the aid of the SplitCom software.[4]

However, after several tests, we found that the limitations of the SplitCom software and the initial data lead to very unsatisfactory results in the splitting of several feedstock crops, vegetable oils and biofuel sectors. We therefore developed an original and specific procedure to generate a database that is consistent in both values and quantities. The general procedure is as follows:

- Agricultural production value and volume are targeted to match Food and Agriculture Organization of the United Nations (FAO) statistics. A world price matrix for homogenous commodities was constructed in order to be consistent with international price distortions (transportation costs, tariffs, and export taxes or subsidies).
- Production technology for new crops is inherited from the parent GTAP sector and the new sectors are deducted from the parent sectors.
- New vegetable oil sectors are built using a bottom-up approach based on crushing equations. Value and volume of both oils and meals are consistent with the prices matrix, physical yields and input quantities.
- Biofuel sectors are built using a bottom-up approach to respect the production costs, input requirements, production volume, and for the different type of ethanols, the different by-products. Finally, rates of profits are computed based on the difference between production costs, subsidies and output prices.
- For Steps 2, 3, and 4, the value of inputs is deducted from the relevant sectors (other food products, vegetable oils, chemical and rubber products, fuel) in the original social accounting matrix (SAM), allowing resources and uses to be extracted from different sectors if needed (*n-to-n*).

[4] SplitCom, a Windows program developed by J. Mark Horridge of the Center for Policy Studies, Monash University, Australia, is specifically designed for introducing new sectors in the GTAP database by splitting existing sectors into two or three sectors. Users are required to supply as much available data on consumption, production technology, trade, and taxes either in US dollar values or as shares information for use in splitting an existing sector. The software allows for each GTAP sector to be split one at a time, each time creating a balanced and consistent database that is suitable for CGE analysis.

- At each stage, consumption data are adjusted to be consistent with production and trade flows.

It is important to emphasize that this procedure, even if time consuming and delicate to operate with so many new sectors, was crucial and differs from a more simplistic approach used in the literature until now. Indeed, each step allows us to address several issues. For instance, Step 1 allows us to have a more realistic level of production compared to the GTAP database wherein production targeting is done only for Organisation for Economic Co-operation and Development (OECD) countries, with some flaws, and therefore has an outdated agricultural production structure for many countries. Building a consistent dataset in value and volume – thanks to the price matrix – is also critical. Targeting only in value often generates inconsistencies in the physical linkage that thereby leads to erroneous assessments (e.g. wrong yields for extracting vegetable oil). Even more important is the role of initial prices, and price distortions, in a modeling framework using constant elasticity of substitution (CES) and constant elasticity of transformation (CET) functions. Indeed, economic models rely on optimality conditions and, in our case, as in all the CGE literature, our modeling approach leads to equalization of the marginal rate of substitution (CES case) to relative prices. It means that the physical conversion ratio is bound to the relative prices. Wrong initial prices, or incorrect price normalization, will lead to convert X units of good i (e.g. imported ethanol) into Y units of good j (e.g. domestic produced ethanol). In the case of a homogenous good, we need to have an initial price ratio equal to one and to ensure with a high elasticity of substitution that this ratio will remain close to one. Otherwise, misleading results appear (e.g. one ton of palm oil will replace only half a ton of sunflower oil, one ton of imported ethanol can replace 1.5 tons of domestic ethanol). This mechanism may be neglected in many CGE exercises where the level of aggregation easily explains the imperfect substitution. In the case of this study, however, we found it imperative to directly address this challenge since we deal with a high level of sector disaggregation, a high level of substitution (among ethanols produced from different feedstocks, among vegetable oils, or among imported and domestic production), and with the critical role of physical linkages, from the crop areas to the energy content of different fuels and meals.

Finally, a flexible procedure is needed (Step 5) since some of our new sectors can be constructed from among several sectors in GTAP. SplitCom allows only a *1-to-n* disaggregation, which is rather restrictive for the more complex configuration that we face with the data. For instance, Brazilian ethanol trade data falls under the beverages and tobacco sector while its production is classified under the chemical products sector. For the vegetable oils, we face similar issues since the value of the oil is in the vegetable oil sector but the value of the oil meals are generally under in the food products sector.

The specific data sources, procedures and assumptions made in the construction of each new sector are described in Al-Riffai, Dimaranan, and Laborde (2010, Annex I).

## 3.2 Global Model

The MIRAGE model (Decreaux and Valin, 2007), a CGE model originally developed at Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) for trade policy analysis, was extensively modified at IFPRI in order to address the potential economic and environmental impact of biofuels policies. The key adaptations to the standard model are the integration of two main 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, was introduced in the model at the AEZ level, allowing for infra-national modeling. The latter feature is particularly valuable for large countries such as Brazil where production patterns and land availability are quite heterogeneous.

Extensive model modifications were done by Al-Riffai, Dimaranan, and Laborde (2010) to adapt the MIRAGE trade policy-focused CGE model for an assessment of the trade and environmental impacts of biofuels policies. Some of the changes made to the model were previously introduced by Bouët et al. (2008) and Valin et al. (2009). In this section, we provide a brief description of the main features of the MIRAGE model. This is followed by the adaptations and innovations made in the areas of energy modeling, the modeling of co-products of ethanol and biodiesel production, and the description of fertilizer use. More detailed explanations of the various modeling changes are provided in the annex to this report.

### 3.2.1 Core Features of the MIRAGE Model

This section summarizes the features of the standard version relevant for this study. MIRAGE is a multisector, multiregion CGE Model for trade policy analysis. 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. Macroeconomic data and SAMs, in particular, come from the GTAP 7 database (see Narayanan, 2008), which describes the world economy in 2004. From the supply side in each sector, the production function is a Leontief function of value added and intermediate inputs: one output unit needs for its production $x$ percent of an aggregate of productive factors (labor, unskilled and skilled; capital; land and natural resources) and $(1 - x)$ percent of intermediate inputs.[5] The intermediate inputs function is an aggregate CES function of all goods: it means that substitutability exists between two intermediate goods, depending on the relative prices of these goods. This substitutability is constant and at the same level for any pair of intermediate goods. Similarly, in the generic version of the model, value added is a CES function of unskilled labor, land and natural resources, and of a CES bundle of skilled labor and capital. This nesting allows the modeler to introduce less substitutability between capital and skilled labor than between these two and other factors. In other words, when the relative price of unskilled labor is increased, this factor is replaced by a combination of capital and skilled labor, which are more complementary.[6]

Factor endowments are fully employed. The only factor whose supply is constant is natural resources. Capital supply is modified each year because of depreciation and investment. Growth rates of labor supply are fixed exogenously. Land supply is endogenous; it depends on the real remuneration of land. In some countries land is a scarce factor (for example, Japan and the EU), such that elasticity of supply is low. In others (such as Argentina, Australia, and Brazil), land is abundant and elasticity is high[7].

Skilled labor is the only factor that is perfectly mobile. Installed capital and natural resources are sector specific. New capital is allocated among sectors according to an investment function. Unskilled labor is imperfectly mobile between agricultural and nonagricultural sectors following a constant CET function: unskilled labor's remuneration in agricultural activities differs from that in nonagricultural activities. This factor is distributed between these two series of sectors according to the ratio of remunerations. Land is also imperfectly mobile amongst agricultural sectors.

[5] The fixed-proportion assumption for intermediate inputs and primary factor inputs is especially pertinent to developed economies, but for some developing economies that are undergoing dramatic economic growth and structural change, such as China, the substitution between intermediate inputs and primary factor inputs may be significant.
[6] In the generic version, substitution elasticity between unskilled labor, land, natural resources and the bundle of capital and skilled labor is 1.1; it is only 0.6 between capital and skilled labor. This structure has been modified for the present exercise.
[7] This assumption, which applies to the standard model, is modified in the version of MIRAGE used in this biofuels study (MIRAGE-BIOF).

In the MIRAGE model there is full employment of labor; more precisely, there is constant aggregate employment in all countries, combined with wage flexibility. It is quite possible to suppose that total aggregate employment is variable and that there is unemployment; but this choice greatly increases the complexity of the model, so that simplifying assumptions have to be made in other areas (such as the number of countries or sectors). This assumption could amplify the benefits of trade liberalization for developing countries: in full-employment models, increased demand for labor (from increased activity and exports) leads to higher real wages, such that the origin of comparative advantage is progressively eroded; but in models with unemployment, real wages are constant and exports increase much more.

Capital in a given region, whatever its origin, domestic or foreign, is assumed to be obtained by assembling intermediate inputs according to a specific combination. The capital good is the same whatever the sector. MIRAGE describes imperfect, as well as perfect, competition. In sectors under perfect competition, there is no fixed cost, and price equals marginal cost.

The demand side is modeled in each region through a representative agent whose propensity to save is constant. The rest of the national income is used to purchase final consumption. Preferences between sectors are represented by a linear expenditure system–constant elasticity of substitution (LES-CES) function. This implies that consumption has a non-unitary income elasticity; when the consumer's income is augmented by *x* percent, the consumption of each good is not systematically raised by *x* percent, other things being equal.

The sector sub-utility function used in MIRAGE is a nesting of four CES functions. In this study, Armington elasticities are drawn from the GTAP 7 database and are assumed to be the same across regions. But a high value of Armington elasticity, i.e. 20, is assumed for all homogenous sectors (single crops, single vegetable oils, ethanol).[8] For biodiesel, we assume the same elasticity as that for other fossil fuels.

Macroeconomic closure is obtained by assuming that the sum of the balance of goods and services and foreign direct investments is constant in terms of share of the world gross domestic product (GDP).

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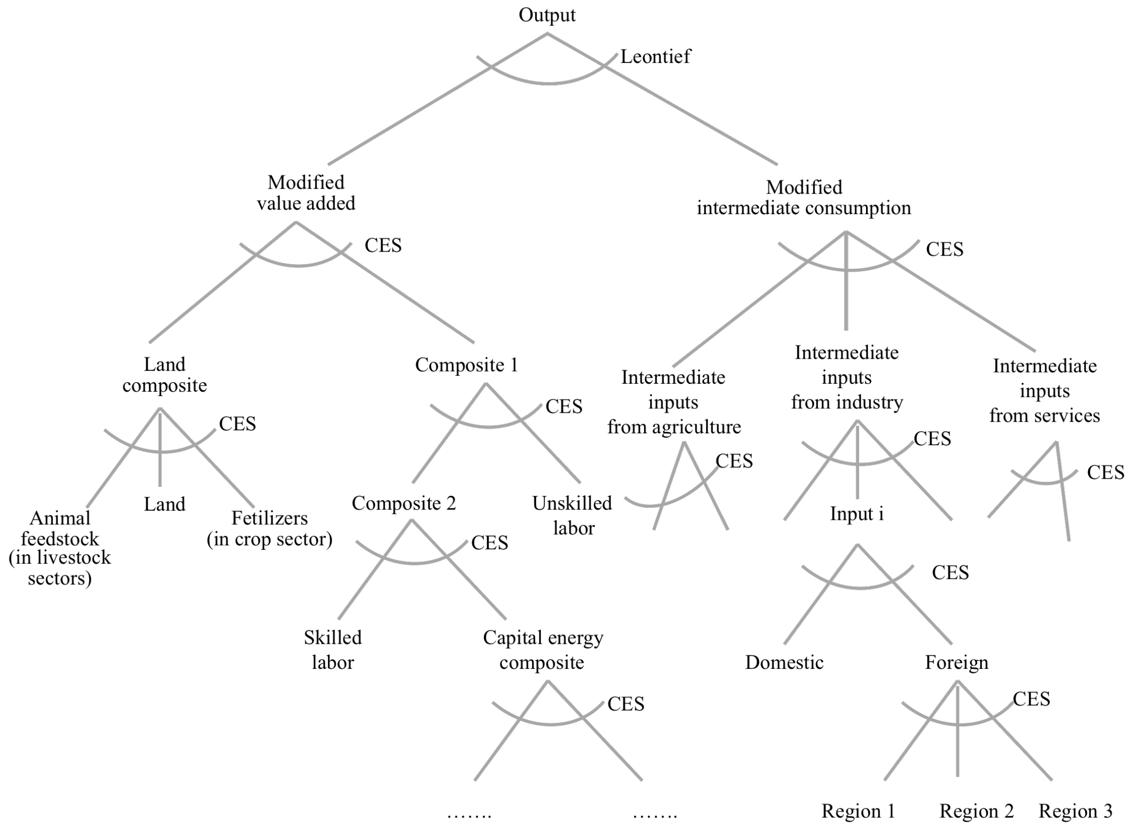
[8] Compared to 10 in the "Global Trade and Environmental Impact Study of the EU Biofuels Mandate" study.

