

Global Biofuel Expansion under Different Energy Price Environments

by

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Abstract

This paper examines the impact of varying energy price paths (reference, low and high petroleum prices) on continued biofuel expansion and the implications on global agricultural commodity markets. It uses PEATSim, a dynamic, partial equilibrium, multi-commodity, multi-region global trade model of the agriculture sector. Continued biofuel expansion spurred by alternative energy programs will lead to increasing agricultural commodity prices and to changes in the patterns of trade in biofuel feedstocks. The ability of countries to achieve their alternative energy goals are largely determined by the future path of energy prices. With low energy prices, demand for biofuel will fall (absent of mandates) and a reduction in biofuel cost of production is needed to keep biofuel competitive with petroleum-based fuel. If energy prices increase, then biofuel use will likely exceed country specific energy targets and will result in much higher agricultural commodity prices. In either event, technological innovation - which lowers biofuel feedstock production cost and increases biofuel conversion efficiency - will be key in achieving biofuel expansion while mitigating impacts on agricultural commodity markets.

Key words: Biofuel expansion, PEATSim, low energy prices, high energy prices, dynamic partial equilibrium model, agricultural trade, biofuel feedstocks

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Countries around the world including the United States, Brazil, and the European Union have instituted programs to promote biofuel production. These countries' programs will continue to influence the biofuel sectors and provide economic incentives for continued biofuel expansion. These actions will likely alter the existing relationships in global agricultural markets as fuel use competes with food and feed uses because of biofuels' reliance on agricultural crops for feedstocks. As a consequence, further increases in biofuel demand has heightened concerns about its impact on food and feed availability. The competition for cropland to grow these crops also raises the issue of the long run feasibility of biofuels expansion. On top of all this, satisfying continued demand for biofuel when the future direction of petroleum prices is uncertain adds complexity to the situation. It is important to understand how expansion of biofuels use will affect agricultural markets and how changes in economic conditions—primarily energy prices will affect biofuels production and demand. Hence, this paper will examine the impacts of biofuel expansion in the United States, EU and Brazil on agricultural markets under different energy price (low vs. high) environments.

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Rapid changes in crude oil and agricultural commodity prices in the last few years have increased the uncertainty about the effects of increased biofuels production on agricultural markets and the feasibility of achieving further biofuel expansion and government targets for biofuel use. As events in 2008 have demonstrated, global commodity markets can change abruptly. In the first half of 2008, agricultural crop and crude oil prices increased rapidly reaching record highs with crude oil price reaching \$147/barrel in July of 2008. This surge in crop and energy prices raised concern about the impact of high commodity prices on the poor and called into question the role of biofuels in reducing the U.S. and global dependence on fossil fuels. Prices for these same products in the latter half of 2008 fell just as quickly as they went up earlier in the year. By the end of 2008, crude oil prices had fallen 60 percent from their July peak and had been fluctuating ever since. More recently, at the end of September, 2009, at \$70 per barrel, crude oil price is still 53 percent down from its July, 2008 peak.

The biofuel sector is confronted by a changed and uncertain economic environment. The high energy price environment that stimulated the biofuel boom in 2006-2008 has transformed into an environment characterized by reduced crop prices, stagnant income, and low and fluctuating energy prices. Nevertheless, government energy policies directed toward the expansion of biofuels are expected to continue to influence the biofuel sectors in many countries, including the United States, Brazil, EU, China, Canada, Argentina, Malaysia, Indonesia and some countries of the Former Soviet Union.

In the United States, the Energy Independence and Security Act (EISA) enacted in December, 2007 mandates the use of 36 billion gallons of biofuels by 2022, with as

much as 15 billion gallons from corn-based ethanol to be used by 2015 and subsequent years; and 21 billion gallons from advanced biofuels. The latter should include 1 billion gallon of biomass-based diesel and 16 billion gallons of cellulosic biofuels. In addition, factors such as blender tax credits for ethanol and biodiesel and import tariffs (54-cent-per gallon tariff on imported ethanol used as fuel); elimination of methyl tertiary butyl ether (MTBE) as an additive in gasoline blending; and other factors, have provided added economic incentives for U.S. biofuel expansion.

The European Union (EU) is also expected to increase the use of biodiesel in the future. The EU region sets a target of obtaining 5 percent of its transportation fuel from biofuels by 2012 and 10 percent by 2020. EU policy has provided a per acre subsidy for the production of energy crops and individual member countries also offer tax credits on biofuels. A significant development in the region is the possible implementation of the Renewable Energy Directive (RED) proposed by the EU Commission and agreed by the EU Parliament in December 2008. The core of the RED is a mandatory goal that requires all member states to use at least 10 percent of renewable fuels in all forms of transport by 2020. The directive also sets a complex sustainability criterion for all renewable fuels used whether produced or imported into the EU. This sustainability requirement will likely limit feedstocks used to rapeseed oil and sunflower oil for biodiesel and sugar and cellulosic materials for ethanol to meet EU liquid biofuel needs.

Brazil has implemented a major substitution of crop-based fuel for petroleum program. Brazil remains one of the largest producers of ethanol, nearly all of it made from sugarcane. It expects its energy needs to triple by 2030. As part of its plans to meet these needs while maintaining its energy independence Brazil has set a goal of producing

17.6 billion gallon of ethanol by 2030 (EPE, 2007). This represents a 12.6 billion gallon increase in ethanol production from the 5.0 billion gallons it produced in 2009 or an average increase of 1.1 billion gallons per year.

