Projecting the effect of oil price regimes on biofuel markets

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Introduction

Average annual global biofuel production reached around 45 billion gallons in 2012/14 and is projected to reach around 65 billion gallons in 2023 (USDA, 2014). For the first-generation feedstocks that are used to produce biofuels are derived from agricultural products such as corn, wheat, sugarcane, soybean and other oilseeds. Alternatively, these products can be used for either feed or food production. The by-product from the feedstocks, such as Dried Distillers Grains with Solubles (DDGS) can also be used in the livestock industry as substitutes for feed grains and oilseed meals. As a consequence, the supply of biofuels in the global market is affected by the supply of these feedstocks, which in turn employ either petroleum or biofuels as a direct or indirect energy input.

Two factors have generated this circular dependency over the last few decades. First, as agricultural sector becomes more mechanized worldwide, direct and indirect energy-related costs become key determinants of commodity supply and biofuel production. The sector is directly affected by high and volatile world oil prices that in turn affect the cost of agricultural production (Nazlioglu and Soytas, 2011). Some models suggest that the direct energy component of agriculture alone is four to five times higher than for manufacturing sectors (Baffes, 2013). Second, the supply of biofuels has increased sufficiently to make it a viable partial substitute for oil in the production, transportation and distribution cycles of agricultural products. The latter is the result of changes in environmental policy, price volatility and other behavioral changes (Beckman, Borchers, & Jones, 2013).

Contrast to the overwhelming predictions, an interesting development in these energy-agriculture dynamics is the recent decline in petroleum prices-West Texas Intermediate average spot prices have fallen about 45 percent since July 2014 and continued to remain below the long-term average prices (EIA, 2015). Some of the main causes for such large and rapid change in petroleum prices are lower global oil demand, increasing inventory (to some extent due to strategic expansion of oil production by several OPEC nations), and expansion of U.S. shale oil production, to mention a few. In the face of these challenges, we examine the interaction between oil prices and the biofuel markets using a partial equilibrium global agriculture model.

We use the Energy Information Administration's (EIA) projected base, high, and low oil price scenarios as basic simulating inputs to the model. We estimate the direct and indirect oil price cost transmission elasticities to the agricultural practices that affect yield, area harvested, production, and prices. By integrating the analysis with the USDA long term agricultural projections to 2023 (USDA, 2014), we simulate the effect of changes in oil prices on biofuel production and prices.

The main objective of this study is to examine the effect of projected changes in oil prices on projected global biofuel production and prices. In this particular case, we will focus on the three major biofuel producing countries (US, Brazil and European Union (EU)). Currently, more than three-quarters of global production is concentrated in these three countries and they are the largest participants in international biofuel markets. While we expect the change in oil prices will exert pressure on biofuel prices, with a moderating influence due to biofuel policies, the question of the magnitude of the pressure is important for understanding the role of agriculture in global

food and fuel supply chain. The projection will also help to look forward the effect of current policies on future performance of agriculture and energy sector.

The remainder of the paper is developed as follows. The next section provides a brief literature review. As the literatures on biofuels are expanding in recent years, this is by no means a complete overhaul of the entire literature. Section 3 describes the Model and detailed specification for the modified version of the PEATSim model that fits the stated purpose. The Data and some Parameter Estimates are given in section 4. The research findings will be discussed in the Results and Discussions section. Finally, a Conclusion summarizes the main results.

Literature Review

Among the main factors that affect biofuel market is changes in the price of oil. It is acknowledged that a large increase in the price of oil would drive rapid expansion of biofuels with adverse effect on global food and feed supply (Timilsina, Mevel, and Shrestha, 2011). In addition, expansion of biofuel production may respond to reducing energy dependence on fossil fuels, diversifying energy supply sources, and implementing improved environmental standards. The effect of changing oil price on biofuel market can be reflected through affecting the market for major feedstocks.

