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Keywords
bioeconomic models, energy, trade analysis and policy

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Abstract

The objective of this study is to analyze the impact of crude oil prices on the EU agricultural sector in an era when the biofuels sector is expanding because of policy initiatives and the desire to find alternative fuel sources. To this end, first a baseline is set up for the EU ethanol, grain, and dried distillers grains markets. In the next step, two different scenarios are run. The first scenario incorporates a 10-Euros-per-barrel increase in the EU crude oil price with the ethanol import tariffs in place. The second scenario incorporates the same shock with the ethanol import tariffs removed. In the first scenario, higher crude oil prices increase ethanol consumption, production, and therefore grain prices. In the second scenario, the impact of trade liberalisation is larger than the impact of the higher crude oil price. So, grain prices decline in this scenario despite an expansion in ethanol consumption. If there were a high enough crude oil price shock, which would affect the EU ethanol market more than trade liberalisation, the net impact on grain, feed, and food prices from the crude oil price shock would be mitigated by the increased trade from trade liberalisation. The study shows that the impact of energy prices on the EU agricultural sector is increasing with the emergence of the biofuels sector. It also illustrates the importance of trade policy in responding to higher crude oil and grain prices.

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1. Introduction

The biofuels sector in the EU is expanding rapidly because of the policy initiatives enacted by the European Commission (EC) and the member states and the high level of crude oil prices. The main objectives of these measures are to find alternative sources of transportation fuel other than crude oil and to provide new sources of demand for agricultural commodities. This development links the energy and the agricultural sectors of the EU much more strongly than before, making it crucial to understand and analyze this new link between the energy and the agricultural sectors.

There have been multiple studies that have analyzed the EU biofuels sector and its impact on the agricultural sector. Gohin (2008) examined the impact of the EU Biofuels Directive, if the indicative targets are met, on the EU agricultural markets. The study used a computable general equilibrium (CGE) model of the EU-15 economy. It found that meeting this target will have significant positive impacts on the prices and production of arable crops. Banse et al. (2008) assessed the implications of the EU Biofuels Directive on the EU and world agricultural sector. They also analyzed the impact of higher crude oil prices on these markets. The study showed that higher crude oil prices lead to higher biofuels demand, which in turn increased biofuel imports and production. Arable crop production increased, with a larger share of agricultural land going into biofuels.

The objective of this study is to analyze the impact of crude oil prices on the EU[1] agricultural sector and the relevant policy implications, in an era when biofuels' share in energy consumption is increasing rapidly. To this end, first a baseline is set up for the EU ethanol, grain, and dried distillers grains (DDG) sectors. In the next step, two different scenarios are run. The first scenario incorporates a 10-Euros-per-barrel increase in the EU crude oil price with the ethanol import tariffs in place. The second scenario incorporates the same crude oil price shock with the ethanol import tariffs removed. In the first scenario, higher crude oil prices increase ethanol consumption, production, and therefore grain prices. In the second scenario, the impact of trade liberalisation is larger than the impact of the higher crude oil price. So, the grain prices decline in the second scenario despite an expansion in ethanol consumption. If there were a high enough crude oil price shock, which would affect the EU ethanol market more than trade liberalisation, the net impact on grain, feed, and food prices from the crude oil price shock would

[1] EU, in this article, refers to all 27 member states.

be mitigated by the increased trade from trade liberalisation.

This article offers a number of contributions to the literature on EU ethanol markets. It provides a detailed model of the EU ethanol market, with linkages to the grains, energy, and DDG markets. This allows the model to capture both the direct and the indirect effects of energy markets on the agricultural sector of the EU. An EU ethanol model is embedded within an international ethanol model, where the world price of ethanol is endogenous. This allows a change in the EU ethanol imports to impact the world ethanol markets and price.

In the following paragraphs, first the EU biofuel policies and then the EU ethanol markets are described. Next, the structures of the international ethanol model, EU ethanol model, DDG model, and grains model are explained. A concise description of the data sources is also provided. After introducing the policy reform scenarios, the key results of the simulations are discussed, followed by the conclusions.

2. EU Biofuel Policies

The EU has a growing ethanol market because of measures implemented in the member states to promote biofuels. The most important one of these measures is the EC's targets for including renewable fuels in the transportation sector's fuel consumption. The EC renewable fuels directive of 2003 promoted the use of biofuels and other renewable fuels for transportation by setting a goal for member states to achieve a 2% share of renewables by the end of 2005 and a 5.75% share by the end of 2010, though these shares are non-binding. In January 2007, the EC proposed a binding 10% target for biofuels in transport fuel by 2020 for all member states (USDA, FAS GAIN Report 2007). In December 2007, the EC had another proposal that suggested that all member states should ensure that 6.5% of their transport fuel consumption comes from biofuels by 2012, in order to be able to reach the legally binding target for 2020. The proposal also states that biofuels should deliver a minimum level of greenhouse-gas savings, should not be produced from raw material cultivated on land converted from high-carbon-stock or high-biodiversity uses, and raw material of EU origin should respect cross-compliance standards (F.O. Lichts 2007). The objectives of promoting biofuels also include reducing greenhouse-effect gas emissions in the context of the Kyoto Protocol. Under the Kyoto Protocol, the EU has committed to an 8% reduction in carbon dioxide emissions by the end of 2012.

Furthermore, there is special assistance for growing energy crops, which was introduced in 2003. A premium of 45 Euros per hectare is paid, for a maximum guaranteed area of 2 million

hectares (from 2007). Farmers can also grow energy crops on the mandatory set-aside land. However, set-aside land planted with energy crops is not eligible for the premium (Bamiere et al. 2007).

These policies have been effective in increasing biofuel production and consumption in the EU. Biofuel consumption in the EU reached a 1.8% share of the total consumption of fuels for transport in 2006 compared to 1% in 2005. In 2006, biodiesel represented 71.6% of the energy content of biofuels dedicated to transport, whereas ethanol had 16.3%, and other biofuels had 12.1% (Biofuels Barometer 2007). The increase in biofuel consumption has increased the demand for feedstocks used in ethanol production and vegetable oil used in biodiesel production. This demand increase combined with supply shortages has caused a dramatic increase in grain and oilseed prices in the EU in the 2007/08 marketing year.