In addition to these programs, many other countries are also acting to increase their use of biofuel. China provided a subsidy for producing fuel ethanol from corn. In 2007, China used approximately 3.5 million tons of corn to produce fuel ethanol. However, due to its food security policy, China recently has been focusing more on ethanol production using non-grain feedstocks such as sweet potatoes and cassava. Canada has mandated that biofuels make up 5 percent of all transportation vehicle fuel by 2010. Argentina also mandates a 5 percent blending of biofuels with gasoline and diesel by 2010. Furthermore, Argentina has a system of differential export taxes resulting in a lower tax rates for biofuel exports than the tax rates on feedstock exports such as corn or soybean oil. This provides an incentive for further investments in Argentina's already large crushing industry.

Objectives

These world-wide mandates, policy incentives and recommendations will create increasing demand for biofuels feedstocks and meeting the increased demand for feedstocks is expected to significantly affect major sectors (grain, oilseeds, livestock) of the global agricultural markets and major biofuel producing and consuming countries such as United States, EU, Brazil, China, Canada, and Argentina, to name a few.

Achieving these goals may depend on the direction of energy prices. At lower crude oil prices, biofuel will be less competitive against petroleum-based fuels; hence, achieving biofuel targets will be less feasible. It remains to be seen if governments would enforce

stated mandates if energy prices are low. Higher energy prices will likely lead to biofuel use exceeding governmental goals while agricultural commodity prices increase further.

For the United States, Brazil and the EU, the emphasis on increasing the availability of alternative fuel sources will likely remain regardless of the direction of energy price because of national security and environmental concerns. The uncertainty in the direction of crude oil prices, however, has implications for the size of the biofuels expansion and the resulting effects on agricultural commodity markets.

Accordingly, this paper examines the impact and implications of expanding biofuel demand in United States, EU and Brazil under varying energy price paths (reference, low, high petroleum price) on domestic and global agricultural markets – specifically, on prices, trade, production and consumption. It also seeks to ascertain the degree to which technological innovation could mitigate the impacts of continued biofuel expansion on global agricultural markets under different petroleum price paths.

Previous studies

There have been several recent studies of the effect of biofuels expansion on agricultural commodity markets. Tokgoz et al (2007) and Tyner and Taheripour (2007) examined effects of ethanol expansion on corn markets. Tokgoz et al. (2007) provided estimates of the impacts of higher oil prices, drought and removal of land from U.S. Conservation Reserve Program. The study filled some gaps and included work on equilibrium prices of co-products of the biofuel industries most importantly distillers' dried grains. The study found that exogenous increases in corn and sugar prices reduce the production of ethanol, while higher gasoline price increase the production of ethanol.

Banse et al. (2007) examined the effect of EU biofuels directive on biodiesel markets. Several other studies such as Hertel et al. (2008), Von Lampe (2006), and Peters et al. (2009) analyzed the effects of U.S. and EU biofuel expansion together. All have found that large increase in biofuels production will lead to increased agricultural commodity prices and major changes in the pattern of agricultural commodity trade.

For the most part these recent studies have assumed that energy (petroleum) prices continue to increase and that income (GDP) growth continues to be strong. Recent developments in energy markets, however, indicate a potential shift to a low energy price environment, meaning that energy prices may not continue to rise and may even fall (Koyama, 2009; Oxford Analytica, 2009). Some economists predict that low petroleum prices will not last and energy prices will ultimately increase (Headey et. al 2009; von Witzke et al 2009). These contradicting future energy price outlooks warrant a look at the different energy price environments so as to compare and contrast different price perspectives. Also, Baker et al. (2008) developed a stochastic and dynamic General Equilibrium (GE) model that captures the uncertain nature of key variables such as crude oil prices and commodity yields. In it, they show that increased subsidies will be needed to increase the production of corn ethanol, biodiesel and cellulosic ethanol. However, international trade in biofuels is not present in the model. An international sector for biofuels is needed to fully analyze the world bioeconomy.

Methodology and Modeling Framework

Given our objective and the many linkages among agricultural commodity markets, it is important to examine the biofuel expansion effects in a framework that captures the linkages among food, feed and fuel markets; and, the linkages between

domestic and global markets. It is also essential to capture the dynamic nature of market adjustments. Hence, for this analysis, we use the dynamic version of the Partial Equilibrium Agricultural Trade Simulation (PEATSim) model, a multi-commodity, multi-region model of global agricultural policy and trade which permits evaluation of cross commodity linkages, interaction and impacts.

PEATSim is written in GAMS and uses PATH (Dirske and Ferris), a Mixed Complementarity Problem (MCP) solver (Dirske and Ferris) which allows it to handle different production-consumption regimes and functional form discontinuities. The model balances supply and demand, and prices are determined at market clearing levels which permit global market equilibrium to be achieved. For this analysis, the dynamic PEATSim model is extended to incorporate ethanol and biodiesel markets and link them to the domestic and international agricultural markets so the model has endogenous biofuel sector representations of the United States, Brazil and EU.

Model structure

PEATSim uses supply and demand equations to capture the economic behavior of producers, consumers and markets in a global framework. It includes variables for production, area, yields, consumption, exports, imports, stocks, world prices, and domestic producer and consumer prices. Identities such as supply and utilization hold for all commodities and regions in the model. The model calibrates each country's agricultural activities to the USDA's 2008 long term projections (USDA). Once the model is calibrated, it can be used to simulate various scenarios. Constant elasticity functions for the behavioral equations were selected because of their ease of

interpretation and well behaved properties. They can be viewed as first order approximations of the true underlying supply and demand equations.

Country Coverage

PEATSim includes 11 countries and 2 regions: the United States, the European Union (EU-25), Japan, Canada, Mexico, Brazil, Argentina, China, India, Australia, New Zealand, South Korea, and the Rest of the World (ROW).

Commodity Coverage

There are thirty-two agricultural commodities: 9 crops (rice, wheat, corn, other coarse grains, soybeans, sunflowers, rapeseed, cotton, and sugar); 10 oilseed, oil, and meal products (soybean, sunflower seed, rapeseed, and other oil); four livestock products (beef and veal, pork, poultry, and raw milk); six dairy products (fluid milk, butter, cheese, nonfat dry milk, whole dry milk, and other dairy products). In addition, there are two biofuel commodities and a byproduct (ethanol, biodiesel, and distiller's dried grains (DDGs)).

