# World Market Impacts of High Biofuel Use in the European Union

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**Abstract**

This study examines the world market impact of an expansion in the biofuel sector in the European Union with particular focus on indirect land-use impacts. In the first scenario, an increase of 1 million tonnes oil equivalent (Mtoe) of wheat ethanol use in the European Union expands world land area used in agricultural commodity production by 366,000 hectares, representing an increase of 0.039% in total area. In the second scenario, an increase of 1 Mtoe of rapeseed oil biodiesel use in the European Union expands world land area by 352,000 hectares, representing an increase of 0.038% in total area.

With additional land use somewhat close between the two scenarios, the main difference is the spatial distribution of the sources of additional supply. Because the wheat sector, especially in the European Union, is large (26.4 million hectares), when wheat use for ethanol production expands, most of the adjustment is met within the European Union, with only a 9% reduction in net exports required. In contrast, since the rapeseed sector is smaller (only 7.8 mha in the EU), 57% of additional rapeseed oil used for expanded biodiesel production is supplied from higher imports, allowing substantial adjustment by countries outside of the European Union.

**Keywords:** biofuels, land use, partial equilibrium model, rapeseed oil biodiesel scenario, wheat ethanol scenario.

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## 1. Introduction

An expert consultation of the European Environment Agency (EEA) and Joint Research Centre (JRC) of the European Union on comparing biofuel international land-use change modeling results, hosted by the Organization for Cooperation and Development (OECD), was held in Paris in January 2009. Three initiatives were passed, with the third initiative directing a joint exercise to analyze land-use implications of policy scenarios on the European Union, United States, and the world.[1]

To pursue this initiative, the German Marshall Fund of the United States (GMF) and the European Commission's Joint Research Centre–Institute for Energy (EU-JRC) contracted a group at the Center for Agricultural and Rural Development (CARD group) at Iowa State University to conduct an analysis of the world market impacts of higher biofuel use in the EU using the CARD Model.[2]

The CARD group developed a new baseline that incorporated new model developments that will likely have significant impacts on land-use change estimates. In particular, the trend parameters of yield equations in the model were updated to reflect more recently available yield, production, and acreage data. Moreover, the yield equations in the models were re-specified to introduce price and cost sensitivity of yield

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[1] Draft document circulated by Dr. Robert Edwards of the EU-JRC, Italy.
[2] This modeling system is called the Food and Agricultural Policy Research Institute (FAPRI) Model when the work is performed by Iowa State and its partner institution at the University of Missouri. When Iowa State runs the modeling system on its own, especially when changes in structure, parameters, and specifications are introduced, the system is called the CARD Model.

(i.e., intensification) and the yield drag impact of bringing more marginal land into production (i.e., extensification).

The CARD group, GMF, and EU-JRC agreed to run two scenarios reflecting high biofuel use in the EU relative to the newly developed baseline. Specifically, the first is a high wheat ethanol use and the second is a high rapeseed oil biodiesel use. After each shock in the respective scenario was introduced, the whole system of models was solved to arrive at a new equilibrium. And the impacts of the scenarios were measured in terms of departures of endogenous variables of interest from their baseline level.

The rest of this technical report is organized as follows. Section 2 presents recent developments in the biofuel sector with particular focus on policy initiatives across the world.[3] Section 3 documents the CARD model used in this analysis, highlighting the new yield specification and new assumptions on co-products. Section 4 describes the two scenarios. Section 5 discusses the results of the analysis. And section 6 concludes the report.

## 2.  Recent Developments in the World Biofuel Sector

Continuous, high crude oil prices and concerns about energy security, together with the negative environmental consequences of fossil fuels, have stimulated the rapid expansion of global biofuel production and use over the last few years. As liquid biofuels, ethanol and biodiesel are currently blended with traditional fuels, gasoline and diesel, and serve as renewable fuel alternatives. They have the potential to become complete substitutes for petroleum products, and how much potential is largely determined by the

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[3] This section is summarized from IEA (2009) and OECD (2008). Readers are referred to these sources for more details.

development and adoption of flex-fuel vehicle (FFV) technology. Currently, any gasoline-powered engine can use E10, a mixture of 10% ethanol and 90% gasoline.

According to the International Energy Agency (IEA 2009), global biofuels supply reached 0.8 mb/d (39 Mtoe) in 2008, yet only accounted for about 1.5% of total road-transport fuel. The increase in the use of biofuels happened mainly in North America and Europe. Ethanol is the most widely used liquid biofuel for transportation in the world. Global production reached 17.3 billion gallons in 2008 after a 32% increase in 2007 (RFA 2009).

Figure 1 shows the top 10 ethanol producers in 2008. The United States has become the largest ethanol producer in the world, producing 9 billion gallons of corn-based ethanol. Brazil is the second-largest world producer, with 6.4 billion gallons of ethanol distilled from sugarcane.