One of the controversial arguments presented against the expansion of biofuels is its ultimate impact on food prices that were experienced in 2007/08 and 2011/12 (Abbott, 2013). In their analysis of the 2006/08 commodity price boom, Baffes and Haniotis (2010) concluded that energy price is a key determinant of food commodity prices and the prices of most commodities respond strongly to energy price change. Using a computable general equilibrium model, Timilsina, Mevel, and Shrestha (2011) projected that a 65 percent increase in oil prices from the baseline would reduce global agricultural output by 0.8 percent in 2020. The loss would be lower if there were no biofuels.

Hertel and Beckman (2010) indicated that the pass-through of energy price volatility to agricultural commodity prices depends critically on renewable energy policies such as the Renewable Fuels Standard (RFS) mandate and on the blend wall. Their analysis suggests that greater volatility in feedstocks is likely to occur as a result of these policies. The pass-through effects of higher oil prices are also largely driven by common macroeconomic determinants of the prices of oil and agricultural commodities (Baumeister and Kilian, 2014). Using National Agricultural Statistics Service (NASS) data, Beckman, Borchers & Jones (2013) found that energy price shocks induce changes in production practices that reduce use of energy-intensive inputs. In particular, they reported that the response to higher energy prices varied by commodity in proportion to the use of energy related inputs like fertilizer.

Unlike the popular argument against biofuel that it is behind the global food price crises (de Gorter, Drabik and Just, 2015), empirical researches find no significant impact of biofuel production on the prices of feedstocks and food products (Ajanovic, 2011). More specifically for the United States, the data showed no evidence for the relationship between oil and corn prices using cointegration analysis where corn is one of the major feedstcoks for U.S. ethanol production (Avalos, 2014). In addition for the US corn ethanol mandates, Baumeister and Kilian

(2014) showed that there was no evidence the mandates have created a tight link between oil and agricultural markets.

The research on biofuel markets and change in oil prices focus on econometric estimates such as value-at-risk, cointegration, vector error corrections (VECM), multivariate generalized autoregressive conditional heteroskedascity (MGARCH) and volatility spillovers estimation using historical data (Avalos, 2014; Zhang, et. al, 2009). Research works that empirically assess the projected impact of changing oil prices on biofuels and the major feedstocks markets in a country-commodity linkage has not attracted the attention of the main stream agriculture-biofuel dialogues.

Unlike much of the studies that focus on historical data and econometric estimation to check the post effect of policy and price changes, this study uses historical data to econometrically estimate the major parameters that can be used in the projection processes. This approach is useful tools for decision-makers considering production, investment, technology, trade or policy alternatives. Moreover, concentrating on the three major biofuels and the required feedstocks producing countries can give a completed insight to the effect on oil prices change on biofuel market. By the nature of their economies, these countries have huge impact on both energy and agricultural market through policy and price structures.

Since oil prices change are the main inputs of this analysis, and prices do carry over all other expected market and regulator changes during the projection period. Hence, we assume the current biofuel and energy polices will remain in effect during the projection period giving price as the main instrument in signaling the overall performance in the three economics under consideration. The basic framework of the model built on the USDA agricultural projections, it is important to underline that except the projected change in oil prices, all other factors are not expected to change throughout the projection period.[1]

Methodology and Modeling Framework

The Partial Equilibrium Agricultural Trade Simulation (PEATSim) model developed by Somwaru and Dirkse (2012) will be used as the basis in the scenario analysis. PEATSim is a dynamic, partial equilibrium, multi-commodity, multiple-region model of global agricultural policy and trade. The model accounts for simultaneous interaction between livestock and crops while maintaining identities such as supply, utilization and consumption. PEATSim contains major crop and oilseed markets, as well as sugar, livestock, dairy and biofuel (ethanol and biodiesel) markets. It allows modeling of different sets of production activities, inter-linkages among various crops and livestock sectors, and interaction of producers and consumers at a global level. The model's flexible specification gives it the capability to incorporate a variety of domestic and trade policy instruments.

Modified PEATSim

We briefly describe below the parts of the PEATSim model that we modify; for the detailed explanation of the basic model, please refer to Somwaru and Dirkse (2012).