Supply/Production

Production of grains, oilseeds, and cotton is the product of area harvested and yield. Area harvested is specified as a constant-elasticity function of the crop's own producer price, the producer prices of other crops and area harvested lagged one year. Yield is a constant-elasticity function of previous period yields and producer prices. Vegetable oil and meal production are specified as products of oilseed crush demand and extraction rates. Livestock production is a function of lagged production and producer prices for livestock, and of a feed cost index. Biofuel production is a function of its price and of a feedstocks cost index.

Demand

Total consumption of each commodity in the model is the sum of food demand, feed demand, crush, fuel demand, and other use. Food demand exists for all commodities except raw milk and oilseed meals. Feed demand is determined by the production of livestock in the model. Crush demand represents the demand for oilseeds to produce oilseed meals and oils. Fuel demand exists for biofuels such as ethanol and biodiesel and is specified as a function of ethanol or biodiesel price, the price of crude oil and GDP. Other use demand which includes seed use and waste is generally small.

Trade

The model balances supply and demand with the condition that world imports equal world exports. For commodity i in region r in year t , net trade (exports minus imports) is equal to:

$$NET_{i,r,t} = PRD_{i,r,t} - FOO_{i,r,t} - FEE_{i,r,t} - CRU_{i,r,t} - FUE_{i,r,t} - OTH_{i,r,t} - STK_{i,r,t},$$

where:

$PRD_{i,r,t}$ = production of commodity i in region r in time t ;

$FOO_{i,r,t}$ = food demand of commodity i in region r in time t ;

$FEE_{i,r,t}$ = feed demand of commodity i in region r in time t ;

$CRU_{i,r,t}$ = crush demand of commodity i in region r in time t (zero for all commodities except oilseeds);

$FUE_{i,r,t}$ = fuel demand of commodity i in region r in time t ;

$OTH_{i,r,t}$ = other use demand of commodity i in region r in time t ; and,

$STK_{i,r,t}$ = net increase in ending stocks between years.

Equilibrium Condition.

Global market equilibrium requires that the sum of net trade across regions be equal to zero for each internationally traded commodity. Therefore, the market clearing condition requires:

$$\sum_r NET_{i,t,r} = 0 \quad \forall i \in \text{traded}$$

Prices

The world reference price is the price that permits world net trade for commodity i in time t to equal zero. It is denominated in U.S. dollars. The domestic price for a traded good in a country or region in any year is equal to the world reference price plus transportation costs multiplied by the exchange rate plus, tariffs, and levies. All domestic prices are denominated in terms of foreign currencies. Exchange rates are treated as exogenous.

Domestic prices for nontraded goods by definition are not linked to the world price or explicitly represented with a price equation in the model. Like the world reference price, they are determined implicitly through the shadow value on the product balance constraint for nontraded goods.

All prices in the model are linked through the domestic price and to the world reference price. As a result, they represent the levels which permit global market equilibriums to be achieved.

Biofuel Sector in PEATSim Model

For this analysis the PEATSim model was extended by incorporating a detailed representation of ethanol and biodiesel markets which were linked to the domestic and

international agricultural markets. Currently, the PEATSim model has a fully operational endogenous biofuel sector for the following:

- U.S. ethanol sector (corn-based) with distiller's dried grains (DDGs) use in the livestock sector;
- Brazil ethanol sector (sugarcane-based); and,
- EU biodiesel sector (rapeseed oil-based).

The biofuel sector in each of these countries is represented by a set of demand and supply curves. The quantity of biofuel produced is specified as a function of its own price and feedstock cost. The quantity of ethanol demand is specified as a function of its own price, the price of crude oil (petroleum), and income (Gross Domestic Product). An additional set of supply and demand curves are also specified for byproducts produced, specifically distillers dried grains (DDG), for corn based ethanol production. The supply of DDG is specified as a fixed proportion of ethanol produced and the demand for DDG is specified as a function of its own-price, livestock production and the price of other feeds.

Data

The data in PEATSim are from the 2008 USDA Long Term Agricultural Projections to 2017, for area, yield, production, consumption, stocks, trade, and world prices. Dairy and sugar information from OECD; non-U.S. biofuel information from FAPRI; and crude oil forecasts from the U.S. Energy Information Agency (EIA) supplement the dataset. Parameter values in the model are synthetic and are drawn from the literature and from other trade models.

Base Model Run

The dynamic PEATSim model has the capability of generating annual changes over a time path. For this analysis, the model's time path, running from 2009-2017, follows the 2008 USDA Long Term Projections. After calibrating the base model to the USDA projections, alternative/hypothetical scenarios were introduced to determine how different agricultural sectors, particularly the grain, livestock and oilseed sectors, will react and adjust.

Alternative Scenarios

The U.S. Energy Information Agency (EIA) provides several potential paths for energy prices to follow (figure 1). Their reference projection shows petroleum prices increasing steadily over time, reaching over \$110 per barrel by 2017. This set of prices was used in calibrating the PEATSim model in the base run. The high energy price path shows petroleum prices rising much more rapidly, increasing 59 percent above the reference price to \$170 per barrel by 2017. This path is based on the major oil-producing countries choosing to maintain tight control over their output of petroleum and developing their reserves more slowly. Finally, the low energy price path shows petroleum prices falling moderately below 2009 price levels through 2017 to slightly above \$50 per barrel. At this price, the price of petroleum in the low energy price scenario is 55 percent below the reference price. This path is based on a more rapid increase in production by major oil-producing countries than occurs in the reference case, increasing their share of world production. These projections provide a reasonable range in which to examine future changes in energy and petroleum prices.