Global Ethanol Production, 2008 (in million gallons)

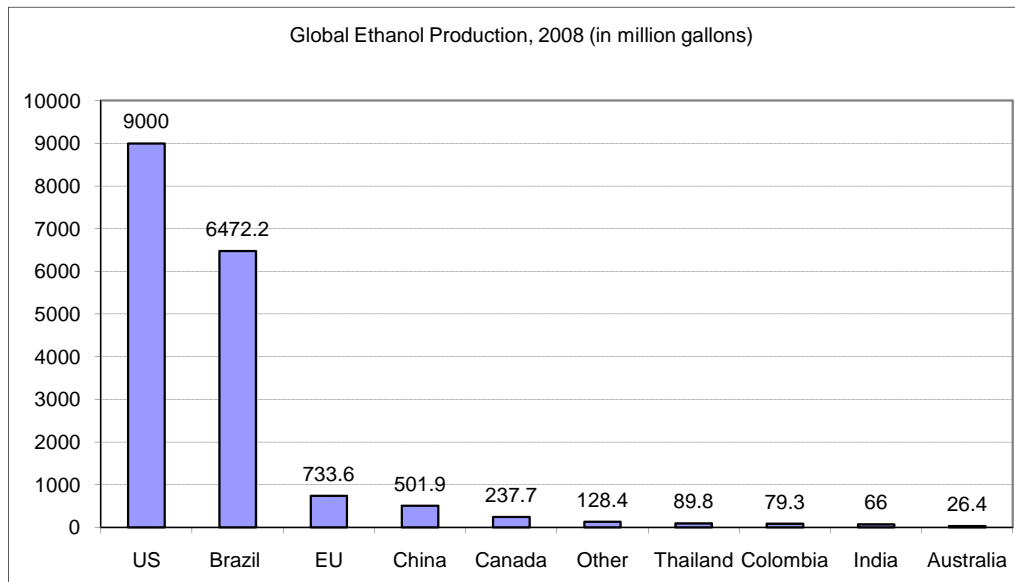| Country | Production |
| --- | --- |
| US | 9000 |
| Brazil | 6472.2 |
| EU | 733.6 |
| China | 501.9 |
| Canada | 237.7 |
| Other | 128.4 |
| Thailand | 89.8 |
| Colombia | 79.3 |
| India | 66 |
| Australia | 26.4 |

**Figure 1. Global ethanol production**

Driven by governmental production subsidies and mandates, Brazil's ethanol production capacity increased dramatically over the past two decades. With extensive production experience, relatively lower labor costs, and suitable sugarcane production conditions, Brazil leads the world in ethanol production efficiency and export market share. On the domestic market, rapid adoption of FFV cars and a developed network of fueling stations make ethanol use account for 45% of total small vehicle fuel consumption.

The EU is the third-largest producer, with 4% of the world's ethanol in 2008, while China accounts for 3% of global production. The other major ethanol producing countries include Canada, Thailand, Colombia, India, and Australia.

Biodiesel production capacity has also grown rapidly over recent years. But compared with ethanol, production of biodiesel is fairly small. With 10.3 billion gallons of capacity, total world biodiesel production was about 3.5 billion gallons in 2008 (F.O. Licht 2008), with the EU as the main producer accounting for about 95% of global production. The EU's capacity in 2008 was about 5.1 billion gallons. The major EU biodiesel producing countries are Germany, France, and Italy.

The production and investment of conventional biofuels have fallen significantly since late 2008. Table 1 shows that total biofuel production capacity, at 0.2 mb/d, is idle. The main reasons include (1) a low crude oil price induced by the financial crisis and world economic recession; (2) weak biofuel prices, which are too low to cover the feedstock and production costs; (3) constrained credit and financing conditions; (4) a limited amount of biofuel that could possibly be blended into gasoline and the diesel pool, the so-called blending wall; and (5) regulatory uncertainties

regarding the savings in greenhouse-gas emissions of the first-generation biofuels. With

ongoing reorganization of the biofuel industry, especially in the United States,

improving market conditions such as lower corn prices will help to bolster the

utilization and profitability of idle production capacity.

**Table 1. Status of Biofuel Production Capacity Worldwide (kb/d)**

|                    | Mid-2008 | September 2009 | New Listings |
|--------------------|----------|----------------|--------------|
| In operation       | 1784     | 2174           | 355          |
| Idle               | 5        | 158            | 145          |
| Shut               | 0        | 55             | 46           |
| Under construction | 820      | 395            | -476         |
| Project            | 864      | 485            | -407         |
| Cancelled          | 23       | 98             | 74           |
| Unknown            | 0        | 137            | 137          |

*Source:* Adapted from IEA (2009), Table 3.4.

The biofuel sector receives different government support measures that affect

biofuel production, distribution, and consumption in various countries. The supporting

policies include (a) a national blending obligation, (b) budgetary support measures such

as subsidies and capital grants, and (c) trade restrictions.

A number of countries have set up national targets for renewable fuels in total fuel

consumption. Table 2 summarizes the targets for selected countries.

Other biofuel support policies besides national targets in selected countries are

discussed in detail next. In the U.S., a $0.51 per gallon tax credit is granted to refiners for

blending ethanol with gasoline. This excise tax credit dropped to $0.45 per gallon in

January 2009 and will expire at the end of 2010. In addition, the U.S. trade restrictions

include a 2.5% ad valorem tariff and a per unit tariff of $0.54 per gallon. The Energy

Independence and Security Act of 2007 (EISA) established a mandate of 36 billion

gallons of renewable fuel by 2022, in which corn-based ethanol remains the main biofuel and will increase by 15 billion gallons until 2015. The amount of biodiesel required by the mandates to be blended into fossil diesel is 500 million gallons by 2009 and at least 1 billion gallons by 2012.