Another source of supply of ethanol in the EU is imports, mainly from Bolivia, Brazil, Egypt, Guatemala, Pakistan, Ukraine, and the United States. In the EU, ethanol is subject to an import duty of 0.386 Euros per gallon (10.2 Euros per hectoliter) for denatured alcohol, and 0.727 Euros per gallon (19.2 Euros per hectoliter) for undenatured alcohol. In 2006, 15% of ethanol imports to the EU were denatured, whereas in 2007 this ratio dropped to 9.4%. These import duties do not apply to countries that are part of the Generalized System of Preferences (GSP) within the Least Developed Countries (Everything But Arms) Initiative, the GSP + granted to 14 countries including most Latin American countries, or those that are part of the Cotonou Agreement. There are also special agreements for ethanol imports from Egypt and Norway. However, Brazil and the United States, which are major producers of ethanol, are not among these countries. Thus, they face the high Most Favored Nation (MFN) import tariffs, discussed above (Bamiere et al. 2007).

3. Development of EU Ethanol Markets

In the EU, the main biofuel is biodiesel, followed by ethanol and ETBE. Biodiesel constitutes approximately 80% of biofuels used for transportation (USDA, FAS GAIN Report 2006). Ethanol is made from wheat, sugar beet, barley, rye, corn, and wine alcohol. Germany, Spain, and France are the major producers of ethanol in the EU, followed by Poland and Italy. Ethanol is blended with conventional gasoline in any proportion up to 5%. ETBE, produced from ethanol, is 50% ethanol and 50% Isobutylene. It is blended with gasoline up to 15% in many EU countries, such as France and Spain (Kojima, Mitchell, and Ward 2007).

In producing ethanol from cereals, a by-product is DDG, which can be fed to animals as a replacement for feed grains. The EU imports DDG as well as producing it domestically. In 2006, EU imported 204 thousand metric tons of distillers and brewers grain from the U.S. and 17 thousand metric tons from other countries. In 2007, imports from the U.S. were 194 thousand metric tons.

The ethanol sectors in many EU member states have responded to policy initiatives and have started to grow rapidly. EU ethanol production was 267 million gallons in 2005 and it increased to 451 million gallons in 2006 and to 773 million gallons in 2007. Ethanol consumption also expanded rapidly. From 254 million gallons in 2005, it increased to 415 million gallons in 2006 and reached 653 million gallons in 2007. Net imports of ethanol also increased to meet the growing demand. Net imports were 17 million gallons in 2005, 119 million gallons in 2006, and 158 million gallons in 2007.

4. International Ethanol Model

The international ethanol model used in this study is a non-spatial, multi-market world model consisting of a number of countries, including a Rest-of-World aggregate (ROW). The general structure of the country model is made up of behavioural equations for production, consumption, stocks, and net trade. Complete country models are established for the U.S., Brazil, EU, Canada, China, and India, while only net trade equations are set up for Japan, South Korea, and ROW. The model solves for a representative world ethanol price (Brazilian anhydrous ethanol price) by equating excess supply and excess demand across countries. Using price transmission equations, the domestic price of ethanol for each country is linked to the representative world price through exchange rates and other price policy wedges. For the U.S. and the EU ethanol models, a domestic ethanol price is solved by equating excess supply with excess demand in these countries.

5. EU Ethanol and Grain Models

The EU ethanol model, which is embedded within the international ethanol model, endogenously solves for a domestic ethanol price for the EU market, by equating supply and demand of ethanol in the EU.[2] The demand for ethanol is composed of two behavioural equations; one for final energy consumption by the transportation sector and one for the share of

[2] The structure of the EU ethanol model is similar to that of the U.S. ethanol model described in Elobeid and Tokgoz (2008).

ethanol in final energy consumption. Ethanol production depends on the net profit margins for ethanol producers. The net import equation depends on the ratio between the domestic and the world ethanol price with the necessary policy wedges. Ethanol production from the ethanol model is utilized to derive the production of DDG and the grain use of ethanol in the EU. The grain used for ethanol is divided into wheat, corn, barley, and rye demand and then linked to the EU grain model by adding their demand to total grain demand in the EU. The EU DDG model consists of DDG production as a by-product of ethanol production, and behavioural equations for DDG consumption and net trade. A DDG price for the EU is solved by equating excess supply with excess demand in the EU.

EU ethanol and DDG models are linked to the EU grains model through demand for feedstocks by the ethanol sector, the grain prices that impact the ethanol producers' costs of production, and the substitution between DDG and other grains for feed use in the livestock sector. The grain prices in the EU are solved endogenously by equating excess supply to excess demand in each grain market. There are behavioural equations for crop acreage, yields, feed demand, non-feed demand, stocks, and net trade. Next is a description of the EU ethanol and DDG models in detail. The elasticities used in the models are given in Appendix A. All prices in the model are expressed in real terms.

Ethanol Demand

The demand for ethanol is composed of two behavioural equations. The first one is final energy consumption by the transportation sector. The second one is demand for ethanol per unit of final energy consumption. Since the ethanol market is closely linked to the energy market, it is crucial to model the link between these two sectors.

Let D_{Energy} denote the final energy consumption in transportation in million gallons of oil equivalent:

$$D_{Energy} = \alpha_1 + \beta_1 \cdot P_G + \phi_1 \cdot GDP\,, \tag{1}$$

where GDP is real gross domestic product in 2000 Euros. P_G is the domestic price of gasoline in Euros per gallon in real terms and is a function of the EU crude oil price through a price transmission equation. The EU crude oil price is a function of the world crude oil price, for which the NYMEX crude oil futures price is used for the projections. In equation (1), $\beta_1 < 0$ and $\alpha_1, \phi_1 > 0$.