Based on these alternative paths the following three scenarios were developed:

- **Reference (Global Biofuel Expansion) Scenario** – includes the EIA’s reference path for petroleum prices and simultaneous global biofuel demand increases (demand curve shifts) for ethanol in the United States and Brazil and biodiesel in the EU. The rationale for this scenario is the continued emphasis by the United States, European Union and Brazil on increasing the availability of alternative fuel sources. These increases in biofuel demand represent stated policies in all three countries/region. The shifts represent the required change in demand needed to meet ethanol use prescribed under the RFS in the United States; the biodiesel consumption needed to satisfy EU’s requirement that 5 percent of transportation fuels come from renewable sources²; and, the average annual increase in ethanol use in Brazil needed through 2017 in order for Brazil to meet its ethanol production and consumption targets in 2030 as laid out in its national energy plan.
- **Low Energy Price Scenario** – includes a 30 percent reduction in petroleum prices accompanied by shifts in biofuel demand as in the Reference Scenario. The recent drop in crude oil prices demonstrates that the high energy cost environment that stimulated the recent expansion of the biofuel sector may not last. This decline in crude oil prices lies within the range bracketed by the U.S. Energy Information Agency low energy price projections (figure 1) and is

² The European Union has a stated goal of meeting 10 percent of total fuel from alternative energy sources, primarily biodiesel, by 2020. Many energy analysts have serious doubts about the European Union’s ability to achieve this target, but believe that European Union efforts will lead to substantial increase in biodiesel production. Hertel et al. estimate that the European Union based on Germany’s experience could achieve a goal of 6 percent by 2020.

consistent with petroleum prices staying within the \$60-80 per barrel range through 2017. As part of this scenario we do not enforce the RFS mandates and allow market forces to determine biofuel production and use. This implicitly assumes that other biofuels incentives used to shift demand in the reference scenario stay in place. This scenario is used to explore the likely effects of reduced petroleum prices on biofuels and associated feedstock use and prices in the absence of government mandates. This scenario also includes determination of the necessary shift in U.S. ethanol supply curve to keep U.S. ethanol consumption at the RFS level as in the Reference Scenario.

- **High Energy Price Scenario** – includes a 30 percent increase in petroleum prices accompanied by global biofuel demand increases as in the Reference Scenario. The consensus among many agricultural economists is that the recent drop in crude oil prices will not last and that the high energy cost environment that stimulated the biofuel development boom will return. As part of this scenario, mandates are not relaxed because they are not binding. In relation to this scenario, the likely profitability and economic feasibility of using cellulosic sources for biofuel production was explored by determining the ethanol price level needed for cellulosic biofuel to become competitive with corn- or sugar-based ethanol.

The Reference Scenario was modeled by shifting biofuels demand functions for ethanol in the United States and Brazil and biodiesel in the European Union until biofuels

targets were met at the reference petroleum prices. These shifts were carried over to the Low and High Energy Price scenarios. In the Low and High Energy Price Scenarios crude oil prices were then changed from their reference levels to the levels specified for each scenario. All other equations and exogenous data (including macroeconomic information such as GDP) remain the same as in the base run, unless modified as part of scenario runs. Scenario results are reported as percentage deviations from the base run.

The expansion of biofuels (corn-based ethanol) production and use in the United States represents a relatively small increase in ethanol use above levels projected in the base model. The expansion in biofuels use needed in the EU and Brazil to meet their program goals represents a much larger increase in biofuels use than projected in the base run.

Results and Discussion:

Since the projected increase in energy prices grows fairly evenly (see figure 1 EIA projections), the discussion of the results will mainly focus on year 2017, the end of the time path. Scenario results are reported as percentage deviations from the base model run.

Reference Scenario

Simultaneous expansion of biofuels in the United States, Brazil and the European Union (EU) increases agriculture commodity prices and alters trade patterns, particularly, of the major biofuel feedstocks: corn, sugarcane and rapeseed. Effects on other crop and livestock product markets are relatively minor, with exception of soybeans and soy oil which are affected by a large increase in rapeseed oil demand.

World corn and sugar prices increased by almost 6 and over 3 percent, respectively, from the base. Whereas, rapeseed and rapeseed oil prices increase over 10 and 17 percent, respectively from the base level. Soy oil prices increases by 4 percent as demand increases as other users of vegetable oils substitute away from rapeseed oil (table 1).

Global trade in biofuels feedstocks is also affected by the increase in biofuels consumption and the resulting impact on biofuels feedstock markets. The United States experiences a large fall in corn exports, down 19 percent from its base level. Global exports of corn decline as well, but by less than half the percent decline in U.S. corn exports, as Brazil and Argentina increase their exports of corn to compensate for the reduction in U.S. exports (figure 2).

In the EU, increasing the share of renewable fuel to total transportation fuel use to 5 percent, leads to a 15 percent increase in the region's biodiesel consumption. As a result, production, prices and imports of rapeseed oil increase (Table 2). Rapeseed oil use increases by about 9.1 percent. Rapeseed oil imports, however, are the major source of supply. In the last year of the simulation, EU rapeseed oil production increases by about 3.5 percent while its rapeseed oil imports increase 39.1 percent. As a result imports provide about two-thirds of the rapeseed oil needed in EU production of biodiesel. The increase in EU imports of rapeseed oil leads to an increase in global exports/trade of rapeseed oil. Global exports of rapeseed oil increase by nearly 10 percent in order to meet growing import demand in the EU. Most of the increases in exports come from Canada and the countries in ROW which includes countries in Asia and the FSU (Figure 3).