**Table 2. National Targets for Renewable Energy and Fuels in 2010**

| Countries | % of renewable energy sources (RES) in total primary energy | Fuels from RES |
|---|---|---|
| EU-25 | 12% | 5.75% |
| Australia | 350 million liters | |
| Canada | 5% renewable content in gasoline by 2010; 2% renewable content in diesel fuel by 2012 | |
| Japan | 50 million liters of biofuels by 2011 (domestic production) | |
| New Zealand | 90% of total electricity | Mandatory target of 3.4% of total transport fuel sales by 2012 |
| United States | 36 billion gallons by 2022 | |

*Source:* Adapted from OECD (2008), Table 1.2.

Besides the mandatory blending requirements in Table 2, Canada provided $2.2 billion (Canadian dollars) for various programs to support domestic biofuel production. There is also an 11.1% ad valorem tariff on ethanol imports from outside countries under the North American Free Trade Agreement.

The EU applies an import tariff of €10.20/hl and €19.20/hl (33.2% and 62.4% in ad valorem terms in 2007 prices and exchange levels) on denatured and undenatured ethanol, respectively. Imports of biodiesel are subject to a tariff of 6.5%. In the majority of EU member states, the tax for ethanol and biodiesel is either exempt or much lower than those for gasoline and fossil diesel because of applied tax concessions.

The government of Japan provided $92.5 million to stimulate domestic biofuel research and production. Import tariffs are reduced to 20.3%. Brazil requires 20%-25% ethanol content in gasoline and mandates a 2% blend of biodiesel from 2008. The latter has been increased to 5% starting in 2013. Also, there exists a 20% import tariff on both undenatured and denatured ethanol in Brazil.

In addition to its production subsidy, about $172 per ton in 2006, China refunds the value-added tax to ethanol producers. Ethanol is exempted from the 5% consumption tax. The losses from producing and distributing E10 are also covered by the government.

## 3. Documentation of the Model

### a. General description of the CARD Model

This study will rely on models maintained by CARD. The CARD Model is a set of multi-market (multi-commodity, multi-country), non-spatial, partial-equilibrium models. The CARD Model includes econometric and simulation sub-models covering all major temperate crops, sugar, ethanol, dairy, and livestock and meat products for all major producing and consuming countries and calibrated on the most recently available data (see Table 3 for commodity and country coverage). The CARD Model is used extensively for market outlook and policy analysis. Extensive market linkages exist in the model, reflecting derived demand for feed in livestock and dairy sectors, competition for land in production, and consumer substitution possibilities for sets of close substitutes such as vegetable oils and meat types. The CARD model and associated numerical analyses have been validated through numerous academic publications, external reviews, and internal annual updates.

**Table 3. CARD Model Inputs and Output**

| Exogenous Drivers | Historical Agricultural Data | Commodities | Major Countries/Regions* | Endogenous Variables (by commodity and country) |
|---|---|---|---|---|
| Population GDP GDP deflator Exchange rate Population Policy variables | Area harvested Yield Production Consumption Exports Imports Ending stocks Domestic prices World prices | Grains: Corn, Wheat, Sorghum, Barley<br><br>Oilseeds (seed, meal and oil): Soybeans, Rapeseed, Sunflower Palm peanuts<br><br>Livestock & products: Beef, Poultry, Pork<br><br>Dairy: Milk, Cheese, Butter, Milk powder<br><br>Sugar: Beet, Sugarcane, Raw sugar<br><br>Ethanol<br><br>Biodiesel | Algeria, Argentina Australia Brazil Canada China Bulgaria&Romania Egypt EU-25 India Indonesia Israel Japan Malaysia Mexico Other Africa Other Asia Other CIS Other Eastern Europe Other Latin America Other Middle East Pakistan Philippines Russia South Africa South Korea Taiwan Thailand Ukraine United States Vietnam Rest of World | World prices Domestic price Production Consumption by use (food, feed, feedstock, seed, crush) Net trade Beginning stocks Ending stocks Land area harvested Yield |

* Country/region coverage differs from commodity to commodity.