Share denotes the share of ethanol consumption in final energy consumption in million gallons.

$$Share = \alpha_2 + \beta_2 \cdot P_E + \phi_2 \cdot P_G + \delta_2 \cdot Policy, \quad (2)$$

where P_E is the domestic price of ethanol in Euros per gallon in real terms. *Policy* is the target set by the EU renewable fuels directive of 2003 and the EC's proposal of 2007 in percentage terms. The policy target is included to capture its impact on the expectations of economic agents, although it is not binding in the model. In equation (2), $\alpha_2, \phi_2, \delta_2 > 0$ and $\beta_2 < 0$. Since ethanol and gasoline are modeled as close substitutes, both ethanol and gasoline prices are included in the equation for the share of ethanol with opposite coefficient signs. Ethanol consumption equals D_{Energy} multiplied by *Share*.

Ethanol Supply

To model the domestic ethanol production in the EU, a profit function for the ethanol plants is used. The profit is expressed as net return per metric ton of feedstock net of capital and operating costs. To account for the different feedstocks in ethanol production, the relative marginal costs from each feedstock are weighted by the share of that feedstock in total production. s_{CN} is the share of corn-based ethanol production in total ethanol production, s_{WH} is the share of wheat-based ethanol production, s_{BA} is the share of barley-based ethanol production, and s_{RY} is the share of rye-based ethanol production. These shares are computed based on historical averages for the EU ethanol industry (USDA, FAS GAIN Report 2007).[3] Thus, the net return for ethanol plants, π^{NET}, is written as

$$\pi^{NET} = (\gamma_E \cdot P_E) + (P_{DDG}) - (s_{CN} \cdot P_{CN}) - (s_{WH} \cdot P_{WH}) - (s_{BA} \cdot P_{BA}) - (s_{RY} \cdot P_{RY}) - CC - OC .$$

In Euros per metric ton, P_{DDG} is the domestic price of DDG, P_{CN} is the price of corn, P_{WH} is the price of wheat, P_{BA} is the price of barley, and P_{RY} is the price of rye. CC is the capital cost of ethanol plants and OC is the operating cost of ethanol plants in Euros per metric ton.[4] A conversion rate (γ_E) is used to convert the ethanol price to Euros per metric ton.[5]

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[3] s_{CN} is 22%, s_{WH} is 39%, s_{BA} is 6%, and s_{RY} is 17%. The remaining 16% of ethanol production is from wine alcohol. These shares are kept constant in the projections.

[4] Capital cost is 32.14 Euros per metric ton and operating cost is 80.34 Euros per metric ton in nominal terms (IEA 2004).

Ethanol production (Y_t) is given as

$$Y_t = \alpha_3 + \beta_3 \cdot \pi_t^{NET} + \theta_3 \cdot \pi_{t-1}^{NET} + \tau_3 \cdot Trend + \delta_3 \cdot Policy, \quad (3)$$

where, $\alpha_3, \beta_3, \delta_3, \phi_3, \delta_3 > 0$.

Ethanol Trade

For trade, a net import equation is used. The import tariff rate is different for denatured ethanol imports and undenatured ethanol imports. An average applied tariff rate ($\tau^{applied}$) is computed based on the historical ratios of denatured and undenatured ethanol imports to the EU. The net import equation is based on the EU ethanol price relative to the world ethanol price as follows:

$$NT = \alpha_4 + \beta_4 \cdot \left(\frac{P_E}{P_E^{World} \cdot \left(1 + \tau^{applied}\right)} \right), \quad (4)$$

where *NT* is the net trade (imports minus exports), and $\alpha_4, \beta_4 > 0$.

DDG Model

DDG production (Y_{DDG}) is computed from each feedstock used in ethanol production separately and summed up. The DDG consumption equation is given as

$$D_{DDG} = \alpha_5 + \beta_5 \cdot P_{DDG} + \delta_5 \cdot P_{CN} + \theta_5 \cdot P_{WH} + \lambda_5 \cdot P_{BA} + \sigma_5 \cdot P_{RY} + \tau_5 \cdot Trend, \quad (5)$$

where $\alpha_5, \delta_5, \theta_5, \lambda_5, \sigma_5 > 0$ and $\beta_5, \tau_5 < 0$ .The DDG import equation is given as

$$NT_{DDG} = \alpha_6 + \beta_6 \cdot \left(\frac{P_{DDG}}{P_{DDG}^{World}} \right) + \tau_6 \cdot Trend + \theta_6 \cdot (D_{DDG} - Y_{DDG}), \quad (6)$$

where $\alpha_6, \beta_6, \theta_6 > 0$ and $\tau_6 < 0$.[6] NT_{DDG} is defined as imports minus exports.

6. Data Sources

Both the international ethanol and the grain models are calibrated on the most recently available data (2007) and used to generate a 10-year baseline through 2017. In general, data for ethanol and DDG supply and utilization were obtained from the U.S. Department of Agriculture's Foreign Agricultural Service reports, the F.O. Lichts Online Database, and the EC's Directorate General for Energy and Transport. Macroeconomic data were gathered from various sources, including the International Monetary Fund and Global Insight. The historical

[5] The conversion rate is 98 gallons per metric ton of feedstock, or 371 liters per metric ton of feedstock.
[6] τ_5 and τ_6 in these equations are negative to account for the historical downward trend of brewers imports by the EU.

world crude oil price is U.S. refiners' acquisition cost of imported crude oil, and the world crude oil price projections are from NYMEX futures prices gathered on January 31, 2008. The EU crude oil price is the Brent Blend (38) for the United Kingdom from the U.S. Department of Energy's Energy Information Administration (2008). The gasoline price for the EU is the member states' average of unleaded gasoline prices including taxes from the EU Energy in Figures Pocket Book (EU Commission Directorate 2007). The grain prices for the EU average are from Eurostat. The EU ethanol price is the average fuel ethanol price from various F.O. Lichts Reports. The historical EU DDG price is the U.S. DDG price converted to Euros per metric ton. The U.S. DDG price is from the U.S. Department of Agriculture Economic Research Service Feed Situation and Outlook Yearbook.

7. Scenarios and Results

Two scenarios are considered as deviations from the baseline. The first scenario is a 10-Euros-per-barrel increase in the EU crude oil price throughout the projection period. The second scenario incorporates a 10-Euros-per-barrel increase in the EU crude oil price and removes the trade barriers in the EU ethanol market. In each scenario, the price shock and the policy reform are fully implemented in 2008 and their impact is measured in deviations for the years 2008 to 2017. The averages of these annual changes are reported as a summary indicator of the impacts in Tables 1 and 2. The annual baseline and scenario results are presented in Appendix B.