### 3.2.2 Modeling Energy and Intermediate Consumption

The most significant of these model modifications is the modeling of the energy sector to introduce energy products, including biofuels, as components of value-added in the production process. Following a survey of energy modeling approaches, the MIRAGE model was modified following a top-down approach, similar to the approach taken with the GTAP-E model (Burniaux and Truong, 2002), wherein energy demand is derived from the modeling of macroeconomic activity. 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).

The paper by Burniaux and Truong (2002) was the inspiration for the elasticities of substitution of the different CES nesting levels described above. The elasticities of substitution are set at 1.1 between energy and electricity, 0.5 between energy and coal, and 1.1 between fuel oil and gas. Based on estimates from Okagawa and Ban (2008) (EU KLEMS estimates), the elasticity of substitution between capital and energy is 0.2 in industry, 0.3 in services and 0.03 in agriculture.

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




*Source:* Bouët, A., B. Dimaranan, and H. Valin (2010)

Finally, it is worth noting that a distinctive feature of this new version of MIRAGE is in the grouping of intermediate consumptions into agricultural inputs, industrial inputs and services inputs. This introduces greater substitutability within sectors. For example, substitution is higher between industrial inputs (substitution elasticity of 0.6) than between industrial and services inputs (substitution elasticity of 0.1). At the lowest level of demand for each intermediate input, firms can compare the prices of domestic and foreign inputs and for the latter, the prices of these foreign inputs coming from different regions. In non-agricultural sectors demand for energy exhibits specific features that are incorporated as follows:

- In the transportation sectors (road transport and air and sea transport) the demand for fuel, which is a CES composite of fossil fuel, ethanol and biodiesel, is less substitutable. The modified value added is a CES composite with very low substitution elasticity (0.1) between the usual composite (unskilled labor and a second composite, which is a CES of skilled labor and a capital and energy composite) and fuel, which is a CES composite with high elasticity of substitution (1.5) of ethanol, biodiesel and fossil fuel.

- In sectors that produce petroleum products, intermediate consumption of oil has been made nearly fixed. The modified intermediate consumption is a CES composite (with low elasticity, 0.1) of a composite of agricultural commodities, a composite of industrial products, a composite of services and a composite of energy products. The latter composite is a CES function (with low elasticity) of oil, fuel (composite of ethanol, biodiesel, and fossil fuel with high elasticity, 1.5) and of petroleum products other than fossil fuel. The share of oil in this last composite is by far the largest one. This implies that when demand for petroleum products increases, demand for oil increases by nearly as much.
- In the gas distribution sector, the demand for gas is made less substitutable. It has been introduced at the first level under the modified intermediate consumption composite, at the same level as agricultural inputs, industrial inputs and services inputs. This CES composite is introduced with a very low elasticity of substitution (0.1).
- In all other industrial sectors we keep the production process illustrated in Figure 1, except that there is no land composite, and fuel is introduced in the intermediate consumption of industrial products.

In addition to the extensive modifications made to address the shortcomings of the MIRAGE global trade model in characterizing the energy sector, modifications were also made in the MIRAGE demand function for final consumption. The LES-CES, which captures non-homothetic behaviour in response to changes in income, was improved through the introduction of new calibration to USDA income and price elasticities (Seale et al., 2003). For China and India, some complementary information was sourced from the Food and Agricultural Policy Research Institute (FAPRI). The LES-CES demand structure was further modified to allow for a separate characterization of demand for fuel relative to demand for other goods. A new LES-CES level is introduced to allow for the lower elasticity of fuel demand to prices. Further details on this modification of the energy demand structure is provided in Annex III in Al-Riffai, Dimaranan, and Laborde (2010). The elasticity of substitution at this level is calibrated to obtain fuel consumption in the baseline consistent with energy model projections (e.g. the EU PRIMES model). The value for all regions is 0.4.

Compared to previous studies, we have devoted more attention to the Brazilian demand for ethanol. Due to the specificity of the Brazilian market with the flex fuel car fleet, the possibility of substitution between gasoline and ethanol is larger in this country. This substitution is represented by a CES function with an elasticity of 2.6. This elasticity has been calibrated to target in the baseline the central demand scenario of ethanol projected by União da Indústria de Cana-de-Açúcar (UNICA) (2010).

### 3.2.3 Fertilizer Modeling

Fertilizers are explicitly introduced in the global database and MIRAGE-BIOF model to capture potential crop production intensification with use of more fertilizers, in response to increased demand for biofuel feedstock crops. The characterization of the crop production response to prices resulting from increased bioenergy demand is particularly important. 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 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).

In this context, crop yields in the model may increase through three channels:

1. Exogenous technical progress (see baseline section);
2. Endogenous "factor" based intensification: land is combined with more labor and capital;
3. Endogenous "fertilizers" (intermediate consumption) based intensification, the mechanism described above.

The model does not include endogenous technical progress based on private or public research and development expenditures in response to relative price changes. However, the increase of capital and labor by unit of land (effect *ii*) plays a similar role.

### 3.2.4 Modeling the Production of Biofuels

The biodiesel and ethanol sectors are modeled in slightly different ways. 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 (see Figure 2). These are combined with other inputs (mainly chemicals and energy) and value added (capital and labour).

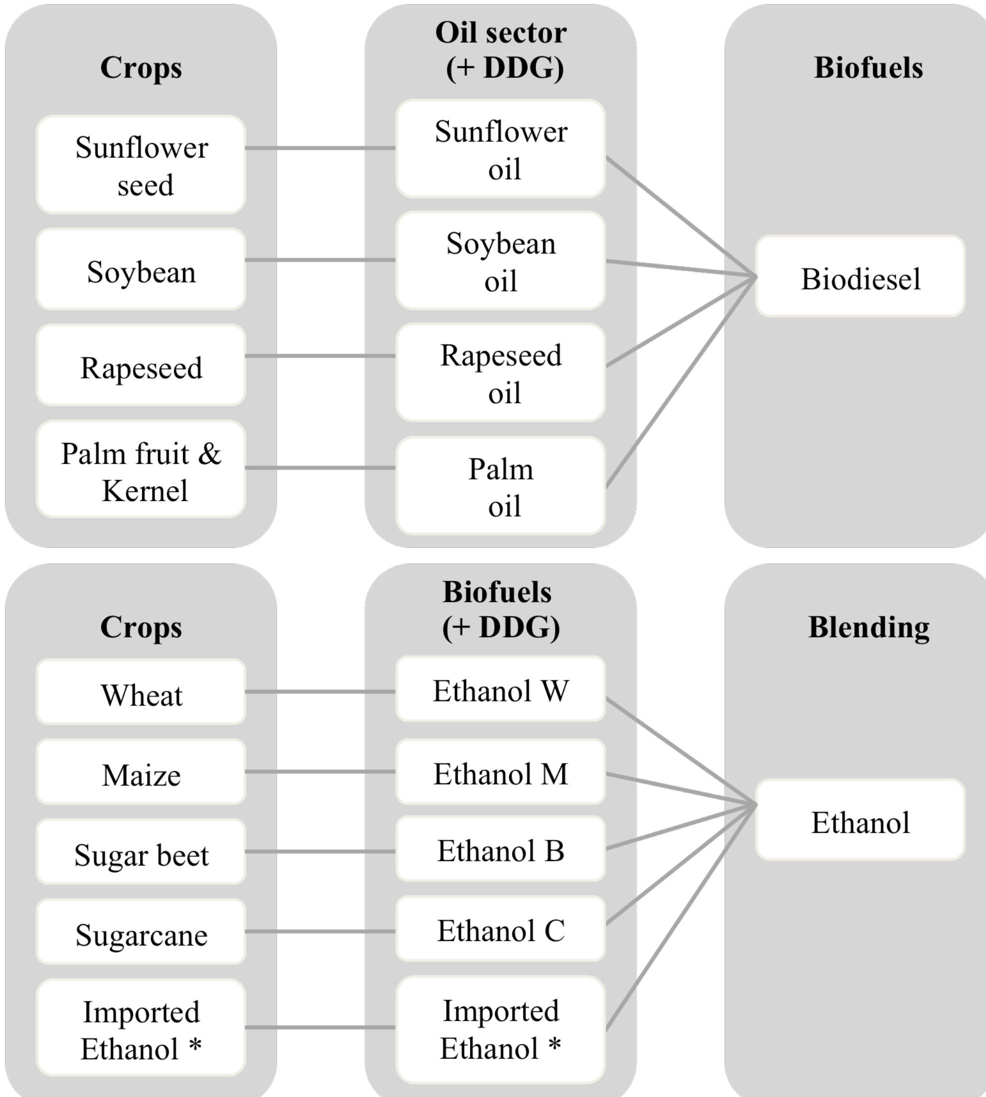
Intermediate consumption is modeled using a CES nested structure with high substitutability assumed among the vegetable oils (an elasticity of substitution equal to 8). The initial dataset and the calibration of the model were set to allow for an initial marginal rate of substitution equal to 1 (e.g. 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.

For the ethanol sector, we first model four subsectors, each one using only one of the following as specific feedstock: wheat, sugarcane, sugar beet or maize. This main input is combined with other production inputs and value added assuming complementarity. Each of these four subsectors, except the sugarcane-based ethanol sector, produces a specific by-product (dried distillers grains with solubles [DDGS] with different properties and prices) and 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 to use imported ethanol from Brazil as an input into their own ethanol production sector.[9] 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).

[9] 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.

**Figure 2 Biofuel Feedstock Schematic**




*Source*: Al-Riffai, P., B. Dimaranan, and D. Laborde (2010)
*Note*: *Only for Central America and Caribbean regions, this represents the re-export channel of Brazilian ethanol in the region. Other inputs and value added are not displayed here.

### 3.2.5 Modeling of Co-products and Livestock Sectors

Co-products of the biofuels industry, such as DDGS, soy meal, and rapeseed meal, are used as substitutes for feed grains in livestock production. It is therefore recognized that in assessing the impact of biofuels development on agricultural markets, co-products should be taken into account since they could lessen the unfavorable impact of biofuels: they reduce the need of land reallocation/extension to replace the crops displaced from the feed and food sectors to bio-energy production. Biofuel co-products are also recognized for their role in potentially mitigating the land-use impact of biofuels, as demand for feed grains are reduced. Kampman et al. (2008) estimated that incorporating by-products into the calculations for land requirements of biofuels reduced land demand by 10-25%.

Accounting for co-products was only recently introduced in CGE assessments of the impact of biofuels development. Taheripour et al. (2008) analysed the impact of including biofuel by-products (DDGS) in an analysis based on the GTAP CGE model. They found significant differences in feedstock output and prices depending on whether the existence of by-products is taken into account.

Co-products play a different role in the ethanol and in the biodiesel production pathways. For ethanol, distillers grains and sugar beet pulp are low value materials that are not profitable without the benefits from ethanol sale (the share of ethanol by-products in total production value is below 20%). On the other hand, the production of oilseed meals is at the heart of oilseed market dynamics in biodiesel production. Oil and meals are co-products that can be valued independently and the demand for one of them directly affects the price of the other. 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 US and EU.[10] 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 feed grains 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,

[10] For Brazil, the co-generation of electricity is taken into account; however, 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.