The modeling system captures the biological, technical, and economic relations among key variables within a particular commodity and across commodities. The model is based on historical data analysis, current academic research, and a reliance on accepted economic, agronomic, and biological relationships in agricultural production and markets. In general, for each commodity sector, the economic relationship that supply equals demand is maintained by determining a market-clearing price for the commodity. In countries for which domestic prices are not solved endogenously, these prices are modeled as a function of the world price using a price transmission equation. Since the sub-model for each sector/commodity is linked to the other sub-models, changes in one commodity sector impacts other sectors. Figure 2 provides a diagram of the overall modeling system.
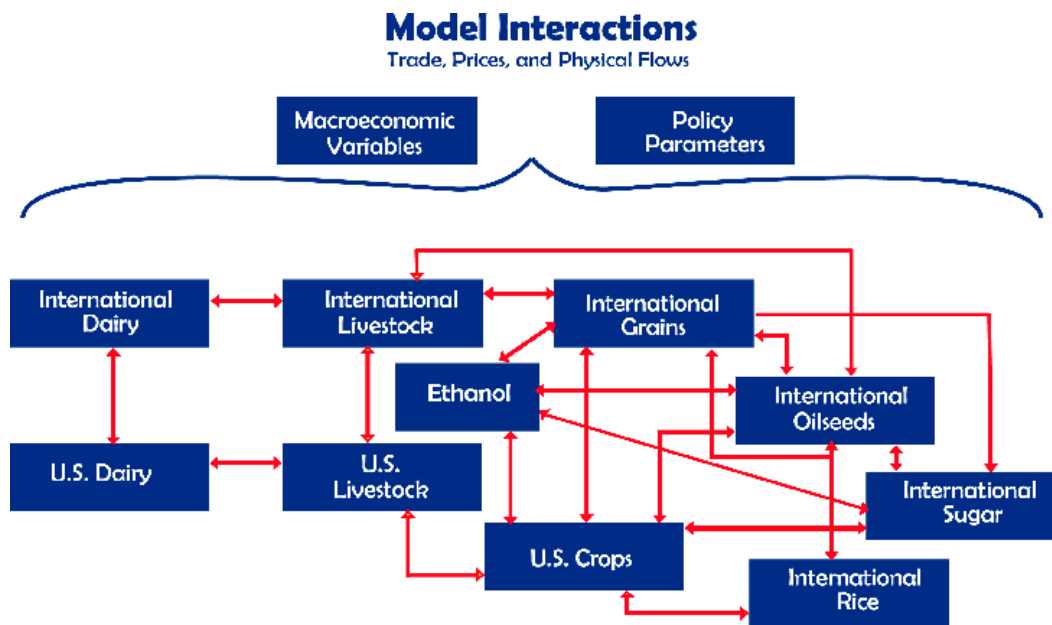


**Figure 2. Model Interactions**

Agricultural supply comes from land harvested multiplied by yields. Land responds to relative agricultural returns reflecting the competition for land among crops

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within defined geographical areas. Oilseeds and grains compete for land in many countries. Within grains, corn and other coarse grains also compete for land. Sugarcane production is often on land unsuitable for other crops. However, it does compete with soybeans in Brazil and with rice in some Asian countries. More specifically, acreage functions in the CARD crops model are expressed as a function of crop prices (own price and the price of competing crops), and lagged acreage and prices. Prices are real, that is, deflated by a gross domestic product (GDP) deflator specific to the country (no money illusion). In all crop area equations, the own-price effects dominates the cross-price effects of competing crops. Symmetry is not imposed. Prices enter acreage functions either as part of real gross returns per unit of land or simply as prices depending on fit and analyst expert opinion.

Because extensive data are available for U.S. agriculture, the U.S. model is divided into nine regions with equations for each crop grown within each region. Expected net returns for the crop and its competing crops determine the planted area under each crop and in each region. The planted area for each crop is adjusted for area under the Conservation Reserve Program. The equation for corn planted area in a given region, for example, is given a linear function depending on net expected returns for corn, barley, cotton, oats, rice, soybeans, sorghum, wheat, sunflower, and peanuts and decoupled payments.

The model is calibrated on 2008/09 marketing year data for crops and 2008 calendar year data for livestock and biofuels, and projections are generated for the period between 2009 and 2023. The model is recursively solved for the annual equilibria. The sub-models also adjust for marketing-year differences by including a residual that is

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equal to world exports minus world imports, which ensures that world demand equals world supply. Elasticity values for supply and demand responses are based on econometric analysis and on consensus estimates.

Agricultural and trade policies for each commodity in a country are included in the sub-models to the extent that they affect the supply and demand decisions of the economic agents. These include taxes on exports and imports, tariffs, tariff rate quotas, export subsidies, intervention prices, other domestic support instruments, and set-aside rates. The models assume that existing agricultural and trade policy variables will remain unchanged in the outlook period.

Data for commodity supply and utilization are obtained from the F.O. Licht online database, the Food and Agriculture Organization of the United Nations (FAOSTAT Online), the Production, Supply and Distribution View of the U.S. Department of Agriculture, the European Commission Directorate General for Energy and Transport, and UNICA—the Brazilian Sugarcane Industry Association, among others. Macroeconomic data such as GDP, GDP deflator, population, and exchange rate are exogenous variables that drive the projections of the model. They were gathered from the International Monetary Fund and Global Insight.

These data sets provide historical data that are used to calibrate the models, and the models provide projections for supply and utilization of commodities and prices. Supply and utilization data include land use, yields, production, consumption, net trade, and stocks.

### b. *Specific description of the CARD biofuel model*

The CARD biofuel model is composed of the ethanol and biodiesel models. The model structure varies from country to country depending on availability of data. They are each described below.