Scenario 1: Impact of Crude Oil Price Shock

With the increase in the crude oil price, the gasoline price increases by 20.01%, which results in a decline of 1.85% in the final energy consumption by the transportation sector, as seen in Table 1. Since ethanol and gasoline are modelled as close substitutes, the share of ethanol in final energy consumption increases by 3.70% because refiners switch to blending ethanol with gasoline. This results in a net increase of 1.78% in ethanol consumption in the EU. The domestic ethanol price increases by 3.00%, leading to an increase of 1.54% in both ethanol and DDG production.

The effect of the crude oil price increase extends beyond the ethanol market, affecting grain and ethanol by-product markets. Higher ethanol production increases grain use in ethanol plants, causing grain prices to increase. For example, the wheat price increases by 0.17%, both barley and corn prices increase by 0.10%, and the rye price increases by 0.30%. Higher DDG production decreases the DDG price by 5.35%, which in turn causes an increase of 1.24% in

DDG consumption and a decrease of 2.81% in DDG net imports. The increase in grain prices is mitigated by the decline in the DDG price, since livestock producers switch to feeding DDG to animals when its price declines and feed grain prices increase.

A higher domestic ethanol price in the EU also leads to an increase of 0.97% in net imports of ethanol. This is translated into a rise of 0.10% in the world ethanol price and a rise of 0.13% in world ethanol net trade. The impacts on the world ethanol market are relatively small since the EU is a small net importer of ethanol.

Scenario 2: Impact of a Crude Oil Price Shock with Trade Liberalisation

In this scenario, the crude oil price shock is implemented with the removal of trade distortions in the ethanol market to analyze how the increased ethanol demand would be met in an open trade regime. In this case, the increase in ethanol consumption coming from higher crude oil prices and gasoline prices is met through higher imports since the removal of trade distortions greatly reduces the imported ethanol price in the EU—a decline of 41.13%, as seen in Table 2. Ethanol net imports increase by 21.26%, decreasing the domestic ethanol price by 3.21%. This in turn increases the share of ethanol in energy consumption by 5.12%. Final energy consumption in the transportation sector drops by 1.85% with the higher crude oil and gasoline prices. Total ethanol consumption increases by 3.18%. Higher ethanol imports by the EU increase the world ethanol price by 2.30% and world net trade by 2.89%. Since the domestic ethanol price in the EU falls, both ethanol and DDG production decline by 1.62%. Grain use in ethanol facilities declines, which in turn leads to lower grain prices. For example, the wheat price decreases by 0.19%, the barley price by 0.10%, the corn price by 0.11%, and the rye price by 0.32%. Lower DDG production increases the DDG price by 5.78%, which results in a decline of 1.29% in DGG consumption and a rise of 3.03% in DDG net imports.

8. Conclusions

The biofuels sector in the EU is expanding rapidly because of the policy initiatives taken by the EC and the member states and the desire to find alternative sources of fuel for transportation. This links the energy and the agricultural sectors of the EU much more strongly than before. Thus, it is necessary to understand this new link between the energy and agricultural sectors and the policy implications of this development for the EU agricultural sector.

This study attempts to analyze the impact of crude oil prices on the EU agricultural sector. First, a baseline is set up for the EU ethanol, grain, and DDG markets. Next, two different

scenarios are run and compared to the baseline. The first scenario introduces a 10-Euros-per-barrel increase in the EU crude oil price with the ethanol import tariffs in place. The second scenario incorporates the same crude oil price shock with the ethanol import tariffs removed.

In the first scenario, higher crude oil prices lead to an increase in ethanol demand and a higher ethanol price. In response, ethanol production rises, increasing demand for the feedstocks used for ethanol production. This leads to higher grain, feed, and food prices in the EU. In the second scenario, the impact of trade liberalisation for the ethanol sector is larger than the crude oil price shock introduced into the model. Thus, the domestic ethanol price decreases with cheaper imports coming into the market. This leads to lower ethanol production, lower demand for feedstocks, and therefore lower grain, feed, and food prices.

Results for the two scenarios show that with open borders, the impact of higher crude oil prices and ethanol sector expansion on grain, feed, and food prices would be changed by the increased trade. In the second scenario, the impact of trade liberalisation is larger than the impact of the higher crude oil price. So, grain prices decline in this scenario despite an expansion in ethanol consumption. If there were a high enough crude oil price shock, which would affect the EU ethanol market more than would trade liberalisation, the net impact on grain, feed, and food prices from the crude oil price shock would be mitigated by the increased trade from the trade liberalisation.

Given the emerging nature of ethanol markets in the EU, this analysis comes with some caveats. Data availability and consistency is limited, which has led to the combination of different data sources. The time series for ethanol data is very short, making econometric estimations difficult. The EU biodiesel sector is not included with the EU ethanol model since the focus has been on grains markets. The crude oil price shock does not impact the variable costs of production for crops in this analysis. Only first generation biofuels are included in this study. The addition of cellulosic and other biomass feedstock in the production of ethanol may yet again change the structure of the market.

This study illustrates that the impact of energy prices on the EU agricultural sector is increasing with the emergence of the biofuels sector, and this link needs to be analyzed thoroughly. The result is not only that grain prices in the EU are affected by and affect ethanol production, but the impact also extends to the livestock sector through feed prices. This study is an attempt to show that attention needs to be given to modeling the linkages between energy,

ethanol, and agricultural markets in the EU to understand the direct and indirect impacts of a change in one market. The study also illustrates the importance of trade policy in responding to higher crude oil and grain prices. With open borders, part of the EU ethanol demand would be met by sugarcane-based ethanol from Brazil. Therefore, this analysis contributes to the food-versus-fuel debate generated by the recent increases in world and EU grain prices, which are partially brought about by the emerging biofuels sector.