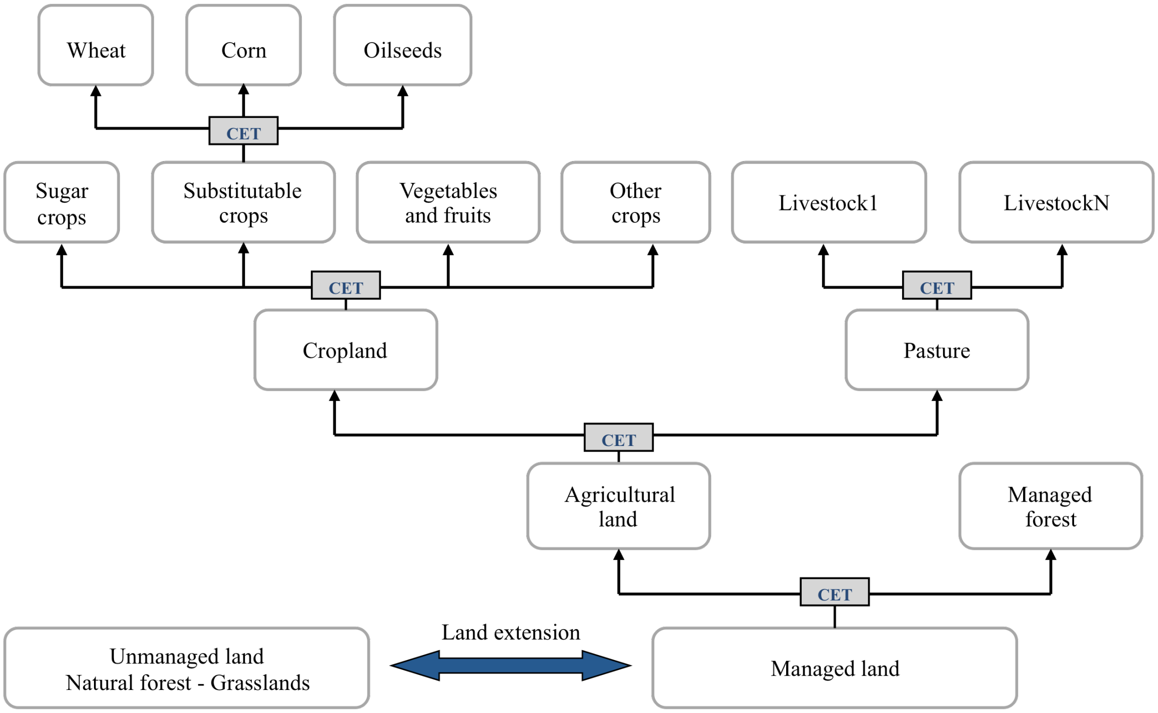
including ethanol and biodiesel co-products, with land. This is treated using a similar approach to our modeling of crop intensification through the substitution of fertilizer for land (land and feedstuffs are substitutable).

Each type of DDGS is also directly traded or consumed by local livestock industries. It is important to emphasize that no other DDGS production is modeled outside of the production of ethanol. It means that the size of DDGS market is more restricted in the model than in the real world and will be totally dependent on the evolution of the ethanol production sectors. It is quite different from the production of meals wherein the vegetable oil production process generates oilcakes. Since the biodiesel sector is a limited destination for the overall vegetable oil sectors, the effects of biodiesel policies are much more limited on these markets.

## 3.3 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 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 3). Detailed documentation of the land-use module including data on AEZs and land-use change modeling are available in Al-Riffai, Dimaranan, and Laborde (2010, see Annex V and VI).

**Figure 3 Land-use Module**




*Source:* Bouët, A., B. Dimaranan, and H. Valin (2010)

### 3.3.1 Land Allocation among Anthropic Activities

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) among 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 pastureland 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 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. However, 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 3 are drawn from the literature. We display the elasticities for the main regions in Table 1.

**Table 1 MIRAGE-BIOF Land Transformation Elasticities**

| | **Level 1: Elasticity across substitutable crops** | **Level 2: Elasticity across crops** | **Level 3: Elasticity between cropland and pasture** | **Level 4: Elasticity between agricultural land and managed forest** |
|---|---|---|---|---|
| US | 0.25 | 0.1 | 0.025 | 0.02 |
| EU | 0.2 | 0.05 | 0.025 | 0.02 |
| Brazil | 0.5 | 0.5 | 0.4 | 0.035 |

*Source:* MIRAGE-BIOF model dataset based on Winrock International estimates

For Brazil, we relied on estimates from Barr et al. (2010). For Level 4, the elasticity has been modified to obtain in the baseline a more consistent trend between the model projection and the stylized fact concerning the evolution of plantations and other agricultural activities as well as the path of deforestation.

We have tried to estimate the matrix of transformation elasticities based on the BLUM dataset. Preliminary tests have shown that the current nested CET structure will need deeper adjustments to reproduce the BLUM historical data. We have therefore chosen the existing modeling approach at this stage but recognize that future research would be desirable in order to capture more efficiently the AEZ/regional specificities in cropland management.

It is important to keep in mind that the high level of the elasticity of substitution between pasture and cropland in the case of Brazil will allow it to easily reallocate large areas of land from pasture to cropland, limiting the need to extend into virgin regions.

### 3.3.2 Land Extension

Land extension takes place at the AEZ level allowing the model to capture the different behaviour across different regions of large countries (e.g. Brazil, Sub-Saharan Africa [SSA]). 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. However, this means that price increases need to be increasingly important to allow for expansion, reflecting the fact that land expansion becomes harder as more available land is used up. If this elasticity gets close to zero, land expansion then becomes impossible. Implicitly, this equation defines what other studies have referred to as a “land supply curve.” Land supply curves are often calibrated on physical values (such as productivity). However, this does not increase their robustness because the most significant indicator is the expansion elasticity at the starting point, and this elasticity depends more on behavioral factors than on biophysical factors (even if biophysical factors can explain a part of the behavior).

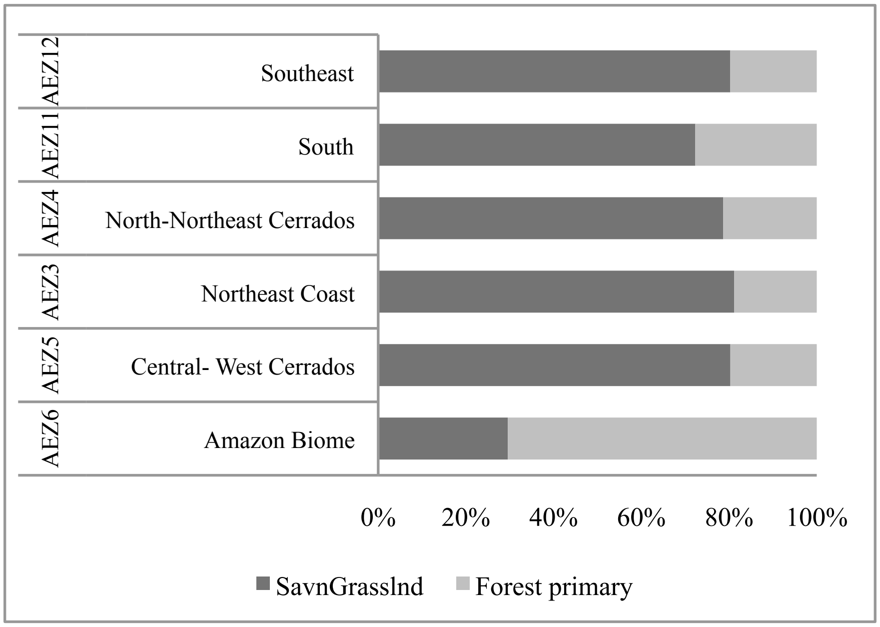
In the MIRAGE-BIOF model, the default value for land expansion has been set at the level of substitution value between managed forest and cropland-pasture aggregate in the substitution tree (see Table 1). However, sensitivity analyses are critical due to the uncertainty in the value of this parameter.

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 Environmental Protection Agency (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 to capture the deforestation that occurs in specific regions. We have also slightly modified the AEZ breakdown to be more consistent with the BLUM nomenclature. This feature is particularly important since sectoral distribution will lead to different deforestation behaviour; for instance, soya crops are closer to the deforestation frontier than sugarcane plantations. The coefficients used in the model are displayed in Figure 4.

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. It is important to keep in mind that this assumption remains strong and research seems to show that recent marginal land extensions were taking place on land with at least average level yields.

**Figure 4 Marginal Land Extension Coefficients for Brazil**




*Source:* MIRAGE-BIOF model dataset based on Winrock International estimates

## 3.4 Greenhouse Gas Emissions and Land-use Change Measurement

A critical component of this study is the assessment of the of balance in $CO_2$ 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 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 RED. 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 coefficients (given in Table 2) are critical to the determination of direct emission savings and, ultimately, the net emissions effects of biofuels. We do not model each production pathway separately but calculate an average composition for the biofuels production sector. Data on that composition remain sparse, however; consequently the current average composition of production capacity in the industry remains uncertain, as well. Moreover, there are major uncertainties with regard to (a) the future weight of each of these production pathways in total production and (b) the possibility for substitution between different pathways to comply with the sustainability criteria defined in the RED. As a result, major uncertainties remain regarding the direct emission savings in the biofuels industry. Concerning sugarcane ethanol, we do not include the average $CO_2$ intake during the growing period of this perennial crop.

We use a consumption approach to allocate direct emission savings: the emission credit is given to the country that consumes the biofuels, not to the producer country. In this we follow the RED even though this may appear to be in contradiction with the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol emission accounting rules that allocate credits for reductions to the producer country.

Lastly, we do not include in our analysis the changes in GHG emissions due to the increase in the use of fertilizer.

**Table 2 Reduction of $CO_2$ Associated with Different Feedstock**

| Feedstock | $CO_2$ Reduction Coefficients |
|---|---|
| Wheat (EU) | -53% |
| Wheat (Other) | -50% |
| Maize (EU) | -56% |
| Maize (Other) | -50% |
| Maize (US) | -56% |
| Sugar beet | -61% |
| Sugarcane | -71% |
| Soya | -50% |
| Rapeseed | -50% |
| Palm Oil | -62% |
| Sunflower | -58% |

*Source:* Al-Riffai, P., B. Dimaranan, and D. Laborde (2010)

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 relied on IPCC coefficients for these different ecosystems. We also included two special treatments specific to the EU and to Indonesia and Malaysia. For the EU, the carbon stock of forest was limited to 50% of the value for a mature forest. It was considered that no primary forest would be affected by the land extension in the EU and that only the areas recently concerned by afforestation would 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. We assumed a marginal coefficient of extension of palm tree plantations on peatlands of 25% for Malaysia and 50% for Indonesia based on information provided in the literature review on peatlands by Edwards (2010). In this case, the value of emissions for peatlands used was 55 tons of $CO_2$ per ha per year.

## 4 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 also introduce alternative trade policy scenarios around this EU and US biofuel mandates scenario impact.

### 4.1 Sectoral and Regional Nomenclature

Even if the database has been developed at a detailed level (57 sectors and 35 regions), it is not practical to run the scenarios at this highly detailed level due to the much larger size of this model (now with twice the number of equations/variables as in the standard MIRAGE model) and the modeling of land extension at the detailed AEZ level. By focusing on the sectors and regions of interest11 in this study on biofuels and agricultural production and trade from a EU point of view, we limit the size of our aggregation to the main players (11 regions) and 43 sectors. Details are provided in Table 3 and Table 4. The sectoral disaggregation covers agricultural feedstock crops and processing sectors, energy sectors and other sectors that also use agricultural inputs.

**Table 3 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) |

[11] This study focuses on the main consumers and producers of biofuels at the world level. The nomenclature has not been defined to identify the heterogeneous effects of such policies on individual Latin American countries. It is important to keep in mind that due to their diversified economic structures (staple food exporters/importers, energy exporters/importers) countries in the LAC aggregate will face very contrasted fortunes.

| Region | Description |
|---|---|
| RoW | Rest of the World |
| SSA | Sub Saharan Africa |
| US | United States |

**Table 4 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 and 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 – Sugar beet | | |
| **RpSdOil** | Rapeseed oil | **EthanolM** | Ethanol - Maize | | |

## 4.2 Baseline Scenario

It is important to emphasize that the underlying GTAP database used for the model was first updated from the 2004 data reference year to 2008. This update was 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.