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[1] For more detailed information about USDA long-term agricultural projections, we direct readers to USDA (2014).

The standard area equation in the PEATSim model captures producers' evaluation of returns to alternative crops when making planting decisions. Originally, the area harvested in PEATSim was given as

1) $\text{AHV}_{i,r,t} = a_{i,r,t}\text{AHV}_{i,r,t-1}^{\lambda_{i,r}} \left[\prod_{i,j}^{n}(\text{PPR}_{i,r,t-1})^{\varepsilon_{ij}} \right]$

        for *i* crop and *j* other crop; *r* country or region; *t* current year and *t-1* previous year

where $\text{AHV}_{i,r,t}$ is crop area harvested; $a_{i,r,t}$ is a measure that captures the past interaction between the expected return and crop area; $\text{AHV}_{i,r,t-1}$ is lagged crop area harvested; $\lambda_{i,r}$ is a partial adjustment parameter; $\text{PPR}_{i,r,t-1}$ is the own lagged producer price; $\text{PPR}_{j,r,t-1}$ is the lagged producer price other crop; and the ε_{ij} are own and cross price elasticities for crop area.

However, in addition to not having a cost component, the area equation generates producer response on the basis of previous year prices only, which ignores expectations with respect to yields. The PEATSim model is modified to accommodate change in oil prices through estimating the cost of production transmission elasticities for the major commodities in major producing countries (Nigatu, et al., 2014). For the area response used in this analysis, lagged producer prices are replaced with expected net return, $\text{ENRT}_{i,r,t}$ as

2) $\text{AHV}_{i,r,t} = a_{i,r,t}\text{AHV}_{i,r,t-1}^{\lambda_{i,r}} \left[\prod_{i,j}^{n}(\text{ENRT}_{i,r,t})^{\varepsilon_{ij}} \right]$

Theoretically, the expected net return, $\text{ENRT}_{i,r,t}$, in turn, is the difference between expected revenue and expected cost

3) $\text{ENRT}_{i,r,t} = \text{EPPR}_{i,r,t}\text{EYLD}_{i,r,t} - \text{ECST}_{i,r,t}$

where $\text{EPPR}_{i,r,t}$ is expected producer price, $\text{EYLD}_{i,r,t}$ is expected yield, and $\text{ECST}_{i,r,t}$ is the expected cost of producing. The difference between expected revenue and expected cost can be in the vicinity of zero (positive or negative), which is fine with a linear model but quite problematic for a growth rate model, such as PEATSim. Thus, for this application, we specify expected net returns as the ratio of expected revenue and expected costs

4) $\text{ENRT}_{i,r,t} = \left[\text{EPPR}_{i,r,t}\text{EYLD}_{i,r,t} \right] / \text{ECST}_{i,r,t}.$

Expected revenue is the product of expected price and expected yield. Given that PEATSim is calibrated to the USDA and OECD-FAO baselines, plus the difficulty modeling futures prices or trends in commodity prices within PEATSim, expected prices are assumed equal to the previous years' producer price, $\text{PPR}_{i,r,t-1}$,

5) $\text{EPPR}_{i,r,t} = \text{PPR}_{i,r,t-1}.$

The current yield specification in PEATSim is

6) $\text{Yld}_{i,r,t} = \gamma_{r,i,t}\,\text{Yld}_{i,r,t-1}^{\lambda y_{i,r}}\,\text{PPR}_{i,r,t-1}^{\varepsilon y_{i,r}}(1 + g_{i,r,t})$

where $\text{Yld}_{i,r,t}$ denotes yield, $\gamma_{r,i,t}$ is a measure that captures the past interaction between the producer price and yields, $\lambda y_{i,r}$ is a partial adjustment parameter, PPR denotes the producer price, $\epsilon y_{i,r}$ is an elasticity measuring the long-run responsiveness of yields to market prices, $g_{i,r,t}$ is a growth rate representing underlying technological improvements in yields that are estimated using historical data.