### i. *Ethanol*

The ethanol model covers eight countries and an aggregate called rest-of-the-world. The world representative ethanol price is the anhyrdrous ethanol price in Brazil. The U.S. model has the most detailed structure. The predominant feedstock used in the U.S. is corn. Total ethanol production is the sum of ethanol produced from corn through the dry- and wet-milling processes, ethanol produced from non-corn sources, and ethanol produced from cellulosic feedstock. Corn ethanol production is based on production capacity and capacity utilization, which are both driven by net revenue from ethanol production. The revenue side accounts for both the revenue contribution coming from the main product—ethanol—as well as the by-products such as distillers grain and corn oil. On the cost side, the largest proportion is the cost of feedstock, followed by fuel and electricity, and then other operating costs. The amount of corn that is required for the level of ethanol production is derived by dividing the ethanol production by the ethanol yield. This derived demand for ethanol feedstocks connects the ethanol sector to the corn sector. On the demand side, there are three major components for ethanol: the additive, voluntary E-10 market, and E-85 market. In the ethanol additive market, which is currently the largest component, oxygenation requirements and blend mandates determine the ethanol demand. The E-85 demand is the most elastic relative to the ratio

of ethanol price to unleaded gasoline price. Net trade is based on the relative price of U.S. and world ethanol.

Brazil is the only exporter of ethanol in the CARD Model and uses sugar as the predominant feedstock. Sugarcane production in Brazil is a product of area planted to sugarcane and the yield of sugarcane. The area planted to sugarcane is expressed as a function of a composite price, which includes the price of sugar as well as the price of ethanol. Sugarcane production is then allocated into feedstock for sugar production and ethanol production based on the relative profitability of both competing uses. Ethanol yield from sugarcane is a function of trend to capture technological improvements over time. Ethanol consumption is based on transport fuel demand and the required blend of ethanol. Being the residual supplier of ethanol in the world, Brazil faces an aggregate excess demand from the rest of the countries in the model. The anhydrous ethanol price in Brazil clears the world ethanol market.

The EU ethanol model has a price transmission specification in which domestic EU ethanol price is derived from the world price, expressed in euros, and includes border duties. The ethanol consumption specification is expressed as a function of real EU ethanol price and policy parameters (i.e., EU's biofuel target). Ethanol production is a function of the real ethanol price and real feedstock price (e.g., wheat). Ethanol net trade is the residual to balance the market. Other countries such as Canada, China, and India have a similar specification as that of the EU, in which price is determined by transmission, net trade is residual, and both ethanol production and consumption are specified.

Japan, South Korea, and the rest-of-the-world have net trade equations only, which are functions of the world ethanol price.

## ii. Biodiesel

In response to its growing importance in agricultural markets in general, and oilseeds markets particular, an international biodiesel model was developed and incorporated into the CARD modeling system. This model is able to project prices and supply and utilization of the biodiesel by the main market participants, as well as the derived demand for the different feedstocks. The countries covered are the major producers and consumers, with varying detail depending on data availability. Supply and utilization is modeled for Argentina, Brazil, European Union, and Indonesia. Net trade is projected for Malaysia, Japan, and the rest-of-the-world. For the case of the United States, a detailed module for supply, demand, and price projections is embedded in the domestic CARD crops model. Drivers of supply and demand are chiefly biodiesel and diesel prices, vegetable oil costs, and relevant policies. Policies affecting supply, domestic utilization (e.g., consumption mandates and tax incentives), and trade of biodiesel are explicitly included. The model endogenously solves for a price that equilibrates world supply and demand.

As mentioned above, the model projects the derived demand for vegetable oils used as feedstock for biodiesel in the different countries covered. The dominant type of vegetable oil utilized by the biodiesel industry varies by country/region. For countries in the Americas, soybean oil is the dominant feedstock. Rapeseed oil is the most commonly used raw material in the EU, and that role is occupied by palm oil in southeastern Asian countries. The feedstock needs derived from the biofuel's production directly impact the

international oilseeds market, and these interactions are captured by linkages between the international biodiesel and oilseeds models.

### c. Accounting for by-products (distillers grain)

Ethanol by-products are modeled for the U.S. and the EU. In particular, distillers grain (DG) by-product is derived from the corn (and other grains) used in dry mill ethanol production using an exogenous DG yield. DG use is determined by three factors specified by meat product (i.e., beef, dairy, pork, and poultry), including adoption rate, maximum inclusion rate, and displacement rate. A DG export equation is also specified and the DG price is solved to clear the market in the U.S. The displacement rate is used to estimate the equivalent corn and soymeal that is displaced by DG, which is subtracted from the corn (and other grains) feed demand and soymeal (and other oilseed meals) feed demand.

The same structure is used in the EU except that the displaced feedstock is an aggregate grain, and the specific feed grain that is displaced is a function of the relative price of the different grains used in the EU such as wheat, corn, and barley.

Efficiency gains from the use of DG in feed rations are accounted for in the case of ruminants but not in the case of monogastrics.

Moreover, the proportion of dry mills that adopt fractionation and extract oil from DG is endogenous in the U.S. biofuel model driven by net revenue from fractionation.

### d. New yield specification

The crop yield assumption is key in accounting for land-use changes for greenhouse gas emissions analysis. In particular, three specific aspects of the yield specification are of significant importance: the parameter associated with the trend,

sensitivity of yield response to price changes, and yield impact of extensification. To better address these concerns, we updated the estimates of the trend parameter in the yield equation for all countries using more recent data to ensure that parameters used in yield equations are recent. Second, we developed a method to calibrate the own-price yield elasticity and the extensification elasticity for the rest of the countries covered in the CARD Model with no direct parameter estimates because of data limitations.