### 4.2.1 Macroeconomic Trends

The baseline scenario reflects recent International Energy Agency forecasts (IEA) (2008) with oil prices reaching $120 a barrel in 2030 current prices. Economic growth projections, now taking into account the effects of the economic crisis, have also been updated with projections data from the World Economic Outlook (April 2009) of the International Monetary Fund. In this context, EU consumption of energy for road transportation is estimated to reach 316 Mtoe in 2020. This figure is in line with the latest projections of European Commission's energy directorate (DG ENER). Since the EU policies are defined as a percentage of energy used for road transportation, this level is quite important for assessing the level of demand of biofuels in the scenario. For Brazil and the US, since policies are defined differently, we do not face the same constraint of accuracy in defining the energy consumption in the baseline.

The choice of 2008/2009 as a reference year is important in our analysis since it significantly affects our results particularly regarding the competitiveness of Brazilian vs. US ethanol. Unfavorable weather conditions and the short-term evolution of the US dollar exchange rate greatly reduced the competiveness of Brazilian ethanol and hence its exports to the US in 2009/2010. We used 2008 and not 2009/2010 as the reference period, since the production and trade patterns then were not strongly influenced by short-term phenomena and are more appropriate for our medium run projections.[12]

In the model, the real exchange rate is endogenous since we assume a constant current account surplus/deficit for each region in terms of world GDP. The baseline leads to a real exchange rate appreciation between the Euro and the dollar by two percent and for the Brazilian real–US dollar real exchange rate by a fall of 5 percent. If these changes slightly increased the competitiveness of Brazilian ethanol in the US market, these fluctuations remain quite limited compared to the evolution in the last decade.

[12] The nominal exchange rate between the Brazilian real and the US dollar increased by 66% between April 2008 and December 2008. This has led to some ethanol exports from the US to Brazil in 2009. Since then (by August 2010), the real/USD exchange rate appreciation has decreased by about 75%.

### 4.2.2 Technology

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). It is important to note that no exogenous growth in palm tree yield is assumed due to the lack of data at our disposal. Therefore, compared to other crops, palm oil suffers a disadvantage in the baseline. Yields in the palm fruit sector can only increase through an endogenous process (intensification). This assumption leads to a loss of competitiveness of this feedstock compared to other oilseeds. We do not assume changes in the yield of the crushing, distilling and biofuel production activities[13].

For sugarcane, the changes in yield are applied directly to the sugar content by ha. For this crop, the yield increase in Brazil is strong but remains consistent with its 1997-2007 evolution. Details are given in Table 5.

In the case of the EU, one sector (sugar beet) suffers from a net decline in yield during the period. It is due to the implementation of sugar reform in the baseline (see below) and its effects on the intensification behavior of producers. We do not include the potential effects of genetically modified sugar beets that, if introduced in the EU, would potentially greatly modify the profitability of the whole sector.

[13] The estimates for annual yield growth implied by our baseline simulations and reported for Brazil in Table 5 are relatively conservative compared to recent estimates obtained by Ludena (2010). The figures are slightly below the average for the last 10 years for Latin America. The exception is for sugarcane for which our estimate is above the average but considers both the evolution of sugarcane yield (tons of sugarcane per hectare) and the sugar content of sugarcane.

## Table 5 Annual Growth of Yield for Main Feedstocks and Decomposition, 2008-2020 (*percentage*)

| Feedstock | Total change | Technical progress | Factor intensity | Fertilizer | Land allocation |
|---|---|---|---|---|---|
| | | | *Brazil* | | |
| Maize | **1.55** | 1.10 | 0.58 | 0.24 | -0.31 |
| PalmFruit | **1.19** | 1.10 | 0.64 | | -0.59 |
| Rapeseed | **1.50** | 1.10 | 0.62 | 0.23 | -0.40 |
| Soybeans | **1.57** | 1.10 | 0.62 | 0.24 | -0.33 |
| Sugarcane or sugar beet | **3.01** | 0.83 | 1.63 | 1.28 | -0.35 |
| Sunflower | **1.53** | 1.10 | 0.62 | 0.23 | -0.37 |
| Wheat | **1.66** | 1.10 | 0.62 | 0.29 | -0.26 |
| | | | *EU27* | | |
| Maize | **1.21** | 0.93 | 0.30 | 0.08 | -0.06 |
| Rapeseed | **1.18** | 0.93 | 0.45 | 0.10 | -0.28 |
| Soybeans | **1.02** | 0.93 | 0.25 | 0.05 | -0.21 |
| Sugar beet | **-0.29** | 0.70 | -0.79 | -0.34 | 0.05 |
| Sunflower | **1.22** | 0.93 | 0.32 | 0.07 | -0.06 |
| Wheat | **1.25** | 0.93 | 0.36 | 0.09 | -0.09 |
| | | | *US* | | |
| Maize | **1.34** | 0.93 | 0.52 | 0.18 | -0.24 |
| Rapeseed | **1.36** | 0.93 | 0.49 | 0.12 | -0.12 |
| Soybeans | **1.34** | 0.93 | 0.36 | 0.10 | 0.02 |
| Sugar beet | **1.07** | 0.70 | 0.43 | 0.12 | -0.14 |
| Sunflower | **1.26** | 0.93 | 0.27 | 0.07 | 0.04 |
| Wheat | **1.36** | 0.93 | 0.35 | 0.12 | 0.04 |

*Source:* MIRAGE-Bios baseline

*Note:* The "total change" column indicates the annual yield change. The four remaining columns give the additive decomposition of this rate. The "technical progress" component is purely exogenous. The "factor intensity" is endogenous of the model (effect of labour and capital by unit of land) as the "fertilizer" one. The "land allocation" reflects the change in average productivity driven by change in land allocation. It combines the loss of productivity due to land reallocation among productive sector (CET effect), the loss of average productivity due to the addition of new land having a marginal productivity below the average, and the change in the distribution of production across AEZ within one country (positive or negative effect depending if production expands in an AEZ with above or below the average productivity).

### 4.2.3 Trade Policy Assumptions

The baseline scenario includes the trade policies that were in place by the end of 2008. The economic partnership agreements between the EU and the African, Caribbean, and Pacific (ACP) countries, negotiated in 2008, are implemented either as ratified interim agreements or a complete economic partnership agreement (e.g. with the Caribbean Community and Common Market [CARICOM], depending on the status of the agreement. Negotiations on trade agreements that were not finalized by the end of 2009 are not included: the Doha Development Agenda, a EU-Association of Southeast Asian Nations agreement and an EU-Ukraine agreement. For the US, the Caribbean Basin Initiative and its preferences are maintained during the period. No trade policy changes are considered for this country.

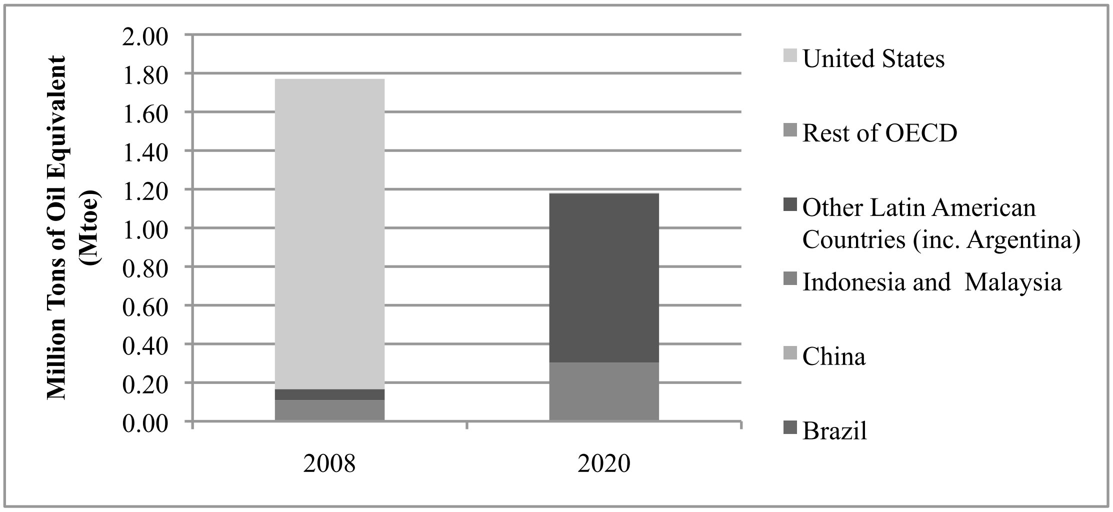
For Brazil, the removal of its ethanol tariff is implemented; however, it has no effect due to the non-existence of ethanol imports in our baseline for this country.[14]

For the EU, the baseline scenario includes the full AVE, around 48%, of the prevailing EU MFN duty bioethanol imports from countries that do not benefit from bilateral or unilateral (GSP) preferential schemes. In reality, this is likely to be an overestimate of the effective AVE. Significant quantities of bioethanol are imported under temporary suspensions of duties and, in the form of denatured ethanol, as chemical products for which a lower duty applies. In the absence of a specific EU tariff line for bioethanol, there are no trade statistics available that permit us to estimate the effective trade-weighted tariff on bioethanol.

Another critical trade policy measure that we incorporate in the baseline scenario is the anti-dumping duties that the EU imposed on US exports of biodiesel in March 2009. Over the last few years, the US has emerged as the major biodiesel exporter to the EU (with more than 80% of market share among all exporters), supplying about 19% of the EU domestic market for biodiesel. However, due to the tax credit given to the US blenders, and the "splash and dash"[15] practice, the EU initiated anti-dumping measures and countervailing duties in March 2009. This contingent protection has reduced US biodiesel exports to the EU to negligible quantities. Allegedly, some of these US exports may now have been replaced partially by exports from Indonesia, Malaysia and Argentina[16] and growing trade flows from Canada and Singapore.[17] In the model, the bulk of the adjustment to the anti-dumping duty is achieved through increased EU biodiesel production (based on EU produced and imported feedstocks). Figure 5 shows EU biodiesel imports by source in 2008 and projected imports in 2020, it clearly indicates the drastic change in the share of imports from the US between the two periods.

[14] 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.
[15] "Splash and dash" practice refers to the collection of US tax credits on imported biofuels sent to Europe.
[16] Argentina, included in the LAC aggregate, gains most of the market share lost by the US. It is a combination of three effects: the end of the "splash and dash" in the US released soybean oil resources used in the process, the competitiveness of Argentina, and ongoing investment plans in the sector (including the role of export taxes structure that create a strong bias in favor of biodiesel exports), and the loss of relative productivity of the palm oil sector due to lack of technological progress assumed in this sector (see the discussion in the yield sector).
[17] These flows can be re-exported US production and in some cases, double "splash and dash" has been detected (tax credit in the US then in Canada). The EC is proposing to extend the contingent protectionist measures to these new flows.

**Figure 5 EU Biodiesel Imports**
**(*by source, Mtoe, baseline*)**




*Source:* Authors' calculations

### 4.2.4 Agri-Energy Policies

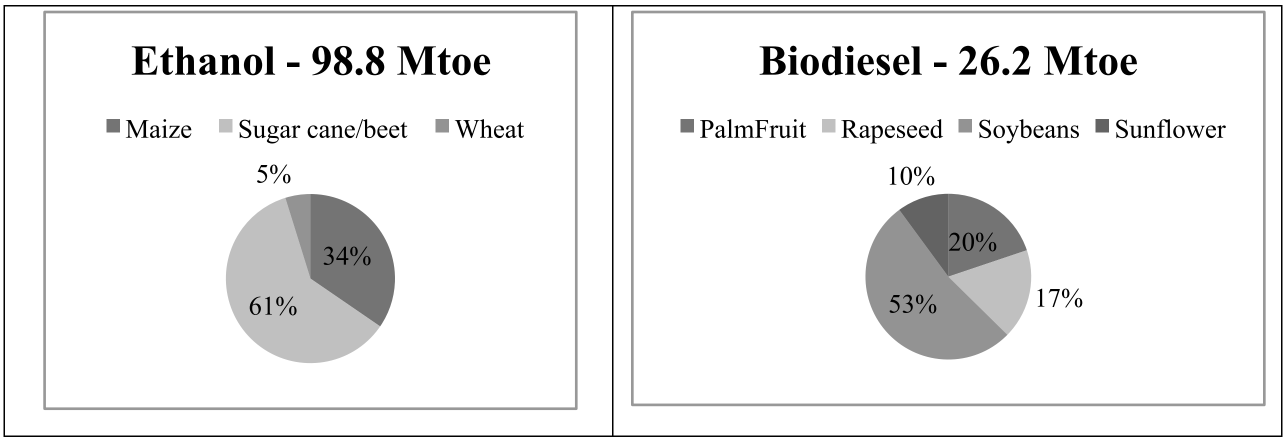
It is important to keep in mind that this study evaluates the impacts of the "incremental" mandate (the additional effort needed to reach the 2020 targets starting from 2008 levels) and not the full mandate in the US and the EU. In the baseline, we freeze the biofuel policies of these two regions in 2008. All tax credits/subsidies remain constant. In 2020, the EU consumption reaches 11 Mtoe, of which 9.1 is provided by biodiesel (3.3% average blending rate). For the US, consumption is about 19 Mtoe (average blending rate of 6.4%) of which 17.8 Mtoe is ethanol.