The increase in Brazil's domestic ethanol use is met partially by an increase in supplies of sugar-based ethanol, as domestic ethanol production increases by 4.8 percent. Some of the increase in domestic demand is met through a reduction in Brazil's ethanol exports. As a result, the effects of increased ethanol use in Brazil on sugar markets are not as great as the effects of the increase in biodiesel use in the European Union on rapeseed markets. The increase in domestic ethanol production leads to a 1.4 percent increase in Brazil's sugar production and a 4.8 percent decline in its sugar imports (table 2). The decline in Brazilian sugar exports is accompanied by a much smaller decline in global exports. Global exports of sugar decline only slightly as the EU and Australia increase their exports of sugar and largely offset the decline in Brazil's exports (figure 4).

The increase in corn, sugar and rapeseed demand have an indirect effect on other crop markets as non-fuel users of these biofuel feedstock crops substitute away from them towards cheaper alternatives and as they face increased competition for land. Soybean markets will be affected the most because they face both increased competition with corn uses for agriculture land in the United States and increased demand for soy oil by non-fuel users of edible oils. Global price for soybeans and soy oil increases over 2 and 4 percent, respectively, reflecting increased demand. Global exports for soybeans and soy oil increase. The pattern of trade for soybeans changes significantly as U.S. exports of soybeans decline and exports from Brazil and Argentina increase. The impact on global production and trade of other crops and livestock products is minor.

Increases in crop feedstock yields above current trends could offset the impact of global biofuel demand increases in domestic and global agricultural markets particularly on crop prices underscoring the importance of improved technology (to increase

feedstock yields). Peters et al (2009) showed that an increase in U.S. corn yield of 1.4 percent above USDA long term projections would offset the increase in corn price due to ethanol expansion.

Low Energy Price Scenario

The results of the low energy price scenario indicate that the ability of the European Union, the United States, and Brazil to achieve their biofuels goals will be adversely affected by a low energy price environment. A 30-percent reduction in price of petroleum causes biofuels consumption to increase substantially less (absent biofuel mandates) than in the reference scenario. Biodiesel use in the European Union is 9.5 percent lower than in the reference scenario while ethanol use in Brazil is 7.0 percent lower and in the United States, 9.5 percent lower.

The smaller increase in biofuels use leads to a significant decline in consumption for biofuels feedstocks relative to the reference scenario (table 2). This reduction in estimated demand for the principal biofuels feedstocks leads to lower price increases than occurred in the reference scenario (table 1) and less change in global trade patterns (table 2). In the low energy price scenario the world price of corn increases slightly, up only 1.2, while the price of rapeseed and rapeseed oil increase by 2.3 and 4.0 percent respectively. The world reference price of sugar remains basically unchanged.

The lower growth in consumption of biofuels feedstocks induces less of a reduction in the food and feed demand for these products relative to the reference scenario and as a result, the impacts of biofuels expansion on global exports and trade patterns for biofuels feedstocks are significantly less. Under this scenario, U.S. corn exports decline by only 4.1 percent and global exports by less than 2 percent. Similar

results are found for rapeseed oil and sugar as well. Global exports of rapeseed oil increase by less than 2 percent (figure 3) and there is no significant change in global exports of sugar (figure 4). The effects of biofuels expansion on global trade in livestock products and other crops under this scenario are negligible.

In addition to examining the effects of the reduction in energy prices, the U.S. ethanol supply curve in the model was shifted out until ethanol consumption increased back to its Reference Scenario level (RFS mandate). The results of this scenario indicate that it would take about a 37 percent decline in U.S. cost of ethanol production to offset the effect of lower energy prices on ethanol demand (figure 5).

If faced with a low energy price environment over the long term, U.S. ethanol production costs will have to fall in order to remain competitive with gasoline. Given that processing yield for corn-based ethanol may have neared their theoretical maximum, efforts to accomplish this would likely focus on developing technologies that will reduce feedstock (corn) production costs and other costs in the conversion process.

High Energy Price Scenario

The results of the high energy price scenario, on the other hand, indicate that a 30 percent increase in petroleum prices (above reference prices) will have a large effect on biofuels and crop markets. In this scenario, biofuels consumption increases above target levels making many government incentives superfluous. This increase in biofuels demand puts even greater upward pressure on biofuel feedstock and other agricultural commodity prices (table 1) than observed in the reference scenario. The price of corn increases nearly 10 percent above the base level while the price of sugar increases by 5 percent. Rapeseed oil price increases by nearly 30 percent and soy oil price increases by

over 7 percent. The effect of increases in livestock product prices, resulting from the increase in feed costs remains fairly moderate as they increase by about 3 percent or less.

Global trade in biofuel feedstocks (corn, sugar, rapeseed oil) is severely affected by the increase in biofuel (ethanol and biodiesel) feedstock use. U.S. exports of corn decline by nearly 32 percent over the base level as U.S. consumption of corn increases by 9 percent (table 2). Global exports of corn decline only 12 percent as Brazil and Argentina increase their exports of corn substantially (figure 2) to compensate for the reduction in U.S. exports. Global exports of rapeseed oil increase substantially as well, up 18 percent (figure 3), in order to meet growing import demand, up nearly 62 percent in the EU (table 2). Brazil's exports of sugar decline by almost 8 percent as Brazil's domestic consumption increases by a little more than 6 percent (table 2). The European Union and Australia increase their exports substantially in response to the decline in Brazil's exports and as a result, global exports of sugar decline by only 3 percent (figure 4).

The impact on global production and trade of other crops and livestock products is greater than in the reference scenario, but remain fairly small as global consumption remains unchanged (table 4) even in the face of higher agricultural commodity prices.

The substantial increase in rapeseed oil prices suggest that other biofuels, such as ethanol, may play a greater role in European Union fuel markets. Greater use of ethanol in the European Union, however, would require movement away from diesel engines toward flex fuel vehicles.

Cellulosic comparison: role of technology

Given the large increase in ethanol consumption and prices in the high energy price scenario it's reasonable to contemplate whether next generation biofuels may replace corn and sugar based ethanol as a cost effective alternative. If this happened it may moderate the effects of biofuels expansion on corn markets.