CARD re-specified its yield equation in its current model version to include several explanatory variables in order to account for price response as well as the impact of extensification. That is, the yield of crop $i$ is a function of trend, ratio of total revenue to variable cost in period $t$, moving average of the ratio of total revenue to variable cost, and total area planted. The last explanatory variable captures the effect of extensification on yield from the additional new land brought into production. That is, we capture the yield drag as more marginal area is brought into production. The first two explanatory variables capture the short-run and long-run effects of intensification. As an example, in the U.S. Corn Belt, the short-run elasticity to gross returns is 0.013 and the long-run elasticity is 0.074. The elasticity to additional land brought into production is -0.023.

That is, the same structure of the yield equations in the U.S. model is used for all the other countries covered by CARD. Since we are constrained by data limitations to estimate the parameters, we use the U.S. parameters as the base values and calibrate country-specific parameters using some reasonable assumption. First, we consider the response of yield to price in the short run as primarily an allocative adjustment, and we assume that it is the same across all countries. Second, the response of yield to long-run price trend involves some adjustment in technology. As such, we assume that a country

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whose actual yield is far from its yield frontier (or potential) has more opportunities to adjust its technology in response to long-term price changes. In the example below, the U.S. yield is 2.94 times larger than Brazil's yield. Using this as the adjustment factor to calibrate the price response of corn yield in Brazil to changes in long-term price trends gives an elasticity of 0.184 for Brazil. For the yield drag due to the increasing use of marginal lands, we use the relative proportion of available land as basis of establishing a calibration factor. For example, we use a calibration factor of 0.81, which gives an extensification elasticity of -0.018 for Brazil. The same procedure is applied to the rest of the countries covered by CARD.

## 4. Description of Scenarios

This analysis starts with the baseline that CARD developed in the middle of 2009. All models were included:

- U.S. Crops Model

- U.S. Dairy Model

- U.S. Livestock and Poultry Model

- International Grains Model

- International Oilseeds Model

- International Cotton Model

- International Rice Model

- International Dairy Model

- International Livestock and Poultry Model

- International Biofuel (Ethanol and Biodiesel) Model

The CARD baseline extends the projection period from 10 to 15 years. Also, this baseline includes all model developments conducted in the summer of 2009. In particular, trend yield parameter estimates were updated to account for recent yield data. And sensitivity of yield to price changes was introduced together with the impact of extensification on yield. Several other model modifications were introduced and are discussed in more detail in the model documentation section.

The first scenario is labeled as a "High EU Wheat Ethanol Consumption," where the initial shock is an increase in the baseline EU ethanol consumption by 5%[4] beginning in 2010. Also, we held the EU net imports of ethanol and ethanol stocks at the baseline level so that all the increase in ethanol consumption is sourced from additional domestic production. Moreover, ethanol production from all feedstocks (including corn, barley, sugar, and others), with the exception of wheat, is held at baseline level so that all the increase in ethanol production is produced using wheat as the feedstock. With these assumptions, a domestic market-clearing price determination mechanism was introduced in the EU ethanol market. The structural ethanol consumption equation remained active so that the higher ethanol price that results from this initial shock can still dampen consumption as the model solves for new market equilibrium.

The second scenario is labeled as a "High EU Rapeseed Oil Biodiesel Consumption." The implementation of this scenario followed the same pattern as the first scenario. That is, the initial shock is an increase in the baseline EU biodiesel consumption by 5% beginning in 2010. Also, we held the EU imports of biodiesel and ending stocks at the baseline level so that all the increase in biodiesel consumption is sourced from

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[4] The contracting parties agreed that the size of the shock is not so crucial since the results will be divided by the volume of extra biofuel in the initial shock to be comparable with results of other models.

additional domestic production. Moreover, biodiesel production from all feedstocks (including soybean oil, sunflower oil, and others), with the exception of rapeseed oil, was held at baseline level so that all the increase in biodiesel production is produced from rapeseed oil as the feedstock. The biodiesel consumption equation remains active so that the higher biodiesel price that results from this initial shock can still dampen consumption as the model solves for a new market equilibrium.

After the shocks were introduced in each of the scenarios, the whole system of models was used to solve for new market equilibrium in the world for all commodities and all countries. The impacts of the scenarios are measured in terms of the departure of the new equilibrium from the baseline values of endogenous variables of interest. In the discussion of results below, the impacts are reported only for 2023 when the long-run equilibrium condition was imposed. The numbers reported needs to be adjusted with the appropriate factor to standardize the shock to 1 Mtoe.

## 5. Discussion of Results

### a. High wheat ethanol use scenario

In the first scenario, ethanol consumption in the EU increases by 5% from the baseline, which in terms of volume is in the range of 57 to 135 million gallons. This increase in ethanol demand causes the ethanol price in the EU to increase, which dampens consumption. The EU's new ethanol consumption level increases by only 2.48% from the baseline to the new equilibrium.[5] By assumption, all the increase in ethanol use in the EU is supplied by new domestic production, which grows by 3.42%.

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[5] The change in ethanol consumption between the baseline and scenario equilibrium solutions is in the range of 28 to 67 million gallons. To normalize in terms of 1 Mtoe ethanol shock, the results must be multiplied by a factor of 18.310 and 7.732.