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. Within this context, there is no significant increase in EU and US demand for ethanol in the baseline and there exists a large demand from the rest of the OECD, the first market for Brazilian exports (80%) in 2020 in the baseline.

The overall world consumption of biofuels will reach 98.8 Mtoe for ethanol (mainly based on sugarcane and sugar beet) and 26.2 Mtoe for biodiesel (of which half is produced from soybean oil). As shown in Figure 6, sugarcane will be the main feedstock for ethanol but maize, driven by the US market will also be quite significant at the global level. Soybeans will be the main feedstock used for biodiesel. It is important to keep in mind that without technological progress in the palm fruit sector this feedstock loses competitiveness compared to the other crops.

**Figure 6 Distribution of Biofuel Production, 2020**
**(*by feedstock, World, baseline*)**




*Source:* Authors' calculations with the MIRAGE-BIOF model

### 4.2.5 Farm Policies

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, since we do not explicitly model the existing sugar policy tool, we mimic the sugar-market reform by reducing the EU MFN tariff on sugar and sugar beet to reproduce the price decrease. Overall, the EU sugar production declines by 10% between 2008 and 2020. The effects of the reform are slightly absorbed by the ethanol industry since sugar beet production declines by only 7.5%.

### 4.2.6 Other Baseline Evolutions

As described previously, 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, sugar beet (+57%) and soybeans (+49%). Demand for cereals faces limited increases (17% for wheat and 24% for maize). These figures are above the FAO-Again 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.

Given these forecasted changes, cropland expansion is expected to reach 1.47 Mios of $km^2$ between 2008 and 2020 (+12%). The largest expansion takes place in Brazil (350,000 $km^2$, half of them extracted from previous pasture land) and in SSA (550,000 $km^2$). In the EU and in the US, the cropland surface will increase moderately between 2008 and 2020: +1% for the former and +3% for the later.

## 4.3 Scenarios

Against this 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. The policy and trade scenarios are designed to answer three questions: (1) What are the impacts of the incremental biofuel policies of the US and the EU on world markets and on Brazil in particular? (2) Does trade liberalization (elimination of tariffs and other duties) on biofuels affect the economic and environmental outcomes of such policies? (3) What will be the effects of discontinued use of imported sugarcane ethanol in the US and the EU?

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 (3.15 Mtoe), 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 RED 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. Based on our previous work and due to the ongoing discussion about the implementation of this target in the EU, 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, of which 40% will be ethanol (approximately 4.4 billion gallons).

The mandate scenarios are combined with different trade policy assumptions. In the first scenario, we assume the status quo: no change between the baseline and the scenario in terms of trade policies. In the second scenario which assumes a unilateral trade liberalization of the biofuels sectors (not the feedstocks) by the US and the 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. In the third scenario, the US and EU discontinue their imports of sugarcane ethanol.

**Box 1 Scenario Descriptions**

- **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;
- **Scenario 2 - Mandate and Trade Liberalization:** Implementation of the EU and US biofuel mandates of targeted consumption of ethanol and biodiesel in 2020, with the assumption of full, unilateral, trade liberalization in biofuels in both countries;
- **Scenario 3 - Mandate without Sugarcane Ethanol:** Implementation of the EU and US biofuel mandates of targeted consumption of ethanol and of biodiesel in 2020, without sugarcane ethanol imports, under a Business as Usual trade policy assumption.

## 5 Results and Discussion

In this section, we present the results of the EU and US mandate scenario along with the two alternative trade policy scenarios, focusing on the potential impacts 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. Aside from results presented in this section, additional results tables are provided in the Annex 1.

## 5.1 Production and Prices

The impacts of the mandate and trade scenarios on production and prices in 2020 are captured as variations relative to the 2020 baseline levels. 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 food prices in Brazil, and on commodity aggregates and oil and fuel prices in major regions.

### 5.1.1 Biofuel Production

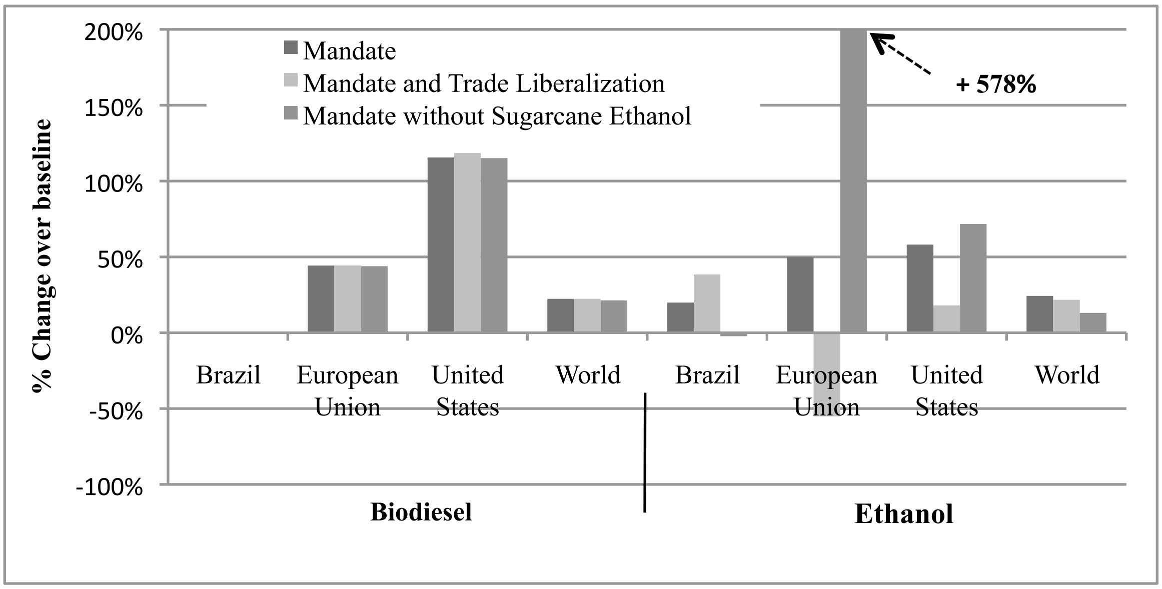
Across all scenarios, global production of biodiesel and ethanol increases to reach the mandated biofuel consumption levels. Because the US policy remains effectively just an ethanol mandate and the EU favors faster growth in ethanol production, biodiesel production will enjoy a much smaller boost compared to ethanol under the mandate scenario. World biodiesel production will reach 32 Mtoe in 2020 while ethanol production will reach 123 Mtoe (Figure 7). 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.

**Figure 7 Domestic Biofuel Production, 2020**




*Source:* Authors' simulations with the MIRAGE-BIOF model

### 5.1.2 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 6, the wheat sector in the EU declines slightly (-0.40%) due the competition of other sectors (sugar beet, 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 drastically boost 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).

Global production of sugarcane and sugar beets will increase by 7.9% in 2020 to support the EU and US mandate production. 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 scenario[18]. When the EU and US markets are closed to sugarcane ethanol, sugar beet production in the EU expands 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 palm fruit, soybeans, and sunflower seeds also experience a larger boost in Brazil under this scenario, as resources become available from sugarcane production.

**Table 6 Feedstock Crop Production, 2020**
**(*1000T and percentage change over baseline*)**

| 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 | US | 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% |
| Sugar beet | EU27 | 126,305 | 4.26% | 0.42% | 13.00% |
| Sugarcane/beet | US | 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 | US | 68,791 | -0.74% | -0.54% | -0.70% |
| Wheat | World | 782,356 | -0.30% | -0.37% | -0.04% |
| Palm Fruit | Brazil | 4,905 | 13.04% | 10.32% | 15.65% |
| Palm Fruit | World | 278,538 | 2.66% | 2.51% | 2.72% |

[18] 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.

| Feedstock crop | Region | Reference level | Mandate | Mandate and trade liberalization | Mandate without sugarcane ethanol |
|---|---|---|---|---|---|
| Rapeseed | Brazil | 149 | 6.82% | 6.61% | 7.26% |
| Rapeseed | EU27 | 25,930 | 3.45% | 3.63% | 2.81% |
| Rapeseed | US | 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 | US | 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 | US | 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

### 5.1.3 Commodity Prices

As shown in Table 7, the EU and US biofuel mandates will result in a small increase in real-world prices of agricultural commodities, especially for feedstock crops. Annex 2 provides a discussion of price changes obtained from partial and general equilibrium models, and indicates why the price changes obtained from our simulations are lower than those obtained using different techniques as documented in earlier literature.

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 the fact that most of the biodiesel traded will come from Southeast Asia and will rely on palm oil.

**Table 7 World Commodity Prices in International Markets (*percentage 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% |
| Palm fruit | 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

In the Brazilian market (Table 8), the rise in commodity prices is broadly consistent with world price increases under the mandate scenario. However, the trade liberalization scenario stimulates greater production of Brazilian ethanol and, consequently, greater demand for factors and inputs for food production and higher food prices. The rise in food prices is alleviated for most commodities under the third scenario when sugarcane ethanol is not supplied in the US and EU markets. The exception is for Brazilian maize that experiences increased demand from the US ethanol market, and some oilseed crops (palm fruit, rapeseed) and vegetable oils (soybean oil) that are supplied to the biodiesel industry.

**Table 8 Food Prices in Brazil (2004=1)**
**(*percentage change over baseline*)**

| | Reference year 2020 | Mandate | Mandate and trade liberalization | Mandate without sugarcane ethanol |
|---|---|---|---|---|
| Cattle | 1.43 | 1.99% | 2.86% | 1.04% |
| Fishing | 1.00 | 0.94% | 1.64% | 0.18% |
| Maize | 1.15 | 2.18% | 1.38% | 2.49% |
| Meat & dairy | 1.05 | 1.44% | 2.32% | 0.49% |
| Other animal | 0.83 | 0.83% | 1.70% | -0.13% |
| Other crop | 0.97 | 1.60% | 2.80% | 0.35% |
| Other food | 0.93 | 1.45% | 2.26% | 0.56% |
| Other oilseeds | 0.96 | 1.47% | 2.59% | 0.30% |
| Palm fruit | 1.33 | 7.87% | 6.88% | 8.49% |
| Palm oil | 1.09 | 5.02% | 4.98% | 4.74% |
| Rapeseed | 1.31 | 4.98% | 4.63% | 4.98% |
| Rice | 1.12 | 0.98% | 1.50% | 0.35% |
| Rapeseed oil | 1.22 | 5.40% | 5.31% | 5.13% |
| Soybeans | 1.19 | 1.99% | 2.03% | 1.71% |
| Soybean oil | 1.31 | 6.97% | 6.76% | 6.79% |
| Sugar | 1.03 | 3.34% | 6.31% | 0.20% |
| Sugarcane | 1.29 | 6.76% | 13.36% | 0.12% |
| Sunflower seed | 1.36 | 4.80% | 4.17% | 5.03% |
| Sunflower oil | 1.21 | 4.60% | 4.26% | 4.57% |
| Vegetable & fruits | 0.99 | 1.27% | 2.13% | 0.32% |
| Wheat | 1.29 | 0.80% | 0.43% | 1.35% |

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

As shown in Table 9, the rise in domestic prices of agricultural commodities in response to 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 SSA. Trade liberalization with the mandate policy will lead to smaller price increases for commodity aggregates in all countries.