Several recent studies have tried to estimate the price at which corn-based ethanol breaks even with next generation ethanol technologies, such as cellulosic conversion. This is made difficult in part due to the impact that the type of feedstock used can have on the cost of producing ethanol and in part because of the sensitivity of production costs to changes in energy prices and crop prices. The cost will also be sensitive to changes in next generation feedstock prices needed to allow them to compete with other crops for land.

A study by Rismiller and Tyner (2009) estimated the costs of alternative technologies for producing biofuels and examined the effects of energy prices and government policies on their relative profitability. The study put the cost of producing next generation biofuels (cellulosic ethanol) at around \$144 per barrel oil equivalent. This was about \$30 higher than estimated costs for corn-based ethanol.

The study by Tokgoz et al. (2007) estimated the break-even price for ethanol produced from corn stover at \$4.50 per bushel of corn. At any corn price below this price, returns to corn based ethanol were higher. In addition, Khanna and Dhungana (2007) found that corn-based ethanol was cheaper than corn stover, switchgrass, or miscanthus derived ethanol even when corn was priced at \$4.00 per bushel³.

³ Neither study assessed the combination of increased oil prices and corn prices on the break-even price for cellulosic based ethanol.

The results of these studies suggest that cellulosic-based ethanol would not become competitive with corn-based ethanol in either the reference or low energy price scenarios. In the reference and low energy price scenarios the price of crude oil stays below the breakeven price for cellulosic ethanol. This indicates that cellulosic based ethanol would not be economically feasible in the next ten years, unless there is a significant technology breakthrough that will reduce production costs or unless there is significant government subsidy comparable to what's given to corn based ethanol.

The price increases observed in the high price scenario do indicate that cellulosic conversion would become economically competitive with petroleum based fuels as the price of crude oil in this scenario, at \$156 per barrel, was higher than the estimated breakeven price for cellulosic ethanol. This would potentially have a significant impact on global agriculture markets as demand for corn for fuel use would decline, causing its price and use as a livestock feed to increase. As a result, we would likely see less of a reduction in U.S. corn exports than seen in the high energy price scenario and consequently less of an impact on related commodities.

The degree to which the growth in an alternative feedstock would reduce the impact on corn markets is difficult to say since the corn price even in the high energy price scenario remains below the \$4.00 per bushel break-even price for cellulosic ethanol. Neither the Tokgoz et al. (2007) nor the Khanna and Dhungana (2007) studies assessed the combination of increased oil prices and corn prices on the break-even price for cellulosic based ethanol so we don't know how much the break-even price with corn-based ethanol will change when both crude oil and corn prices increase together. The

study by Rismiller and Tyner (2009) found that cost of corn-based ethanol increased much more rapidly with an increase in the price of energy than cellulosic-based ethanol.

Conclusion:

The future path of petroleum prices will have a significant effect on future expansion of biofuels and its impact on global agricultural commodity markets and trade. The path will also largely determine the ability of the United States, the European Union and Brazil to meet energy goals for biofuel use laid out in their alternative energy programs. If crude oil prices follow the most likely path as projected by EIA (reference scenario) then these countries will meet biofuels program goals or targets with moderate impacts on global agricultural markets and trade. The volume of global trade in biofuel feedstocks changes with corn and sugar trade declining and rapeseed trade increasing. However, the global use of these commodities will increase leading to increase in their domestic and world prices. The pattern of trade will also change as U.S. and Brazilian exports of their major biofuels feedstocks (corn, sugar) decline and as other leading exporting countries increase their exports in response.

If petroleum prices remain in the \$50-\$80 per barrel range (low price scenario) rather than increase as expected, then biofuels consumption will not increase much above USDA long term projections and as a result the effects of biofuel expansion on agriculture trade will be slight. Also, biofuel consumption will be likely met through traditional biofuel feedstocks as second generation technologies remain economically infeasible. This means that it is unlikely that the United States, the European Union or Brazil will meet their alternative energy (biofuels) targets, unless subsidies are greatly increased, mandates are enforced or production costs reduced. Results from this analysis

indicate that costs of production will need to be reduced significantly, 37 percent in the case of corn based ethanol, for biofuels targets to be met in this low energy price environment.

If petroleum prices increase significantly more than expected—into the \$150/barrel range (high price scenario) then we would see an increase in biofuel use above program goals. This will accentuate the impacts of biofuels expansion policies on global agricultural markets, commodity prices and the direction of agricultural trade that were described in the reference scenario. This would likely heighten concerns about the effect of biofuels expansion on the food security situation in low-income countries.

The differing outlooks for biofuels expansion based on the future path of energy prices could dampen investor interest in biofuels. The results of this analysis suggest that technological change could play a crucial role in reducing the uncertainty in the outlook for biofuels expansion by reducing production costs and developing non-food feedstocks. Lowering production costs would permit biofuel to compete with petroleum based fuels in a low energy price environment while developing non-food related feedstocks would reduce the impact of biofuels expansion on traditional food and feed crop prices. This is because the results from this analysis show that the impacts of a large expansion in biofuels consumption are limited primarily to the principal feedstock markets. Thus, if the principal biofuels feedstocks are no longer food-related then the impact of the expansion of biofuels on agricultural markets will likely be reduced.

Efforts in technological innovation should focus on reducing the cost of producing ethanol by increasing feedstock conversion efficiency and increasing feedstock yields. Improvements in these areas would have the simultaneous effect of increasing the

competitiveness of biofuels with petroleum-based fuels while reducing the effect of biofuels expansion on feedstock markets.