Table 1: Impact of a 10-Euros-per barrel crude oil price shock

Average 2008-2017	World Ethanol Price	World Ethanol Net Exports	EU Crude Oil Price	EU Gasoline Price	EU Domestic Ethanol Price
	(Euro/gallon)	(Million Gallons)	(Euro/gallon)	(Euro/gallon)	(Euro/gallon)
Baseline	0.943	2011	1.22	4.97	2.66
Scenario 1	0.943	2014	1.46	5.97	2.74
% chg from baseline	0.10%	0.13%	19.48%	20.09%	3.00%

European Union	EU Imported Ethanol Price	Ethanol Production	Ethanol Consumption	Ethanol Net Imports	Final Energy Consumption
	(Euro/gallon)	(Million Gallons)	(Million Gallons)	(Million Gallons)	(Million Gallons OE)
Baseline	1.64	1,222	1,222	278	126,184
Scenario 1	1.64	1,240	1,243	281	123,867
% chg from baseline	0.06%	1.54%	1.78%	0.97%	-1.85%

European Union	Share of Ethanol in Energy Consumption	Grain Use in Ethanol	DDG Production	DDG Consumption	DDG Net Imports
	(Ratio)	(Thousand Metric Ton)	(Thousand Metric Ton)	(Thousand Metric Ton)	(Thousand Metric Ton)
Baseline	0.0096	10082	3,088	3,147	173
Scenario 1	0.0100	10233	3,134	3,186	168
% chg from baseline	3.70%	1.54%	1.54%	1.24%	-2.81%

European Union	Wheat Price	Barley Price	Corn Price	Rye Price	DDG Price
	(Euro/Metric Ton)	(Euro/Metric Ton)	(Euro/Metric Ton)	(Euro/Metric Ton)	(Euro/Metric Ton)
Baseline	174.45	150.61	151	153	81.16
Scenario 1	174.75	150.75	151	154	76.87
% chg from baseline	0.17%	0.10%	0.10%	0.30%	-5.35%

Table 2: Impact of a 10-Euros-per-barrel crude oil price shock with trade liberalization

Average 2008-2017	World Ethanol Price	World Ethanol Net Exports	EU Crude Oil Price	EU Gasoline Price	EU Domestic Ethanol Price
	(Euro/gallon)	(Million Gallons)	(Euro/gallon)	(Euro/gallon)	(Euro/gallon)
Baseline	0.943	2011	1.22	4.97	2.66
Scenario 2	0.964	2063	1.46	5.97	2.58
% chg from baseline	2.30%	2.89%	19.48%	20.09%	-3.21%

European Union	EU Imported Ethanol Price	Ethanol Production	Ethanol Consumption	Ethanol Net Imports	Final Energy Consumption
	(Euro/gallon)	(Million Gallons)	(Million Gallons)	(Million Gallons)	(Million Gallons OE)
Baseline	1.64	1,222	1,222	278	126,184
Scenario 2	0.96	1,202	1,260	335	123,867
% chg from baseline	-41.13%	-1.62%	3.18%	21.26%	-1.85%

European Union	Share of Ethanol in Energy Consumption	Grain Use in Ethanol	DDG Production	DDG Consumption	DDG Net Imports
	(Ratio)	(Thousand Metric Ton)	(Thousand Metric Ton)	(Thousand Metric Ton)	(Thousand Metric Ton)
Baseline	0.0096	10082	3,088	3,147	173
Scenario 2	0.0101	9920	3,038	3,106	178
% chg from baseline	5.12%	-1.62%	-1.62%	-1.29%	3.03%

European Union	Wheat Price	Barley Price	Corn Price	Rye Price	DDG Price
	(Euro/Metric Ton)	(Euro/Metric Ton)	(Euro/Metric Ton)	(Euro/Metric Ton)	(Euro/Metric Ton)
Baseline	174.45	150.61	151	153	81.16
Scenario 2	174.13	150.46	151	153	85.76
% chg from baseline	-0.19%	-0.10%	-0.11%	-0.32%	5.78%

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Appendix A: EU Ethanol and DDG Model Elasticities

Equation	Elasticity
EU Ethanol Demand	
Share of Ethanol in Energy Demand[b]	
Price of ethanol	-0.548
Price of gasoline	0.506
Policy	0.567
Energy Demand[a]	
Price of gasoline	0.767
Income	0.103
EU Ethanol Production[b]	
Lagged Profit Margin	0.051
Current Profit margin	0.794
Trend	0.816
Policy	0.409
EU Ethanol Net Imports[b]	
Ratio of domestic to world ethanol price	0.678
Gasoline Price Equation[a]	
Price of crude oil	0.673
EU Crude Oil Price Equation[a]	
Price of world crude oil	0.886
EU DDG Consumption[a]	
Price of DDG	-0.617
Price of Wheat	0.137
Price of Corn	0.130
Price of Barley	0.126
Price of Rye	0.087
Trend	-0.066
EU DDG Net Imports[a]	
Ratio of domestic to world DDG price	0.167
Trend	-0.162
Consumption-Production	0.050

a Elasticities are estimated at the sample average for 2000 through 2004.
b Elasticities are estimated at the sample average for 2005 through 2007.