The response to expected output prices is moderated by adding expected costs to the yield equation

$$7) \qquad \text{Yld}_{i,r,t} = y_{i,r,t} \text{Yld}_{i,r,t-1}^{\lambda y_{i,r}} \left(\text{PPR}_{i,r,t-1}^{\epsilon y_{i,r}} \Big/ \text{ECST}_{i,r,t}^{\epsilon y c_{i,r}} \right) (1 + g_{i,r,t}).$$

Where $\text{Yld}_{i,r,t-1}$ is lagged yield.

It is assumed that the response to changes in expected input costs is proportional to the price response elasticity and hence, yield cost elasticity, $\epsilon y c_{i,r}$, equals to 30 percent of the value of long-run responsiveness of yields to market prices, $\epsilon y_{i,r}$.[2] Thus, expected yield is

$$8) \qquad \text{EYLD}_{i,r,t} = (1 + g_{i,r,t}) \text{Yld}_{i,r,t-1}.$$

Expected revenue, $\text{EREV}_{i,r,t}$, is then

$$9) \qquad \text{EREV}_{i,r,t} = \text{EPPR}_{i,r,t} \text{EYLD}_{i,r,t}$$

Expected crop production costs

Demand for crop production inputs is derived from the demand for agricultural goods, and as such, we expect that prices of fertilizer, agrochemicals, seed and other inputs are endogenously related to the market conditions for agricultural products. For example, petroleum prices are strongly and positively correlated with fertilizer prices. At the same time, it seems safe to assume that agricultural markets have little impact on petroleum prices. Hence, we use current as well as previous year petroleum prices as proxies for prices of direct and indirect energy related and other inputs that determine expected crop production costs. Previous year prices capture costs associated with inputs produced in the previous year and differences in cropping seasons which occur especially in the northern and southern hemisphere. The petroleum price, POIL, which is expressed in real U.S. dollars, is converted to local currency by multiplying it by each region's real exchange rate REXR

$$10) \qquad \text{ECST}_{i,r,t} = c_{i,r,t} \left(\text{REXR}_{r,t} \text{POIL}_t \right)^{\psi_{i,r}} \left(\text{REXR}_{r,t-1} \text{POIL}_{t-1} \right)^{v_{i,r}}$$

where $\psi_{i,r}$ (*psi*) and $v_{i,r}$ (*upsilon*) represent elasticities measuring the transmission of changes in current and previous year crude oil prices to production costs for each crop (*i*) in each region (*r*),

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[2] We present a sensitivity analysis with 10 and 50 percent value.

while $c_{i,r,t}$ is a calibration factor that permits replication of base scenario production costs. The values of $\psi_{i,r}$ and $v_{i,r}$ are obtained by estimating the relationship between production costs in each region and world oil prices using Ordinary Least Squares with cross-section (commodity or state) Seemingly Unrelated Regression techniques.

These changes result in the modified area equation as

$$11) \quad \text{AHV}_{i,r,t} = a_{i,r,t}\text{AHV}_{i,r,t-1}^{\lambda_{i,r}}\left[\prod_{i,j}^{n}\left(\{\text{PPR}_{i,j,r,t-1}(1+g_r)\text{YLD}_{i,j,r,t-1}\}/\text{ECST}_{i,r,t}\right)^{\varepsilon_{ij}}\right].$$

Data

The model employs the same macroeconomic and demographic data—such as the gross domestic product (GDP), the GDP deflator, exchange rates, population, and population growth rates, as well as world petroleum prices—as in the 2023 USDA agricultural projections. The model replicates the projections for most commodities and countries (USDA, 2014). For those commodities and countries that are not included in the USDA baseline projections (dairy products, sugarcane, sugar beets, sugar, and biofuels), the model replicates the 2014-2023 OECD-FAO Agricultural Outlook (OCED/FAO, 2014). Alternative projections for the biofuel market are obtained by imposing higher and lower oil, gasoline, and diesel prices based on the EIA's 2014 energy outlook (EIA, 2014).