**Table 9 Food Prices of Commodity Aggregates (2004=1)**
**(*percentage 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% |
| Primary food | 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% |
| Primary food | EU27 | 1.06 | 0.36% | 0.22% | 0.53% |
| All crops | US | 1.00 | 0.59% | 0.38% | 0.64% |
| Animal | US | 1.02 | -0.15% | -0.06% | -0.23% |
| Primary food | US | 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% |
| Primary food | SSA | 1.25 | 0.33% | 0.16% | 0.50% |

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

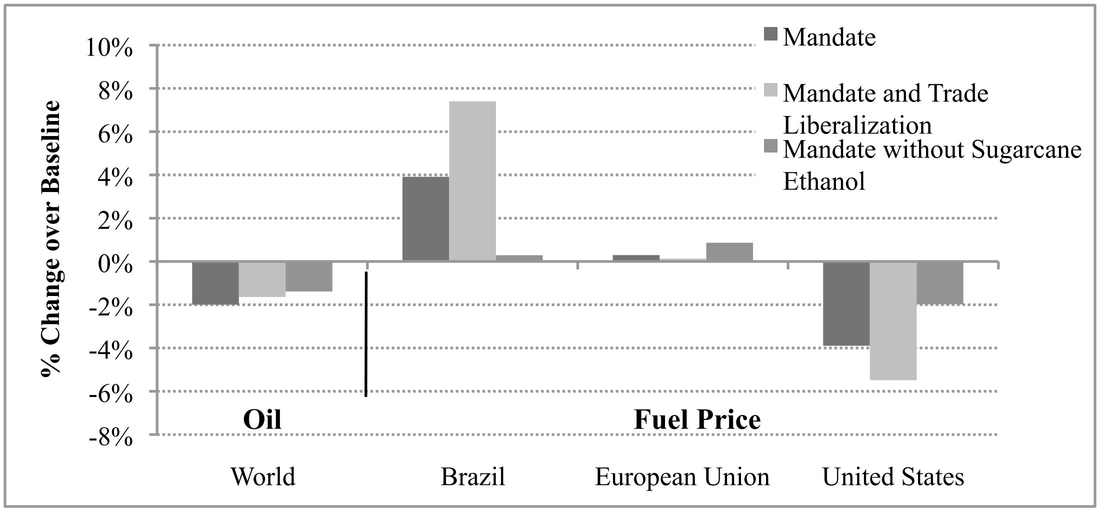
### 5.1.4 Fuel Prices

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 8). The mandate scenario has favorable impacts in terms of transport fuel prices in the US, with a 3.9% decline against the 2020 baseline price[19]. 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 to

[19] 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.

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%.

**Figure 8 Oil and Fuel Prices, 2020**




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

## 5.2 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.

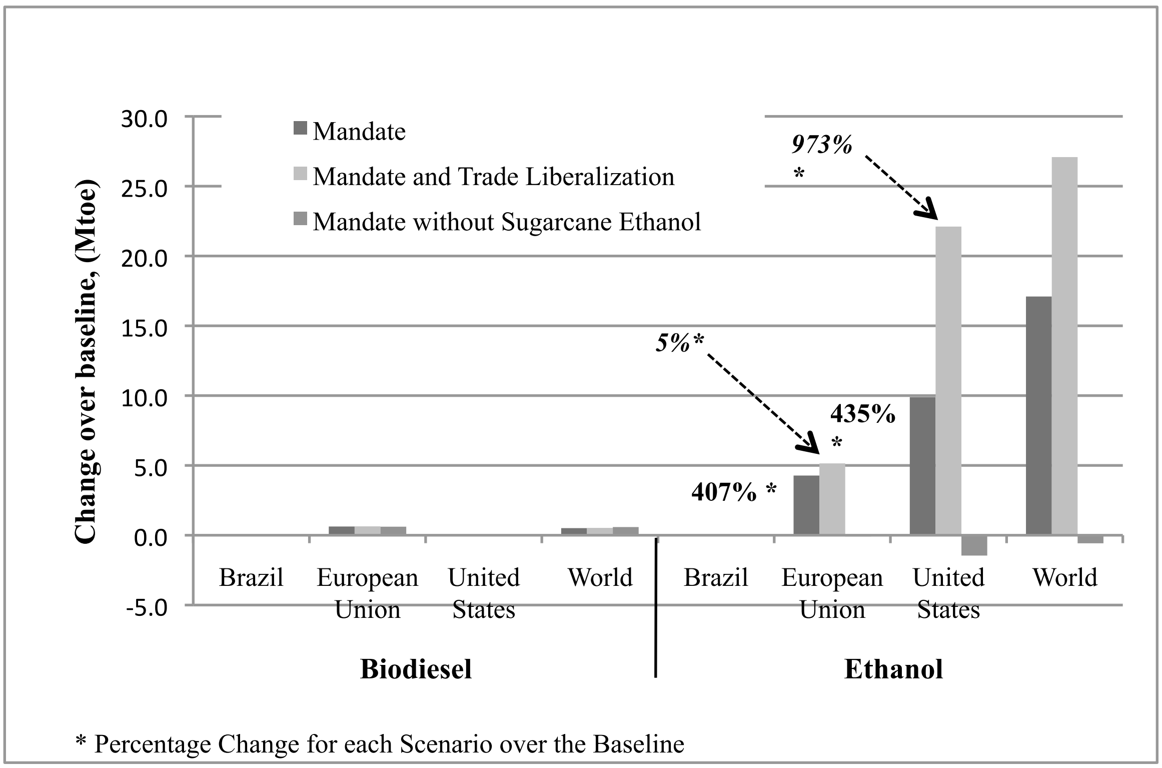
### 5.2.1 Biofuel Imports

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 9). 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 LAC 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 LAC 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 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 9 Biofuel Imports, 2020**
***(Mtoe,)***




*Source:* Authors' calculations with the MIRAGE-BIOF model

### 5.2.2 Feedstock Trade

Aside from their impacts on trade in biofuels, the EU and US mandates also significantly affect trade in biofuel feedstocks. Table 10 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%[20], respectively, to augment their domestic feedstocks for ethanol production.

**Table 10 European Union and United States Feedstock Imports by Trading Partner (*percentage 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 | US | Brazil | 3 | 63.64% | 20.97% | 84.30% |
| Maize | US | EU27 | 95 | 64.98% | 28.35% | 51.57% |
| Palm Oil | EU27 | Brazil | 42 | 36.66% | 29.76% | 43.91% |
| Palm Oil | US | 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 | US | Brazil | 79 | 54.87% | 42.44% | 64.08% |

*Source:* Authors' calculations with the MIRAGE-BIOF model

## 5.3 Macroeconomic Impacts

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

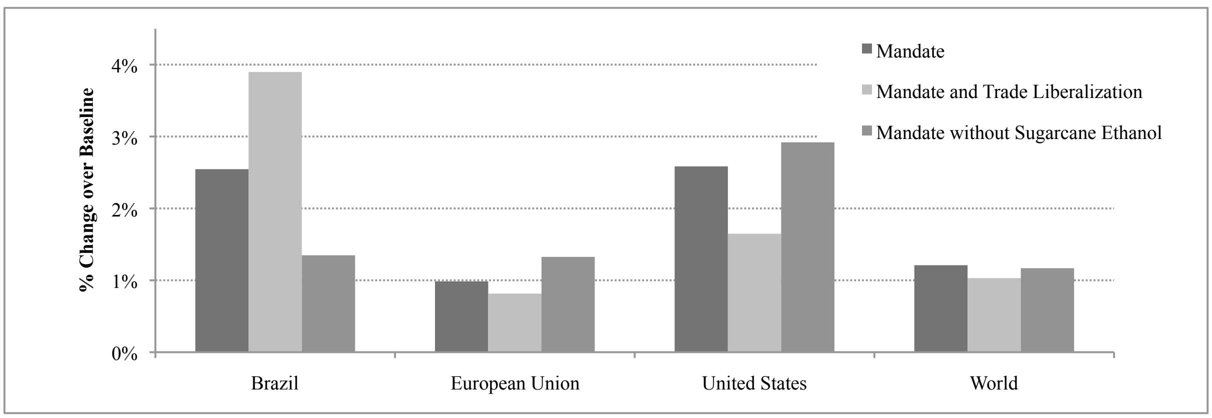
### 5.3.1 Agricultural Value Added

Figure 10 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

[20] The initial level of US imports of corn from Brazil is very low.

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 10 Agricultural Value Added, 2020**




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

### 5.3.2 Employment

The impacts of the mandate on value added in Brazil can be examined more closely in terms of changes in employment of unskilled labor in the different agricultural sectors.

Table 11 shows that the US and EU mandates will increase employment in feedstock crop production in sectors related to ethanol and biodiesel production, such as maize, sugarcane, palm fruit and oil, rapeseed and rapeseed oil, soybeans and soybean oil, sunflower seeds and oil, and ethanol. Employment in sectors such as rice, sugar, meat and dairy, and other oilseeds (not used for biodiesel) will decline. With trade liberalization in ethanol exports to the EU and US, faster growth in employment occurs in the sugarcane and ethanol sectors in Brazil at the expense of employment growth in most agricultural sectors, which either decline or grow more slowly than in the mandate scenario. Under the third scenario, employment in the Brazilian sugarcane and ethanol sectors decline, while employment in the biodiesel feedstock sectors and maize sector expand.

**Table 11 Unskilled Labor in Brazil (Selected Sectors)**
**(*percentage change over baseline*)**

| Agricultural sector | Mandate | Mandate and trade liberalization | Mandate without sugarcane ethanol |
|---|---|---|---|
| Maize | 1.03% | -3.87% | 5.31% |
| Meat and dairy | -0.62% | -0.85% | -0.26% |
| Other oil seeds | -2.76% | -5.75% | 0.25% |
| Palm fruit | 11.36% | 7.67% | 14.80% |
| Palm oil | 12.60% | 10.32% | 14.67% |
| Rapeseed | 5.41% | 4.14% | 6.83% |
| Rice | -1.48% | -2.62% | -0.29% |
| Rapeseed oil | 4.99% | 4.44% | 5.36% |
| Soybeans | 0.48% | -0.77% | 2.04% |
| Soybean oil | 2.50% | 2.00% | 2.93% |
| Sugar | -6.42% | -14.63% | -0.15% |
| Sugarcane | 13.73% | 29.29% | -1.86% |
| Sunflower Seed | 4.41% | 2.94% | 6.00% |
| Sunflower oil | 6.24% | 6.24% | 6.40% |
| Wheat | -2.54% | -4.46% | 0.27% |
| Ethanol (sugar cane) | 20.52% | 43.94% | -1.75% |

*Source:* Authors' calculations with the MIRAGE-BIOF model

The changes in real wages of skilled and unskilled labor, in the agricultural and non-agricultural sector, are shown in Table 12**.** It is the unskilled agricultural labor in the US, EU and Brazil that receives the benefit of increased wages under the mandate policy. Wages of unskilled agricultural labor in Brazil rise by 1.9% with the mandate policy and will see an even larger increase, 3.4%, when the mandate is combined with trade liberalization**.** Under this scenario, skilled labor and unskilled labor in the non-agricultural sectors in Brazil will face wage declines as the expansion of sugarcane and ethanol production leads to stronger demand for unskilled agricultural labor. It should be noted, however, that our results may overestimate the demand for unskilled agricultural labor in 2020, since the model assumes average current technology and does not consider the technological shift with the ongoing increased mechanization in this sector, especially in regions where greater sugarcane expansion is taking place.