Appendix B: Scenario Analyses

Table B.1: Impact of a 10-Euros-per-barrel crude oil price shock

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
World						(Euro per Gallon)					
Ethanol Price											
Baseline	1.12	0.92	0.96	0.94	0.90	0.89	0.92	0.96	0.97	0.97	0.99
Scenario 1	1.12	0.92	0.96	0.94	0.90	0.89	0.92	0.96	0.97	0.97	0.99
Percentage Change	0.00%	0.09%	0.12%	0.11%	0.12%	0.12%	0.11%	0.10%	0.09%	0.09%	0.08%
Ethanol Net Exports						(Million Gallons)					
Baseline	1114	1272	1328	1346	1433	1565	1842	2232	2630	3017	3449
Scenario 1	1114	1274	1331	1349	1436	1567	1844	2234	2632	3019	3452
Percentage Change	0.00%	0.15%	0.20%	0.19%	0.18%	0.15%	0.12%	0.10%	0.09%	0.08%	0.07%
EU											
Crude Oil Price						(Euro per Gallon)					
Baseline	1.05	1.16	1.16	1.19	1.22	1.25	1.26	1.26	1.25	1.24	1.23
Scenario 1	1.05	1.40	1.40	1.43	1.46	1.49	1.50	1.50	1.49	1.48	1.47
Percentage Change	0.00%	20.44%	20.44%	20.04%	19.51%	19.02%	18.86%	18.93%	19.07%	19.17%	19.28%
Gasoline Price											
Baseline	4.25	4.72	4.72	4.82	4.96	5.09	5.13	5.11	5.07	5.05	5.02
Scenario 1	4.25	5.72	5.72	5.82	5.95	6.08	6.13	6.11	6.07	6.04	6.01
Percentage Change	0.00%	21.12%	21.12%	20.70%	20.13%	19.61%	19.44%	19.51%	19.66%	19.76%	19.89%
Ethanol Production						(Million Gallons)					
Baseline	773	973	1048	1118	1157	1198	1246	1295	1344	1395	1447
Scenario 1	773	997	1067	1137	1175	1216	1264	1312	1361	1411	1463
Percentage Change	0.00%	2.44%	1.83%	1.68%	1.57%	1.49%	1.40%	1.33%	1.27%	1.20%	1.14%
Ethanol Consumption											
Baseline	653	900	988	1076	1134	1193	1256	1319	1384	1451	1519
Scenario 1	653	926	1010	1098	1155	1213	1276	1339	1404	1471	1538
Percentage Change	0.00%	2.87%	2.23%	1.99%	1.84%	1.72%	1.61%	1.51%	1.42%	1.34%	1.26%
Ethanol Net Imports											
Baseline	158	205	218	236	255	272	288	302	318	335	351
Scenario 1	158	207	220	239	258	275	290	305	320	337	353
Percentage Change	0.00%	1.00%	1.29%	1.13%	1.07%	1.00%	0.93%	0.87%	0.83%	0.79%	0.75%
Final Energy Demand						(Million Gallons Oil Equivalent)					
Baseline	115453	116082	118325	120489	122598	124705	126990	129419	131900	134400	136928
Scenario 1	115453	113522	115819	118051	120219	122374	124708	127184	129709	132253	134825
Percentage Change	0.00%	-2.21%	-2.12%	-2.02%	-1.94%	-1.87%	-1.80%	-1.73%	-1.66%	-1.60%	-1.54%
Share of Ethanol						(Ratio)					
Baseline	0.006	0.008	0.008	0.009	0.009	0.010	0.010	0.010	0.010	0.011	0.011
Scenario 1	0.006	0.008	0.009	0.009	0.010	0.010	0.010	0.011	0.011	0.011	0.011
Percentage Change	0.00%	5.19%	4.44%	4.10%	3.86%	3.66%	3.47%	3.29%	3.13%	2.98%	2.84%
Domestic Ethanol Price						(Euro per Gallon)					
Baseline	2.21	2.46	2.46	2.53	2.58	2.63	2.69	2.74	2.78	2.84	2.90
Scenario 1	2.21	2.52	2.55	2.61	2.66	2.71	2.77	2.82	2.87	2.92	2.98
Percentage Change	0.00%	2.50%	3.52%	3.20%	3.13%	3.06%	3.00%	2.95%	2.91%	2.87%	2.82%
Imported Ethanol Price											
Baseline	1.82	1.61	1.66	1.64	1.59	1.58	1.61	1.65	1.67	1.67	1.69
Scenario 1	1.82	1.62	1.66	1.64	1.59	1.59	1.61	1.65	1.67	1.67	1.69
Percentage Change	0.000%	0.05%	0.07%	0.07%	0.07%	0.07%	0.06%	0.06%	0.05%	0.05%	0.05%
Corn Farm Price						(Euro per Metric Ton)					
Baseline	190.25	178.91	152.62	151.06	153.22	152.69	150.35	147.98	144.62	141.58	138.42
Scenario 1	190.25	178.97	152.79	151.21	153.37	152.84	150.50	148.13	144.77	141.73	138.58
Percentage Change	0.00%	0.04%	0.11%	0.10%	0.10%	0.10%	0.10%	0.10%	0.11%	0.11%	0.11%
Wheat Farm Price											
Baseline	232.25	193.50	176.66	174.83	176.71	175.85	173.77	171.90	169.28	167.22	164.81
Scenario 1	232.25	193.61	176.98	175.16	177.03	176.17	174.08	172.21	169.60	167.54	165.13
Percentage Change	0.00%	0.06%	0.18%	0.19%	0.18%	0.18%	0.18%	0.19%	0.19%	0.19%	0.19%
Barley Farm Price											
Baseline	207.60	175.80	155.08	151.76	153.21	152.39	149.71	147.03	143.51	140.45	137.15
Scenario 1	207.60	175.84	155.22	151.92	153.37	152.55	149.87	147.19	143.66	140.61	137.31
Percentage Change	0.00%	0.02%	0.09%	0.11%	0.10%	0.10%	0.10%	0.11%	0.11%	0.11%	0.11%
Rye Farm Price											
Baseline	188.85	160.18	156.32	151.37	153.24	153.92	153.16	152.38	151.21	150.01	148.78
Scenario 1	188.85	160.40	156.93	151.85	153.73	154.41	153.64	152.85	151.68	150.47	149.23
Percentage Change	0.000%	0.14%	0.39%	0.31%	0.32%	0.32%	0.31%	0.31%	0.31%	0.31%	0.31%
DDG Price											
Baseline	114.68	95.64	84.17	80.83	82.05	81.43	79.74	78.91	77.57	76.41	74.81
Scenario 1	114.68	93.86	79.05	76.33	77.54	76.95	75.27	74.44	73.09	71.91	70.30
Percentage Change	0.00%	-1.87%	-6.09%	-5.57%	-5.50%	-5.50%	-5.60%	-5.66%	-5.78%	-5.89%	-6.03%