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We assume this increase in ethanol production comes entirely from wheat as the feedstock, which increases by 7.84%. Also, distillers grain production in the EU also increases by 4.58%.

At the end of the projection period, the use of wheat for ethanol production increases by 714,000 metric tons in the EU. This is supplied from different sources, with the largest share of supply coming from a 39% increase in production. Of the increase in production, the increase in yield contributes 5% and the other 95% is contributed by the increase in area. The rest of the additional supply comes from a reduction in the other uses of wheat. The decline in wheat feed use accounts for 35%, wheat food use decline accounts for 17%, and a decline in wheat net exports accounts for 9%. The share contributed by the decline in the change in stocks is very small.

With the net ethanol imports in the EU fixed at the baseline level, the impact of this scenario on the world ethanol sector is channeled primarily through the higher feedstock prices such as wheat, corn, and sugar, pushing the world ethanol price to increase by 0.01%.

With increasing demand for wheat as a feedstock in ethanol production, the wheat price in the EU increases by 1.02%. The EU also has lower exportable surplus, with its net exports declining by 0.36%, which pushes the world price of wheat up slightly, by 0.02%, encouraging other exporters to fill in the deficit in the market and importers to reduce their demand.

As the United States and other wheat exporters fill the short supply of wheat in the world, the world wheat price increases by 0.02%, inducing a 0.008% increase in

wheat area in the U.S. and increasing wheat net exports by 0.03%. And with wheat becoming more profitable, less land is planted to corn and soybeans in the U.S.

The impact of this scenario on the livestock sector reveals some interesting differences in the feeding practices of livestock producers. For example, wheat accounts for a substantial share in feed expenditure in the EU. Hence, the livestock sector in the EU is adversely impacted by the increasing use of wheat for ethanol production. As the EU wheat price increases, production of beef, pork, and broiler declines by 0.003%, 0.016%, and 0.018%, respectively. As a result, the EU, which is a net importer of beef and poultry in the baseline, imports more of both meats in this scenario and exports less pork to the world. With a few exceptions, other meat producers in the rest of the world including the U.S. and Brazil have feed rations that are not as dependent on wheat but are more dependent on the other feed grains, particularly corn. So as these countries supply the higher import demand for beef and poultry by the EU, and fill the lower EU pork exports in the world market, the demand for corn and soymeal by the livestock sector increases.

A similar pattern holds for the dairy sector impact. The EU, a net exporter in all dairy products, has lower net exports in this scenario. As a result, the world price of dairy products also increases.

Total world crop area increases by 47,000 hectares, representing an increase of 0.005%. Brazil's pasture area increases by 0.001%.

### b. High rapeseed oil biodiesel scenario

In the second scenario, biodiesel consumption in the EU increases by 5% from baseline levels, which in terms of volume is in the range of 116 to 169 million gallons. A

5% increase in the EU's consumption of biodiesel, holding imports constant, will result in expanded domestic production and increased feedstock demand. Similar to the first scenario, we forced all of that additional demand to be met by rapeseed oil, from both local and foreign origin.

The increased demand puts upward pressure on output prices, and domestic production of biodiesel rises to meet the increased demand. With the net biodiesel imports in the EU fixed, the main impact of this scenario is through the increased demand of rapeseed oil, which is met by a combination of higher net imports (19.35% over baseline levels) and higher domestic production (0.781% over baseline levels). Simultaneously, a 3.23% rise in EU biodiesel prices creates an increase in demand, and the new equilibrium (induced by the demand shock) is obtained at a domestic consumption that is on average 2.34% over baseline levels.[6]

While EU biodiesel production increases by 2.36%, the assumption that all the expanded supplies utilize rapeseed oil as a feedstock implies an increase of production based on that oil of 3.49%. This expanded demand for rapeseed oil in the EU-27 results in a price increase of 5.38% for that vegetable oil. Higher rapeseed oil prices provide incentives for EU producers to expand their crush activities by 0.78%. The enhanced demand for rapeseed leads to a price increase of 3.82%.[7] The rapeseed price increase, and thus incentives to expand area for this crop, are moderated by the production technology in which increased rapeseed meal supply obtains as a result of higher oil demand, as these are jointly produced in relatively fixed proportions. All else equal, the price of rapeseed

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[6] The change in biodiesel consumption between the baseline and scenario equilibrium solutions is in the range of 56 to 75 million gallons. To normalize in terms of 1 Mtoe biodiesel shock, the results must be multiplied by a factor of 5.937 and 4.427.
[7] Globally, rapeseed crushing increases by a somewhat lower magnitude (0.69%) over baseline levels.

meal declines when the demand for that crop's oil increases. For this scenario, the price of rapeseed meal declines on average by 5.57% from baseline levels.

The area of rapeseed harvest in the EU is expected to increase 0.58% in response to the resulting higher price of the seed. Worldwide, the area devoted to this crop increases by 0.65%. However, as reported earlier, most of the increased rapeseed oil demand in the EU-27 is met through increased imports. This enhanced EU-27 import demand is met through a combination of increased exports by countries such as Canada, Australia, and the CIS block and reallocation of trade from other parts of the world.