**Table 12 Real Wages (Skilled and Unskilled)**
**(*percentage change over baseline*)**

| Region | Labor category | Reference level year 2020 | Mandate | Mandate and trade liberalization | Mandate without sugarcane ethanol |
|---|---|---|---|---|---|
| Brazil | Skilled | 1.47 | 0.15% | -0.01% | 0.11% |
| Brazil | Unskilled -Agri | 1.32 | 1.90% | 3.47% | 0.34% |
| Brazil | Unskilled - NonAgri | 1.31 | 0.02% | -0.11% | 0.04% |
| Brazil | Unskilled – Total | 1.31 | 0.15% | 0.14% | 0.06% |
| EU27 | Skilled | 1.48 | 0.06% | 0.06% | 0.02% |
| EU27 | Unskilled -Agri | 1.24 | 0.23% | 0.20% | 0.30% |
| EU27 | Unskilled - NonAgri | 1.34 | 0.05% | 0.05% | 0.02% |
| EU27 | Unskilled – Total | 1.33 | 0.06% | 0.05% | 0.03% |
| US | Skilled | 1.32 | 0.07% | 0.07% | 0.03% |
| US | Unskilled -Agri | 1.05 | 0.24% | 0.20% | 0.24% |
| US | Unskilled - NonAgri | 1.21 | 0.08% | 0.10% | 0.04% |
| US | Unskilled – Total | 1.21 | 0.08% | 0.11% | 0.05% |

*Source:* Authors' calculations with the MIRAGE-BIOF model

### 5.3.3 Real Income Effects

The real income effects of the EU and US mandates shown in Table 13 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 than 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 SSA[21] 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.

**Table 13 Real Income and Terms of Trade**
**(*percentage 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 | US | 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% |

[21] 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 the population.

| Indicator | Region | Reference year 2020 (US$ billion) | Mandate policy | Mandate and trade liberalization | Mandate without sugarcane ethanol |
|---|---|---|---|---|---|
| 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 | US | | 0.36% | 0.21% | 0.32% |

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

For the EU and the US, the best outcome is the mandate with the status quo on trade policies; 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; 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]).

## 5.4 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 14 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 11). 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 by savannah/grassland (e.g. 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;

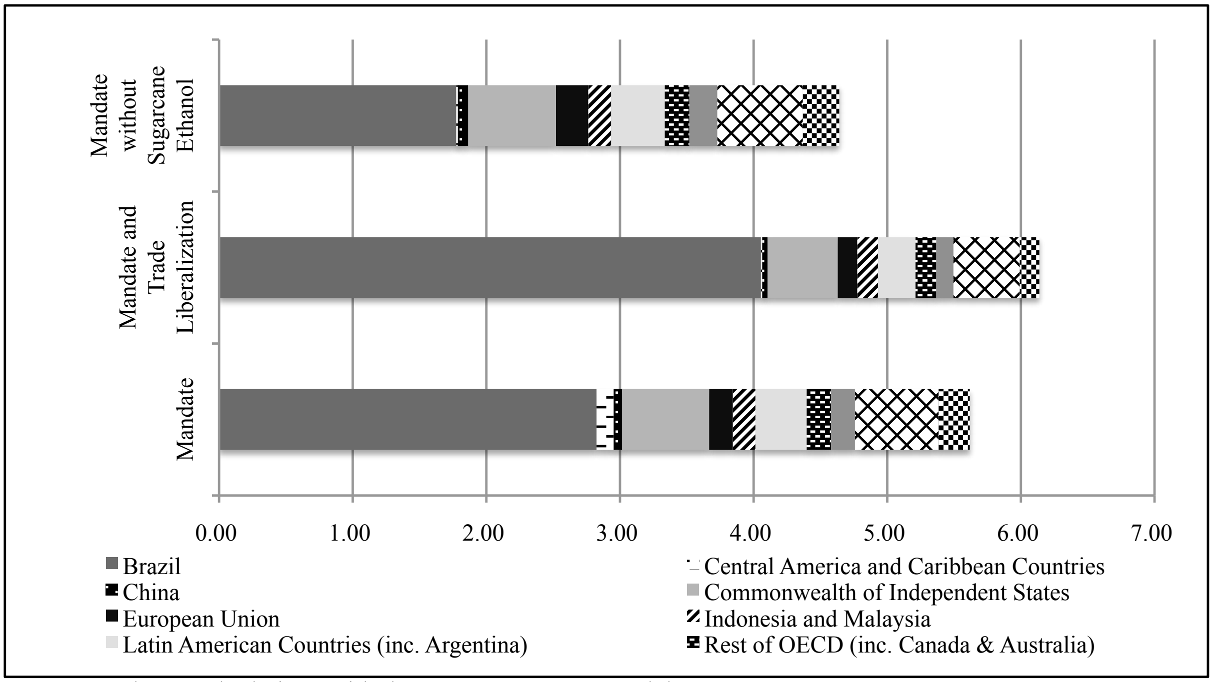
otherwise they will have no incentives to intensify production and may continue with deforestation. The other regions that are affected are the EU, CIS, LAC and Indonesia/Malaysia.

**Table 14 Land Use**
**(*percentage change over baseline*)**

| | | Reference year 2020 (1000 ha) | 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 | US | 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%* |
| Grasslnd | US | 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 | US | 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 | US | 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 | US | 161,001 | | | |
| Primary forest | World | 2,669,467 | *-0.01%* | *-0.01%* | *-0.01%* |

*Source:* Authors' calculations with MIRAGE-Biof Model

**Figure 11 Agricultural Land Extension MHa, 2020**




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

## 5.5 Greenhouse Gas Emissions

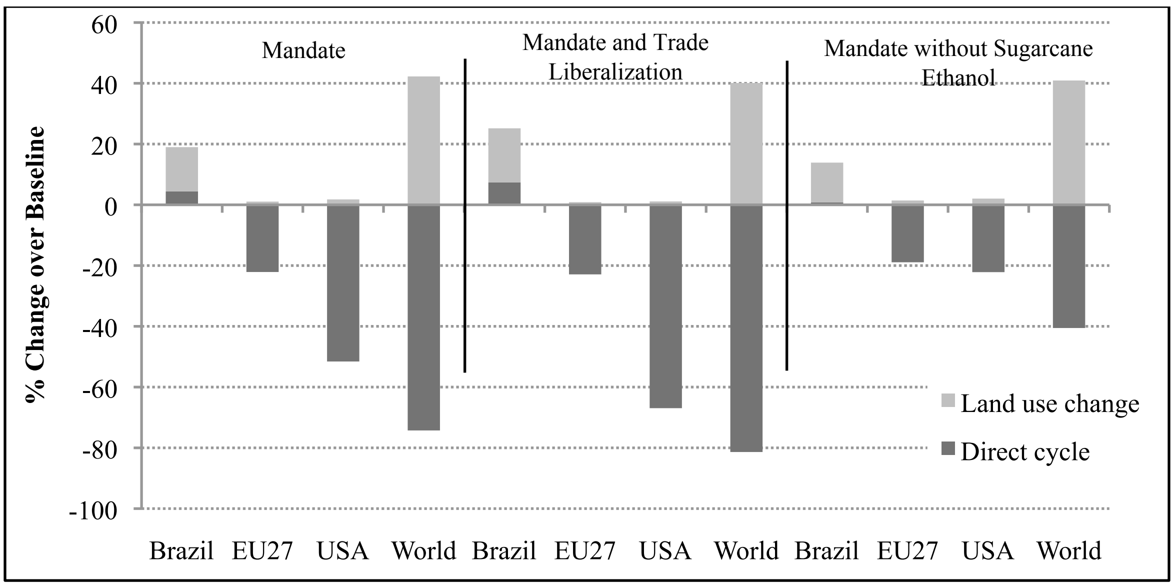
GHG emissions balance accounts for direct emissions savings in the biofuel production cycle and the emissions associated with changes in land use[22]. As shown in Figure 12, the sum of direct emissions reductions[23] generated by the substitution of fossil fuel by biofuels and implied by the mandate at -74 million tons of $CO_2$ 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 $CO_2$ equivalent in 2020. Direct emissions reductions are significantly less (-41 mt$CO_2$eq) 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 mt$CO_2$eq) than under the pure mandate scenario (-32 mt$CO_2$eq). Even if the liberalization leads to more emissions through indirect land-use effects, using efficient imported biofuels delivers a net missions 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.

[22] The GHG emissions from fertilizers and intensification are not captured in this analysis.
[23] Each MJ of fossil fuel is assumed to generate 25gr. of carbon, i.e. about 92 gr. of $CO_2$.

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 reductions[24], but further reductions can be achieved when the trade barriers are removed along with the mandate.

**Figure 12 Emissions Balance, 2020**
**(*MTCO$_2$eq*)**




*Source:* Authors' Calculations using 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 15 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 land-use change 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 -20.8g$CO_2$/MJ under the US and EU mandates, and -28g$CO_2$/MJ if the mandates are not associated with an open trade policy. However, the GHG emissions balance

[24] This does not consider the effects of fertilizers.

turns positive at +7.9 $gCO_2$/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. $CO_2$ variations, which are not directly related to biofuel policies (such as the income effects on the steel industry), are excluded.

**Table 15 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 over a 20-year period ($gCO_2$/MJ) | -20.83 | -27.98 | 7.92 |

*Source:* Authors' Calculations with the MIRAGE-BIOF Model

## 6 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.

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 $CO_2$ 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 $CO_2$ 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 $CO_2$ 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.

# Annex I Additional Results

## Table 16 Biofuel Consumption
### (*percentage change over baseline*)

| Biofuel | Region | Reference year 2020 (Mtoe) | Mandate | Mandate with trade liberalization | Mandate without sugarcane ethanol |
|---|---|---|---|---|---|
| Biodiesel | Brazil | 4.21 | -0.16% | -0.07% | -0.23% |
| Biodiesel | China | 0.18 | -3.63% | -4.70% | -3.07% |
| Biodiesel | EU27 | 9.10 | 45.41% | 45.59% | 44.92% |
| Biodiesel | IndoMalay | 3.78 | 0.68% | 0.58% | 0.50% |
| Biodiesel | LAC | 0.48 | -16.83% | -15.69% | -16.12% |
| Biodiesel | US | 1.25 | 151.66% | 154.85% | 143.89% |
| Biodiesel | World | 26.17 | 22.37% | 22.36% | 21.36% |
| Ethanol | Brazil | 34.90 | -4.61% | -7.74% | -0.83% |
| Ethanol | CAMCarib | 1.28 | 136.73% | -18.22% | -46.13% |
| Ethanol | China | 14.81 | 0.68% | 0.58% | 0.45% |
| Ethanol | EU27 | 1.87 | 250.32% | 250.74% | 249.13% |
| Ethanol | LAC | 0.75 | -6.68% | -1.19% | 0.20% |
| Ethanol | US | 17.80 | 107.07% | 109.70% | 49.90% |
| Ethanol | World | 98.81 | 24.29% | 21.72% | 13.08% |

*Source:* Authors' Calculations using the MIRAGE-BIOF Model

## Table 17 European Union Biofuel Imports by Partner (*percentage change over baseline*)

| Biofuel | Region | Reference year 2020 (Mtoe) | Mandate | Mandate with trade liberalization | Mandate without sugarcane ethanol |
|---|---|---|---|---|---|
| Biodiesel | Brazil | 0.00 | 57.12% | 50.70% | 63.34% |
| Biodiesel | China | 0.00 | 79.16% | 78.99% | 79.46% |
| Biodiesel | IndoMalay | 0.30 | 86.08% | 84.86% | 86.13% |
| Biodiesel | LAC | 0.87 | 41.37% | 42.82% | 39.78% |
| Biodiesel | RoOECD | 0.00 | 84.88% | 189.35% | 88.28% |
| Biodiesel | US | 0.00 | 10.44% | 13.90% | 73.84% |
| Biodiesel | World | 1.18 | 52.86% | 53.82% | 51.80% |
| Ethanol | Brazil | 0.98 | 416.65% | 491.49% | -99.99% |
| Ethanol | CAMCarib | 0.06 | 298.02% | -99.11% | -100.00% |
| Ethanol | US | 0.01 | 121.46% | 5217.11% | 12581.97% |
| Ethanol | World | 1.05 | 407.43% | 490.40% | -8.22% |

*Source:* Authors' Calculations with the MIRAGE-BIOF Model

## Table 18 Biofuel Blending Rates

| Biofuel | Region | 2008 blending rate | 2020 blending rate | Mandate | Mandate and trade liberalization | Mandate without sugarcane ethanol |
|---|---|---|---|---|---|---|
| Biodiesel | Brazil | 1.5% | 6.1% | 6.1% | 6.1% | 6.1% |
| Biodiesel | EU27 | 2.7% | 2.7% | 4.0% | 4.0% | 4.0% |
| Biodiesel | US | 0.1% | 0.4% | 1.0% | 1.0% | 1.0% |
| Ethanol | Brazil | 40.2% | 52.3% | 49.9% | 48.4% | 51.8% |
| Ethanol | EU27 | 0.6% | 0.6% | 2.0% | 2.0% | 2.0% |
| Ethanol | US | 5.1% | 6.0% | 12.2% | 12.2% | 8.9% |
| All biofuels | Brazil | 41.7% | 58.5% | 56.0% | 54.5% | 57.9% |
| All biofuels | EU27 | 3.3% | 3.3% | 6.0% | 6.0% | 6.0% |
| All biofuels | US | 5.2% | 6.4% | 13.2% | 13.2% | 9.8% |

*Source:* Authors' Calculations with the MIRAGE-BIOF Model

*Note:* Figures in this table are additive: the mandate on a single fuel is reported for the quantity of total fuel (gasoline + diesel + biofuel).