Table B.1: (continued)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
DDG Production					(Thousand Metric Ton)						
Baseline	1954	2459	2649	2825	2923	3028	3149	3273	3397	3524	3655
Scenario 1	1954	2519	2697	2872	2969	3073	3193	3316	3440	3566	3697
Percentage Change	0.00%	2.44%	1.83%	1.68%	1.57%	1.49%	1.40%	1.33%	1.27%	1.20%	1.14%
DDG Consumption											
Baseline	1622	2328	2710	2887	3030	3128	3235	3356	3477	3598	3723
Scenario 1	1622	2346	2760	2930	3072	3169	3275	3395	3515	3636	3760
Percentage Change	0.00%	0.77%	1.85%	1.49%	1.39%	1.31%	1.23%	1.16%	1.11%	1.05%	1.00%
DDG Net Imports											
Baseline	194	206	188	180	173	170	167	166	162	159	155
Scenario 1	194	203	182	175	168	165	162	161	158	154	150
Percentage Change	0.00%	-1.04%	-3.21%	-2.88%	-2.80%	-2.82%	-2.90%	-2.98%	-3.06%	-3.14%	-3.23%
Wheat Use for Ethanol											
Baseline	3078	3873	4171	4449	4603	4768	4959	5154	5350	5550	5757
Scenario 1	3078	3967	4248	4524	4676	4839	5029	5223	5418	5616	5822
Percentage Change	0.00%	2.44%	1.83%	1.68%	1.57%	1.49%	1.40%	1.33%	1.27%	1.20%	1.14%
Corn Use for Ethanol											
Baseline	1488	1872	2016	2150	2225	2305	2397	2491	2586	2682	2782
Scenario 1	1488	1918	2053	2187	2260	2339	2430	2524	2619	2715	2814
Percentage Change	0.00%	2.44%	1.83%	1.68%	1.57%	1.49%	1.40%	1.33%	1.27%	1.20%	1.14%
Barley Use for Ethanol											
Baseline	474	596	642	685	708	734	763	793	823	854	886
Scenario 1	474	610	654	696	719	745	774	804	834	864	896
Percentage Change	0.00%	2.44%	1.83%	1.68%	1.57%	1.49%	1.40%	1.33%	1.27%	1.20%	1.14%
Rye Use for Ethanol											
Baseline	1342	1688	1818	1939	2007	2079	2162	2247	2332	2419	2509
Scenario 1	1342	1729	1852	1972	2038	2109	2192	2277	2362	2448	2538
Percentage Change	0.00%	2.44%	1.83%	1.68%	1.57%	1.49%	1.40%	1.33%	1.27%	1.20%	1.14%

Table B.2: Impact of a 10-Euros-per-barrel crude oil price shock with trade liberalization

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
World						(Euro per Gallon)					
Ethanol Price											
Baseline	1.12	0.92	0.96	0.94	0.90	0.89	0.92	0.96	0.97	0.97	0.99
Scenario 2	1.12	0.94	0.98	0.96	0.92	0.91	0.94	0.98	0.99	0.99	1.01
Percentage Change	0.00%	2.57%	2.15%	2.37%	2.61%	2.69%	2.49%	2.19%	2.06%	1.99%	1.84%
Ethanol Net Exports						(Million Gallons)					
Baseline	1114	1272	1328	1346	1433	1565	1842	2232	2630	3017	3449
Scenario 2	1114	1325	1377	1398	1489	1617	1893	2281	2679	3068	3500
Percentage Change	0.00%	4.16%	3.69%	3.86%	3.92%	3.31%	2.76%	2.20%	1.88%	1.69%	1.48%
EU											
Crude Oil Price						(Euro per Gallon)					
Baseline	1.05	1.16	1.16	1.19	1.22	1.25	1.26	1.26	1.25	1.24	1.23
Scenario 2	1.05	1.40	1.40	1.43	1.46	1.49	1.50	1.50	1.49	1.48	1.47
Percentage Change	0.00%	20.44%	20.44%	20.04%	19.51%	19.02%	18.86%	18.93%	19.07%	19.17%	19.28%
Gasoline Price											
Baseline	4.25	4.72	4.72	4.82	4.96	5.09	5.13	5.11	5.07	5.05	5.02
Scenario 2	4.25	5.72	5.72	5.82	5.95	6.08	6.13	6.11	6.07	6.04	6.01
Percentage Change	0.00%	21.12%	21.12%	20.70%	20.13%	19.61%	19.44%	19.51%	19.66%	19.76%	19.89%
Ethanol Production						(Million Gallons)					
Baseline	773	973	1048	1118	1157	1198	1246	1295	1344	1395	1447
Scenario 2	773	954	1034	1100	1135	1176	1225	1276	1325	1374	1426
Percentage Change	0.00%	-1.98%	-1.36%	-1.62%	-1.84%	-1.86%	-1.71%	-1.52%	-1.47%	-1.47%	-1.39%
Ethanol Consumption											
Baseline	653	900	988	1076	1134	1193	1256	1319	1384	1451	1519
Scenario 2	653	937	1026	1113	1172	1232	1294	1357	1422	1489	1557
Percentage Change	0.00%	4.16%	3.85%	3.46%	3.38%	3.26%	3.07%	2.86%	2.71%	2.60%	2.48%
Ethanol Net Imports											
Baseline	158	205	218	236	255	272	288	302	318	335	351
Scenario 2	158	261	270	292	315	334	348	360	375	393	408
Percentage Change	0.00%	27.66%	23.99%	23.44%	23.37%	22.46%	20.79%	19.01%	18.01%	17.41%	16.49%
Final Energy Demand						(Million Gallons Oil Equivalent)					
Baseline	115453	116082	118325	120489	122598	124705	126990	129419	131900	134400	136928
Scenario 2	115453	113522	115819	118051	120219	122374	124708	127184	129709	132253	134825
Percentage Change	0.00%	-2.21%	-2.12%	-2.02%	-1.94%	-1.87%	-1.80%	-1.73%	-1.66%	-1.60%	-1.54%
Share of Ethanol						(Ratio)					
Baseline	0.006	0.008	0.008	0.009	0.009	0.010	0.010	0.010	0.010	0.011	0.011
Scenario 2	0.006	0.008	0.009	0.009	0.010	0.010	0.010	0.011	0.011	0.011	0.012
Percentage Change	0.00%	6.51%	6.10%	5.59%	5.43%	5.23%	4.95%	4.67%	4.44%	4.26%	4.08%
Domestic Ethanol Price						(Euro per Gallon)					
Baseline	2.21	2.46	2.46	2.53	2.58	2.63	2.69	2.74	2.78	2.84	2.90
Scenario 2	2.21	2.41	2.40	2.46	2.49	2.53	2.59	2.64	2.69	2.74	2.80
Percentage Change	0.00%	-2.02%	-2.71%	-2.83%	-3.43%	-3.73%	-3.68%	-3.45%	-3.36%	-3.45%	-3.45%
Imported Ethanol Price											
Baseline	1.82	1.61	1.66	1.64	1.59	1.58	1.61	1.65	1.67	1.67	1.69
Scenario 2	1.82	0.94	0.98	0.96	0.92	0.91	0.94	0.98	0.99	0.99	1.01
Percentage Change	0.00%	-41.57%	-40.66%	-41.11%	-42.13%	-42.33%	-41.70%	-40.78%	-40.47%	-40.50%	-40.10%
Corn Farm Price						(Euro per Metric Ton)					
Baseline	190.25	178.91	152.62	151.06	153.22	152.69	150.35	147.98	144.62	141.58	138.42
Scenario 2	190.25	178.86	152.48	150.93	153.06	152.51	150.16	147.80	144.44	141.39	138.23
Percentage Change	0.00%	-0.03%	-0.09%	-0.08%	-0.10%	-0.12%	-0.12%	-0.12%	-0.12%	-0.13%	-0.14%
Wheat Farm Price											
Baseline	232.25	193.50	176.66	174.83	176.71	175.85	173.77	171.90	169.28	167.22	164.81
Scenario 2	232.25	193.41	176.41	174.56	176.39	175.48	173.38	171.52	168.91	166.85	164.42
Percentage Change	0.00%	-0.04%	-0.14%	-0.15%	-0.18%	-0.21%	-0.22%	-0.22%	-0.22%	-0.23%	-0.24%
Barley Farm Price											
Baseline	207.60	175.80	155.08	151.76	153.21	152.39	149.71	147.03	143.51	140.45	137.15
Scenario 2	207.60	175.76	154.98	151.62	153.06	152.22	149.53	146.85	143.33	140.27	136.96
Percentage Change	0.00%	-0.02%	-0.07%	-0.09%	-0.10%	-0.11%	-0.12%	-0.13%	-0.13%	-0.13%	-0.14%
Rye Farm Price											
Baseline	188.85	160.18	156.32	151.37	153.24	153.92	153.16	152.38	151.21	150.01	148.78
Scenario 2	188.85	159.99	155.83	150.98	152.72	153.34	152.57	151.83	150.68	149.46	148.22
Percentage Change	0.00%	-0.11%	-0.31%	-0.26%	-0.34%	-0.38%	-0.38%	-0.37%	-0.35%	-0.37%	-0.38%
DDG Price											
Baseline	114.68	95.64	84.17	80.83	82.05	81.43	79.74	78.91	77.57	76.41	74.81
Scenario 2	114.68	97.09	88.21	84.50	86.73	86.79	85.28	84.23	82.71	81.74	80.35
Percentage Change	0.00%	1.51%	4.80%	4.54%	5.70%	6.59%	6.95%	6.74%	6.63%	6.97%	7.39%