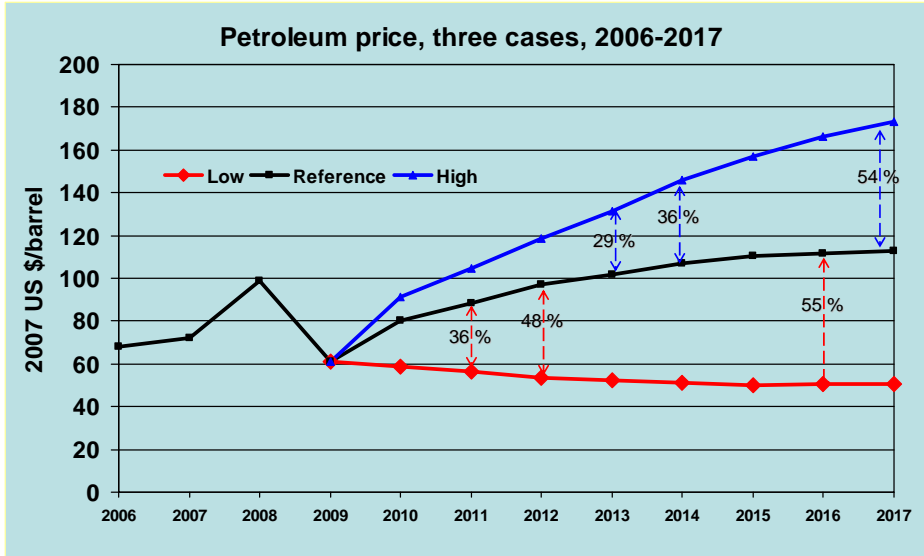
Cellulosic technologies show promise of becoming competitive with corn-based ethanol in a high energy price environment in part because their production costs are less sensitive to changes in energy prices. If the costs of these technologies or other biofuels technologies could be sufficiently reduced to allow them to compete with corn-based ethanol in even a low energy price environment, they would go a long way to reducing the dependence of biofuels expansion on the direction of energy prices and moderating the impact of biofuels expansion on agricultural commodity markets.

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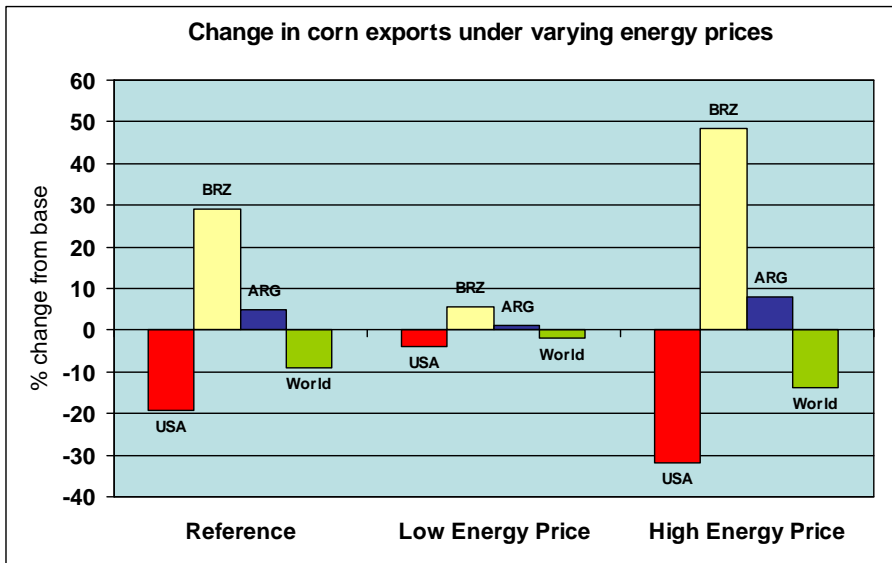
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Figure 1. The future value of petroleum price is uncertain



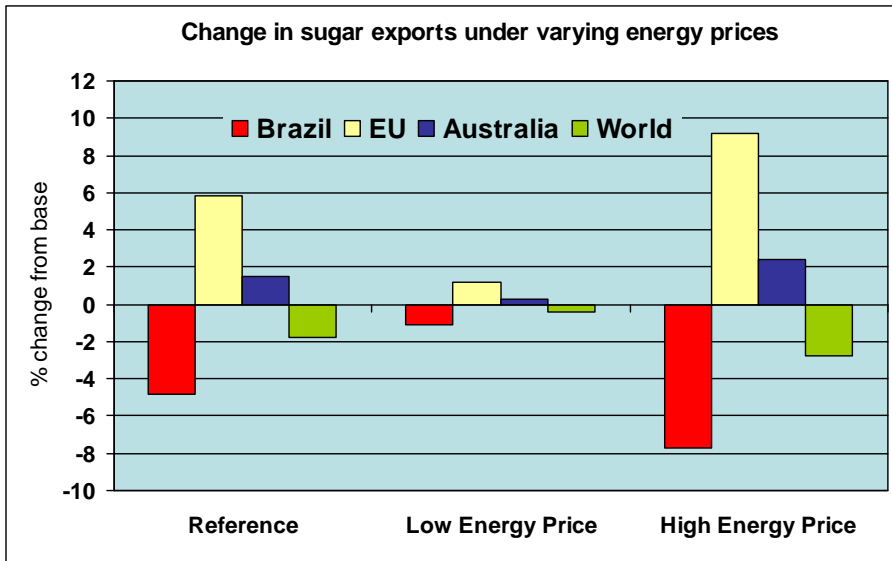
Source: Energy Information Agency, U.S. Dept of Energy, March, 2009

Figure 2. To meet global biofuel demand increases, exports of corn increase in other countries of the world to compensate for export decline from United States.