Figure 1. EIA's Projected Oil Price
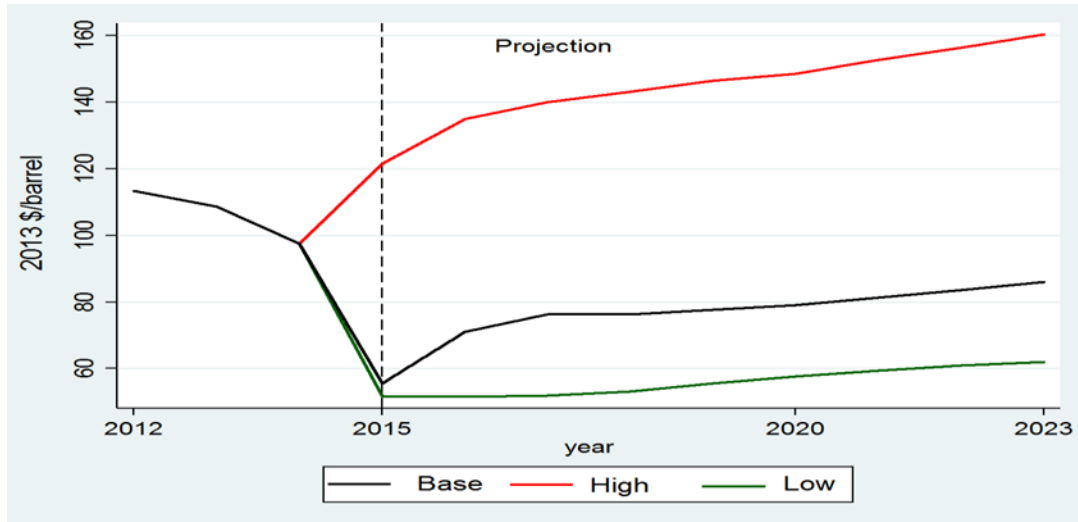
As shown in Figure 1, the base oil price scenario at the beginning of the projection period, 2015, seems to capture the recent oil price trend reaching around $50 per barrel. By the end of the projection period, the oil price is expected to fall in the range of $62 for low price to $160 per barrel for high oil price scenario. The base price is expected to increase at annual rate of 5 percent throughout the projection period and reach about $86 per barrel by 2023.

Estimated Parameters

Oil price-production cost transmission elasticities

The modified PEATSim model is designed by introducing oil price-production cost transmission elasticities. These elasticities measure the percent change in the total variable cost of producing a crop in a certain region or country as a result of a one percent change in oil price. Based on the current and previous year's oil prices and available data, two elasticities are estimated for the five major crops (corn, wheat, rice, soybean, cotton), sugarcane, sugarbeets, other coarse grains (barley, sorghum, millet), and other oilseeds (peanuts, rapeseed, sunflower seed).[3]

Even though we concentrate on US, EU and Brazil, the structure of the model is built on these three countries and Argentina, Australia, Canada, China, India, Japan, Korea, Mexico, Russia and Rest of world. European Union (EU) cost data are limited to corn and wheat. Sugarcane cost data is available for Brazil, where it is the main feedstocks used in Brazilain ethanol productoin. National average cost data are used for the EU and the United States, with sample periods of 1997-2011 and 1995-2012, respectively. State data were used to estimate transmission elasticities for the US, and regional data is used for Brazil. For both of these regions, sample periods and the composition of states for each commodity varied according to geographic and climatic conditions. The elasticities were estimated using Ordinary Least Squares with cross-section (commodity or state) Seemingly Unrelated Regression techniques for all regions except the EU and the results are shown in Table 1.