## Table 19 Intensification Index for Cultivation (*percentage change over baseline*)

| | | Mandate | Mandate with trade | Mandate without sugarcane ethanol |
|---|---|---|---|---|
| Maize | Brazil | 2.60% | -1.48% | 6.40% |
| Maize | EU27 | 1.37% | 0.46% | 2.42% |
| Maize | US | 3.43% | 1.47% | 4.34% |
| Other crop | Brazil | -1.97% | -3.96% | 0.00% |
| Other crop | EU27 | 0.47% | 0.64% | 0.28% |
| Other crop | US | -0.04% | 0.14% | -0.07% |
| Other oilseeds | Brazil | -1.63% | -4.43% | 0.94% |
| Other oilseeds | EU27 | 0.30% | 0.60% | -0.07% |
| Other oilseeds | US | 0.04% | 0.37% | -0.29% |
| Palm fruit | Brazil | 13.50% | 10.87% | 15.93% |
| Palm oil | Brazil | 14.97% | 11.62% | 18.14% |
| Rapeseed | Brazil | 7.07% | 6.80% | 7.55% |
| Rapeseed | EU27 | 4.46% | 4.62% | 3.80% |
| Rapeseed | US | 1.83% | 2.24% | 1.53% |
| Rice | Brazil | -0.19% | -0.45% | 0.02% |
| Rice | EU27 | 0.01% | 0.01% | 0.05% |
| Rice | US | -0.23% | -0.16% | -0.26% |
| Soybeans | Brazil | 1.91% | 1.59% | 2.47% |
| Soybeans | EU27 | 0.54% | 0.99% | -0.29% |
| Soybeans | US | -0.23% | 0.55% | -0.71% |
| Sugar beet or cane | Brazil | 28.30% | 61.69% | -2.12% |
| Sugar beet or cane | EU27 | 40.55% | 5.07% | 90.39% |
| Sugar beet or cane | US | 2.15% | 0.00% | -0.15% |
| Sunflower | Brazil | 6.00% | 5.48% | 6.69% |
| Sunflower | EU27 | 3.72% | 3.79% | 3.14% |
| Sunflower | USA | 2.09% | 2.32% | 1.79% |
| Sunflower oil | Brazil | 7.20% | 6.36% | 8.09% |
| Sunflower oil | EU27 | 7.05% | 7.04% | 6.35% |
| Sunflower oil | US | 2.11% | 2.99% | 0.96% |
| Vegetable and fruits | Brazil | -1.01% | -1.81% | -0.30% |
| Vegetable and fruits | EU27 | 0.14% | 0.11% | 0.10% |
| Vegetable and fruits | US | 0.70% | 0.34% | 0.83% |
| Wheat | Brazil | -1.00% | -2.08% | 0.86% |
| Wheat | EU27 | -0.23% | -0.43% | 0.38% |
| Wheat | US | -0.53% | -0.42% | -0.40% |

*Source:* Authors' Calculations with the MIRAGE-BIOF Model

## Table 20 GDP and Welfare
## (*percentage change over baseline*)

| Indicator | Region | Reference year 2008 (US$ billion) | Reference year 2020 (US$ billion) | Mandate | Mandate with trade | Mandate without sugarcane ethanol |
|---|---|---|---|---|---|---|
| GDP | Brazil | 617 | 888 | -0.03% | -0.29% | 0.06% |
| GDP | Caribbean | 266 | 375 | -0.01% | 0.01% | 0.03% |
| GDP | China | 1,769 | 4,380 | -0.04% | -0.03% | -0.04% |
| GDP | CIS | 805 | 1,136 | -0.02% | -0.02% | -0.03% |
| GDP | EU27 | 11,536 | 13,761 | 0.02% | 0.02% | 0.00% |
| GDP | IndoMalay | 391 | 635 | -0.01% | -0.02% | 0.01% |
| GDP | LAC | 1,125 | 1,537 | 0.00% | 0.01% | -0.01% |
| GDP | RoOECD | 6,629 | 8,115 | 0.01% | 0.01% | 0.00% |
| GDP | RoW | 3,353 | 5,417 | 0.02% | 0.02% | -0.01% |
| GDP | SSA | 562 | 877 | -0.06% | -0.05% | -0.06% |
| GDP | US | 10,609 | 12,980 | 0.01% | 0.03% | -0.02% |
| GDP | World | 37,662 | 50,101 | 0.01% | 0.01% | -0.01% |
| Welfare | Brazil | 578 | 835 | 0.34% | 0.42% | 0.12% |
| Welfare | CAMCarib | 288 | 406 | 0.13% | 0.01% | 0.01% |
| Welfare | China | 1,630 | 4,194 | 0.00% | 0.01% | -0.01% |
| Welfare | CIS | 726 | 1,030 | -0.65% | -0.55% | -0.46% |
| Welfare | EU27 | 11,607 | 13,857 | 0.05% | 0.03% | 0.02% |
| Welfare | IndoMalay | 321 | 537 | 0.01% | 0.05% | 0.08% |
| Welfare | LAC | 1,091 | 1,491 | -0.14% | -0.11% | -0.08% |
| Welfare | RoOECD | 6,363 | 7,754 | 0.00% | -0.01% | -0.02% |
| Welfare | RoW | 3,231 | 5,254 | -0.42% | -0.35% | -0.31% |
| Welfare | SSA | 551 | 863 | -0.48% | -0.40% | -0.34% |
| Welfare | US | 11,269 | 13,868 | 0.04% | -0.01% | 0.02% |
| Welfare | World | 37,655 | 50,089 | -0.04% | -0.04% | -0.04% |

*Source:* Authors' Calculations with the MIRAGE-BIOF Model

## Annex II Price Changes in Partial and General Equilibrium Models

In the absence of modeled linkages to the rest of the economy, partial equilibrium models (PEMs) tend to overestimate the effect of exogenous shocks on prices and other indicators in their system. There are several PEMs[25] that have been developed and used to explore, and analyze, the implications of various policy mandates. These PEMs focus on the agricultural sector and its policies and attempt to provide policy implications at the country, regional and even global level.

The sectoral structure in these models is highly detailed and allows one to focus on the most recent international interest, mostly recently the global biofuel debate. In trying to address country-level and/or global-policy analysis by using PEMs, other individual modules have to be linked to a central PEM[26]. Despite the extensive level of detail PEMs provide to the sector under study, they do not link that sector of study to the other markets/sectors such as the product, factor and global markets in the system. Factor markets in particular, play a critical role in the long-term adjustments to any shock, for instance, land can be extended or improved through investment and labor will flow to expanding markets thus raising productivity. Most of these mechanisms are endogenous to the economy and PEMs cannot capture them. As a result, the link between policy choices and economic outcomes is not as comprehensive or as encompassing as it would be in a CGE model.

Typically in PEMs, the results show higher magnitudes for the variables of focus. As an example, in an agricultural sector PEM, a mandate targeting increased blending ratios of ethanol with gasoline is considered an exogenous shock and would ultimately increase the demand for feedstock and other crops. The result would be an increase in the price, and supply, of biofuel feedstock, other substitute agricultural crops and activities. In this PEM, the multiplier (direct) effects of such a shock may be concentrated in one sector and are only fed exogenously to the remaining modules to calculate values for indicators of interest. The lack of this intersectoral link

[25] Most notable PE models in the recent literature are; CAPRI (Britz and Wetzel, 2008), AGLINK/COSIMO (OECD, 2007), FAPRI and IMPACT (Rosegrant et al, 2008).
[26] For example, the demand module(s) in CAPRI feed commodity prices to its supply module in order to determine supplier decisions, (Britz and Witzle, 2008) and the IMPACT model is fed water use data by crop and region from a water module (Rosegrant et al, 2008).

and its ensuing iterative process of feeding back and forth within and amongst sectors in the economy leads to results with higher magnitudes than those obtained by CGE models[27].

Once an individual sector is linked to the rest of the economy, as is the case in a CGE model, not only do the direct effects of this exogenous shock leak or transfer to the other sectors and agents in the modeled economy, but also indirect effects also take place to add another layer of analysis to the results. For instance, given the same exogenous shock mentioned above of a biofuel mandate, the resultant increase in feedstock, and other crop supply and prices, may have other sectoral implications outside the agricultural sector.

In a CGE model that models a country that produces ethanol from sugarcane, such a biofuel mandate would lead to an increase in the supply and price of sugarcane. Sugarcane is also an input for sugar, which is a food product and is also a feedstock for producing ethanol. In the case of sugar for food, the increase in the price of sugarcane, may have various effects on the demand for sugarcane in the food processing industry. Assuming that the price elasticity of demand for sugarcane in the food processing sector does not exactly offset the price elasticity of sugar supply in the same sector, ceteris paribus, the demand for sugarcane (to produce sugar for consumption) will change. Depending on the magnitude of this change, there will be back and forth effects on factor allocations, and consequently, factor income allocations, incomes of sugarcane farmers (and other farmers in the system), the sugar producing industry, other sectors in the economy, the consumption of sugar (and thus the consumption and saving decisions of the households), the saving investment balance, the trade balance, the current account balance and finally GDP. However, the process continues by feeding back into the agricultural sector and out again until eventually the system reaches an equilibrium in all its variables.

The increase in the price of sugarcane (and consequently in the price of sugar), in the absence of any support policies for fuel ethanol production, and in the absence of any subsidies on its consumer price and depending on the price of oil, this price increase may lead to an increase in the price of fuel ethanol. In short, the impacts of such a biofuel mandate would not stop with the impacts only on one sector, as in a PEM, in a CGE model the ripple effects of this biofuel mandate (or an exogenous shock) would keep circulating and expanding to include more

[27] The extent of the price, demand and supply responsiveness would depend on the price elasticities as well as the production function(s) assumed for the sector.

sectors and agents so that there are more macro indicators affected, albeit with less magnitude than the typical PEM.

Based on the absence of their intersectoral linkages, PEMs that have analyzed the recent commodity price hikes may not have appropriately reflected the longer-term price trends as previously expected. In the recent literature, there is a renewed debate about a new plateau that now exists for commodity prices after the recent commodity price increase. The movement of commodity prices are a function of several factors, both supply side and demand side that, if they coincide, may bring about the “perfect storm” that led to the 2007/2008 commodity price hikes (Trostle 2008 and Hertel, 2010). The literature states that commodity price variability overwhelms price trends (Baffes and Haniotis, 2010) and that it is difficult to predict future trends based on historic trends alone. Model structure, assumptions used, the time period under study, country-specific stylized factors and global links all contribute to determining commodity price trends and forecasts. Furthermore, commodity markets should not be analyzed in isolation from one another nor from the rest of the economy as they are strongly interlinked through their substitutability and/or complementarity. A CGE model of the biofuel sector would analyze the commodity markets au lieu of the recent biofuel mandates and as such would, given the intersectoral linkages, give rise to results that are more moderate and more realistic in the longer term, than a PEM.

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