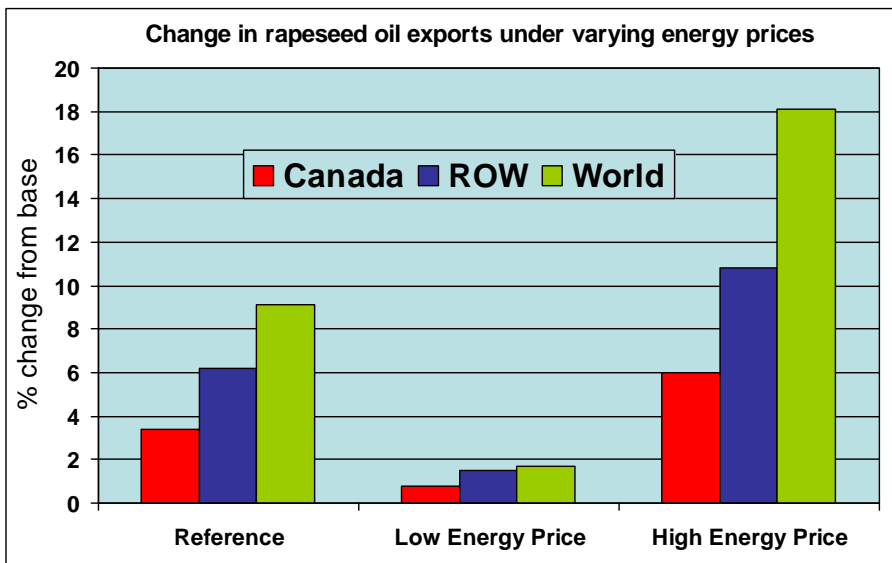
Source: PEATSim Model Results

Figure 3. To meet global biofuel demand increases, exports of sugar increase in other countries of the world to compensate for export decline from Brazil.



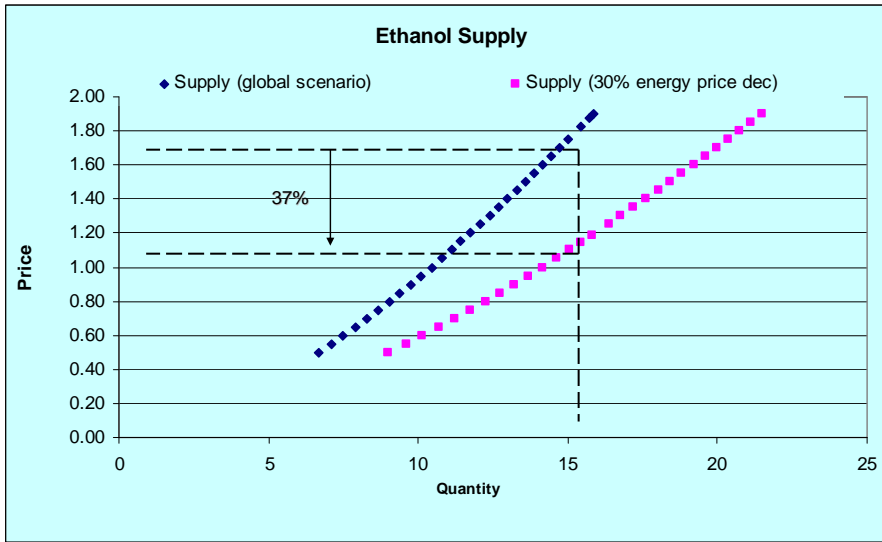
Source: PEATSim Model Results

Figure 4. To meet global biofuel demand increases, exports of rapeseed oil in other countries of the world increase to meet increased demand from the European Union.



Source: PEATSim Model Results

Figure 5. Supply curve shift needed to keep ethanol competitive with declining energy price (30 % reduction in petroleum price)



A 37 % reduction in ethanol production cost is needed to keep ethanol use at reference scenario levels. This implied increased efficiency of U.S. ethanol production will allow it to compete with gasoline.

Table 1. Change in world price of selected agricultural commodities with varying energy price scenarios.

Commodity	Reference	Low Energy Price	High Energy Price
	% change from base		
<i>Corn</i>	5.9	1.2	9.8
<i>Rapeseed</i>	10.0	2.3	16.8
<i>Rape oil</i>	17.4	4.0	29.3
<i>Rape meal</i>	-5.5	-1.4	-8.7
<i>Sugar</i>	3.1	0.6	5.0
<i>Wheat</i>	1.6	0.3	2.6
<i>Soybeans</i>	2.1	0.4	3.4
<i>Soy oil</i>	4.4	1.0	7.2
<i>Beef & veal</i>	2.0	0.4	3.3
<i>Pork</i>	1.2	0.2	2.0
<i>Poultry</i>	1.5	0.3	2.5

Source: PEATSim model results

Table 2. Impacts of global biofuel demand shifts on major biofuel feedstocks under varying energy prices

Region	Commodity	Reference Scenario			Low Energy Price Scenario			High Energy Price Scenario		
		Prod'n	Cons'n	Trade *	Prod'n	Cons'n	Trade *	Prod'n	Cons'n	Trade *
		% change from base								
U.S.	Corn	1.3	5.5	-19.4	0.3	1.1	-4.1	2.2	9.0	-31.8
EU	Rape seed	2.4	3.4	18.6	0.6	0.8	4.4	3.9	5.8	32.5
	Rape Oil	3.5	9.1	39.1	0.8	2.3	9.7	5.9	14.7	61.8
	Rape Meal	3.5	4.2	5.9	0.8	1.0	1.5	5.9	6.9	4.5
Brazil	Sugar	1.4	3.8	-4.8	0.3	0.8	-1.0	2.2	6.1	-7.7
Global	Corn	1.4	1.3	-9.1	0.3	0.3	-1.9	2.2	2.2	-13.7
	Sugar	1.0	1.0	-1.8	0.2	0.2	-0.4	1.5	1.6	-2.8
	Rape seed	2.4	2.4	5.8	0.6	0.6	1.4	3.9	3.9	9.7

Exports for USA and Brazil, Imports for EU

Source: PEATSim model results