Table 1. Petroleum price-production cost transmission elasticities

	Corn	Rice	Wheat	Other grains	Rapeseed	Soybeans	Sunflower seed	Sugar cane
Current year petroleum price-production cost transmission elasticities, ($\psi_{i,r}$)								
Brazil	0.29	0.13	0.18	0.23		0.21		0.07
EU-28	0.08	0.13	0.16	0.07	0.16	0.15	0.15	-
US	0.14	0.11	0.23	0.11		0.13		0.12
Previous year petroleum price-production cost transmission elasticities, ($v_{i,r}$)								
Brazil	0.06	0.13	0.24	0.05		0.15		0.03
EU-28	0.08	0.10	0.08	0.07	0.08	0.12	0.12	-
US	0.11	0.11	0.11	0.09		0.11		0.09

The costs of producing corn, other grains and soybeans in Brazil are more sensitive to oil price changes than other crops. On the other hand, the cost of sugarcane, the main feedstocks for ethanol production in Brazil is not sensitive to change in oil prices. This indicates that Brazilian ethanol policy, which has a root in the 1970 oil crisis, has undergone major transformation in terms of capacity and economies of scale for the last four decades to withstand changes in global

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[3] The change in oil price is designed to affect area harvested and yield for products listed here. Livestock products and processed foods made of them are not directly affected by the change in energy price.

oil prices. The US has significantly higher cost elasticity for wheat compared to the other countries, but corn and soybean costs of production respond modestly to change in oil prices. Generally, the EU has relatively low cost elasticities for the commodities considered, suggesting its common agricultural policy for insulating producers from world energy price fluctuations.

Yield Growth Rate

One of the parameter used in running the PEATSim model is the average annual yield growth rate shown in Eq (8). Based on the historical data, we estimated the annual yield growth rate for major commodities as shown Table 2. Except for wheat and corn, the growth rate for most commodities in Brazil is expected to be higher than in the US and EU. US corn, EU oilseeds and Brazilian sugarcane that are used for feedstocks in their respective biofuel production will enjoy higher growth rates than other commodities.

Table 2. Average yield growth rate, %

	Corn	Rice	Wheat	Other grains	Rapeseed	Soybeans	Sunflower seed	Sugar cane
Brazil	1.01	0.94	0.53	1.03	-	1.14	-	1.1
EU-28	0.6	0.13	0.27	0.28	0.73	0.61	0.8	
US	1.15	0.48	0.83	0.42	-	0.93	-	-

Results and Discussion

Change in Area Harvested

As specified in Eq (11), the first and most important change coming from the modified PEATSim model is area harvested. The model now becomes more proactive in responding to oil price changes that helps to analyze the situation in biofuel market. U.S. wheat, Brazilian sugarcane, and EU soybean area harvested are expected to relatively respond the most compared to the base, as seen in Table 3. U.S. wheat and EU soybean are not the major feedstocks in the US and EU biofuel production, respectively.

Table 3. Change in area harvested from the base given high and low oil price scenarios, 2015-23 average

	USA		Brazil		EU-28	
	High	Low	High	Low	High	Low
change from the base value, %						
Corn	-1.1	0.0	-1.0	-2.0	-0.2	0.2
Soybean	-0.5	0.1	-1.4	0.7	-2.0	1.6
Wheat	-1.9	1.4	-2.2	1.5	-1.0	0.4
Sugarcane	0.4	-0.4	3.3	-2.0	-	-
change from the base value, 1000 hectare						
Corn	-357	-15	-147	-307	-21	21
Soybean	-149	43	-450	242	-10	8
Wheat	-337	254	-43	30	-265	115

| | Sugarcane | 1 | -1 | 356 | -220 | - | - |

For high oil price scenario, sugarcane production in Brazil will increase by around 356 thousand hectares per year throughout the projection period compared to the base. This will enable more biofuel production in Brazil from sugarcane. Corn and sugarcane area harvested in Brazil will decline more than 300 and 200 thousand hectares as a result of low oil price compared to the base, respectively. Corn and soybean area harvested in the US will decrease as a result of high oil price compared to the base. But the reduction in area harvested for both feedstocks in the US for low oil price will be minimal compared to the base. For high oil price scenario, wheat area harvested in the US and EU will experience an annual decline of about 337 and 265 thousand hectares compared to the base, respectively.