The price increase in rapeseed oil shifts some demand away to other vegetable oils such as those derived from soybeans, sunflower, and palm, putting some pressure on their prices. The prices of soybean and sunflower oil increase by 0.79% and 1.05%, respectively, over the baseline. Simultaneously, the depressed rapemeal price (combined with higher vegetable oil prices) reduces the prices of soybean and sunflower meal by 1.12% and 2.53%, respectively. The combined impact is a dampened price change for soybean seeds at 0.012%.

At the end of the projection period, the use of rapeseed oil for biodiesel production and other industrial uses increased by 275,000 metric tons. This is supplied from different sources, with the largest shares of 57% and 31% coming from increases in net imports and production, respectively. Most of the rest of the additional supply comes from an 11% reduction in the food uses of rapeseed oil, with a reduction in ending stocks accounting for the small balance.

A reduction in protein meal prices has the impact of lowering feed costs, expanding world supplies, and reducing EU prices of beef, pork, and poultry by 0.041%,

0.166%, and 0.110%, respectively. For the cases of poultry and beef, the cost reductions dominate the price increase, which results in production increases and lower net imports.

The response of the pork sector is somewhat different. It is dominated by the lower net exports of pork, as other countries also benefit from the lower feed cost. As a result, the price of pork in the EU declines, overwhelming the cost reduction derived from cheaper protein meals and reducing production by 0.005%. On the other hand, consumption increases by 0.013% in response to the lower prices. Also, it should be noted that the cost reduction is partially offset by increases in the prices of grains in the feed, in particular, wheat. The price of this grain in the EU-27 increases by 0.639%.

The price of milk and dairy products (with the exception of nonfat dry) decline over the projection period. However, the net trade results are mixed, with net exports of butter and cheese increasing, while those of nonfat dry and whole milk powder declining for this scenario.

Total world crop area increases by 90,000 hectares, representing an increase of 0.0096%.


### 6.  Summary and Conclusion

This project analyzes and quantifies the effects of increasing ethanol as well as biodiesel consumption in the European Union on EU and world agricultural markets. By assumption, all the increases in ethanol and biodiesel use in the EU are supplied by new domestic production coming from wheat and rapeseed oil, respectively. Two scenarios were run accordingly using the international CARD/FAPRI modeling system with new model developments.

The major effects of EU expansion of ethanol consumption, which is met by domestic production from wheat as the feedstock, occur through wheat prices trickling down to other crop prices. Higher ethanol demand pushes up the ethanol price and leads to higher production in the EU. With increasing demand for wheat as a feedstock in ethanol production, both wheat production and the wheat price in the EU increase. Higher domestic demand for wheat causes a lower exportable surplus, with wheat net exports declining. Consequently, the world price of wheat increases slightly. The United States and other wheat exporters increase the supply of wheat to the world market to compensate for the short supply from the EU. U.S. wheat exports increase 0.03% and wheat area increases 0.008%. With wheat becoming more profitable, less land is planted to corn and soybeans in the United States.

As wheat accounts for a substantial share of the feed ration in the EU, livestock and dairy production are adversely impacted by the increasing use of wheat for ethanol production. The EU either imports more or exports less meat and dairy products in this scenario.

In the second scenario, increased biodiesel consumption, which is assumed to be met by expanded domestic production from rapeseed oil, results in a higher biodiesel price as well as higher domestic production and net imports of rapeseed oil. A higher rapeseed oil price directly induces higher crush activities, leading to an increase in rapeseed production and a higher price as well as an increase in the rapeseed meal supply. A higher price of rapeseed causes expansion of its planting area in both the EU and the world while a sufficient rapeseed meal supply dampens the meal price.

A reduction in protein meal prices transmits to livestock and dairy production costs. Because the proportion of meal in the broiler feed ration is higher than that in the beef and pork feed ration, the poultry price declines more than do beef and pork prices. Therefore, the increase in poultry consumption is bigger than the increases in either pork or beef consumption. In addition, beef consumption in many countries declines because of strong substitution effects between poultry and beef. EU beef and poultry imports decrease. Also, EU pork exports decline as world trade demand declines because of production expansion in most importing countries.

Because of lower meal prices, world dairy prices decline over the projection period except for the price of butter. Consequently, world dairy trade demand increases. As world cheese prices decline less than other dairy prices, more milk is diverted to cheese production in most countries. A lower supply of butter in the world markets results in higher world butter prices. In the EU, as rapeseed oil is cheaper, consumers switch from butter to rapeseed oil, and butter consumption declines. Because the production of cheese is more profitable than the butter/nonfat dry production, more milk is diverted to cheese production in the EU. EU cheese production increases while butter and nonfat dry production decreases. Lower domestic consumption and higher world prices cause the EU to export more butter.

Given the emerging nature of the world ethanol and biodiesel markets, our study comes with some caveats. Limited data availability for ethanol markets makes econometric estimations of elasticities used in the biofuel model difficult. The scenario results provided here are dependent upon several assumptions, such as the ability of the livestock sector to adapt to the use of biofuel co-products in feed rations. As

entrepreneurs around the world push for new breakthroughs in biofuel and co-product

production and usage, it is possible that some of the assumptions used for this analysis

may need to change.

## 7. References

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