Table B.2: (continued)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
DDG Production					(Thousand Metric Ton)						
Baseline	1954	2459	2649	2825	2923	3028	3149	3273	3397	3524	3655
Scenario 2	1954	2410	2613	2779	2869	2971	3095	3223	3347	3472	3604
Percentage Change	0.00%	-1.98%	-1.36%	-1.62%	-1.84%	-1.86%	-1.71%	-1.52%	-1.47%	-1.47%	-1.39%
DDG Consumption											
Baseline	1622	2328	2710	2887	3030	3128	3235	3356	3477	3598	3723
Scenario 2	1622	2314	2671	2852	2987	3079	3186	3309	3433	3554	3677
Percentage Change	0.00%	-0.62%	-1.46%	-1.21%	-1.44%	-1.56%	-1.53%	-1.39%	-1.27%	-1.24%	-1.22%
DDG Net Imports											
Baseline	194	206	188	180	173	170	167	166	162	159	155
Scenario 2	194	207	193	184	178	176	173	171	168	165	161
Percentage Change	0.00%	0.84%	2.53%	2.35%	2.90%	3.38%	3.60%	3.55%	3.51%	3.72%	3.95%
Wheat Use for Ethanol											
Baseline	3078	3873	4171	4449	4603	4768	4959	5154	5350	5550	5757
Scenario 2	3078	3796	4115	4377	4519	4680	4874	5076	5271	5468	5676
Percentage Change	0.00%	-1.98%	-1.36%	-1.62%	-1.84%	-1.86%	-1.71%	-1.52%	-1.47%	-1.47%	-1.39%
Corn Use for Ethanol											
Baseline	1488	1872	2016	2150	2225	2305	2397	2491	2586	2682	2782
Scenario 2	1488	1835	1989	2116	2184	2262	2356	2453	2548	2643	2744
Percentage Change	0.00%	-1.98%	-1.36%	-1.62%	-1.84%	-1.86%	-1.71%	-1.52%	-1.47%	-1.47%	-1.39%
Barley Use for Ethanol											
Baseline	474	596	642	685	708	734	763	793	823	854	886
Scenario 2	474	584	633	673	695	720	750	781	811	841	873
Percentage Change	0.00%	-1.98%	-1.36%	-1.62%	-1.84%	-1.86%	-1.71%	-1.52%	-1.47%	-1.47%	-1.39%
Rye Use for Ethanol											
Baseline	1342	1688	1818	1939	2007	2079	2162	2247	2332	2419	2509
Scenario 2	1342	1655	1794	1908	1970	2040	2125	2213	2298	2383	2474
Percentage Change	0.00%	-1.98%	-1.36%	-1.62%	-1.84%	-1.86%	-1.71%	-1.52%	-1.47%	-1.47%	-1.39%