Crop Production

United States is projected to produce around 36 and 31 percent of the global corn and soybean (Table 4). From 378 million metric tons of corn, about 35 percent will be used as the main feedstocks in producing ethanol in the US (USDA, 2014). The production of both corn and soybean are not as such sensitive to oil price changes where low oil price scenario will result in relatively insignificant production gains compared to the base. Brazil produces more than 820 million metric tons or more than 40 percent of the global sugarcane throughout the production period. More than 50 percent of sugarcane production is used as a feedstock in ethanol production where it is expected to respond to change in oil prices (Valdes, 2011). High oil price will lead to more than 3 percent annual increase in sugarcane production compared to the base, where sugarcane production will decrease by about 2 percent annual rate compared to the base for a falling oil price during the projection period. Wheat production is expected to be sensitive to oil price change in the US and Brazil. Whereas it is less sensitive in EU where is used as a major feedstock in ethanol production.

Table 4. Crop production and change from the base given high and low oil price scenarios, 2015-23 average

|	USA		Brazil		EU-28		Global	
Average annual base production and global proportion								
	MMT	%	MMT	%	MMT	%	MMT	%
Corn	378	36	78	7	74	7	1051	100
Soybeans	99	31	104	32	1	0	324	100
Wheat	58	8	5	1	147	20	736	100
Sugarcane	28	1	829	41	0	0	2043	100
Change from the base value, %								
	High	Low	High	Low	High	Low	High	Low
Corn	-1.1	0	-0.9	-2	0	0.2	-0.4	-0.2
Soybeans	-0.6	0.2	-1.6	1	-2.1	1.7	-0.9	0.6
Wheat	-2.1	1.6	-2.6	1.9	-1.1	0.6	-0.9	0.6
Sugarcane	0.3	-0.3	3.6	-2.2	-	-	1.3	-0.8

Note: MMT million metric tons

Biofuel Production

Major producing Countries

As shown in Figure 2 biofuel production will increase for high, while decrease for low, oil price scenario at different magnitude and scale for all of the three major producing countries. With the base oil price in place, ethanol production in Brazil will experience a 6 percent annual growth rate over the projection period, and the total ethanol production will reach around 17 billion gallon by 2023. EU will continue to be the major biodiesel producer where biodiesel production will reach around 4 billion gallon by 2023 with about 5 percent annual growth rate over the projection period. EU biofuel production will continue to grow until 2020 when production will start to level out. After 2020, EU biofuel production is not expected to respond to oil price changes. This could be as a result of limited biofuel production capacity and attractive investment alternative in other sectors.

Figure 2. Biofuel Production in Major producing Countries, 2012-2023
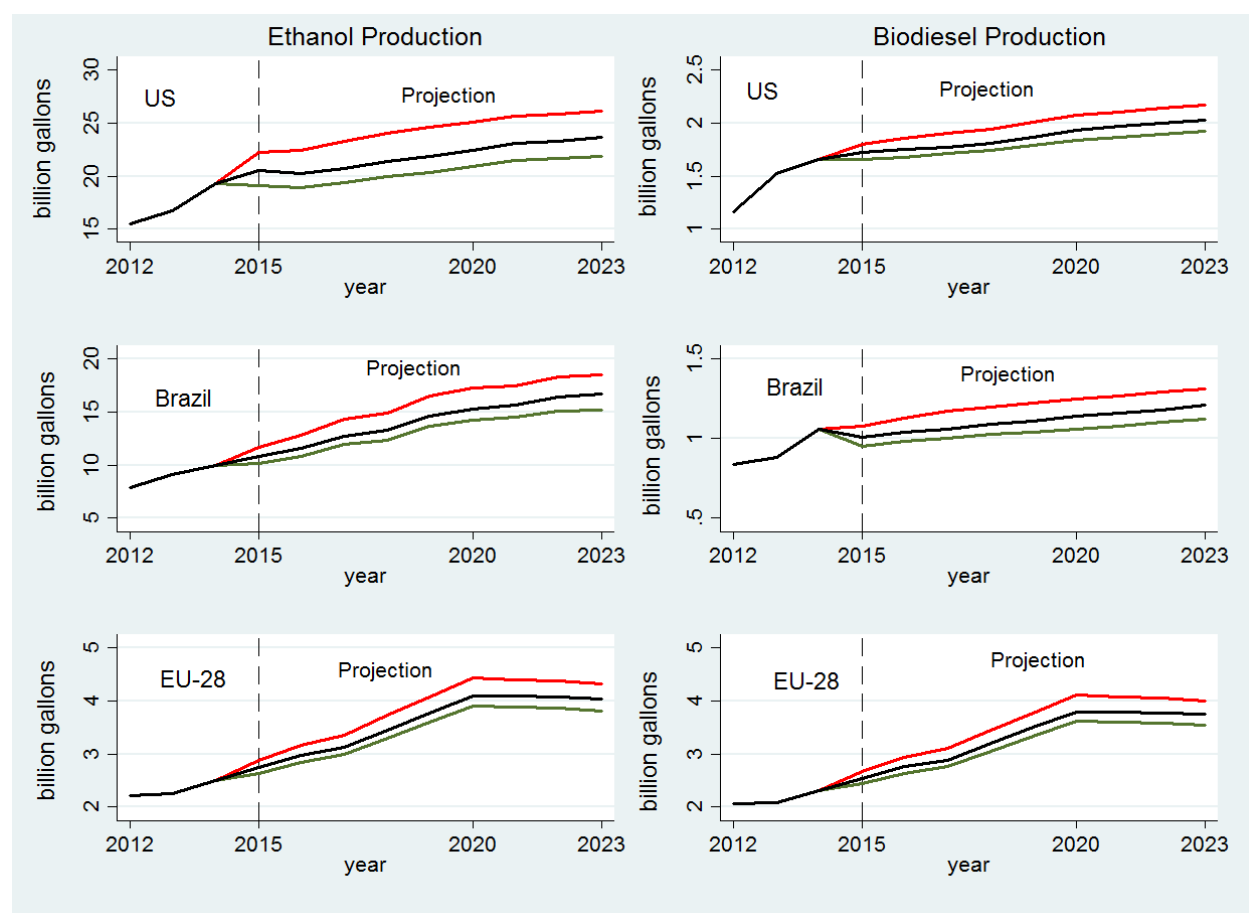
US will continue to be the world's leading ethanol producer where under the base oil price scenario, both ethanol and biodiesel production will grow at annual rate of around 2 percent. With the Renewable Fuel Standard (RFS) and Blend wall policy in place, US ethanol production

from the first-generation feedstock will reach around 24 billion gallon, whereas biodiesel production will reach around 2 billion gallon at the end of the projection period. An increased biofuel production will also result in more supply of DDGS for livestock production that otherwise depends on grains such as corn.

With rising oil price scenario, ethanol production in the US and Brazil, that produce more than three quarter of the global ethanol, are expected to increase more than 10 percent. Annually, additional 2.5 billion and 1.6 billion gallons of ethanol will be produced with the high oil price scenario compared to the base in the US and Brazil, respectively (Table 5). A falling oil price will have a lesser impact, about 7 percent, in decreasing ethanol production in the US and Brazil.

EU produces around 40 percent of the global biodiesel. With high oil price, its annual biodiesel production will increase around 300 million gallons compared to the base. A falling oil price will decrease its biodiesel production by about 200 million gallons compared to the base. In the US and Brazil, biodiesel production will increase or decrease by about 100 million gallons compared to the base for high and low oil price, respectively.

Table 5. Change in biofuel production from the base scenario, 2015-23 average

Biofuels	Country/ Region	Historical average 2012-14	Base average 2015-23	High	Low	High	Low
				billion gallons		%	
Ethanol	Brazil	9.0	14.1	1.6	-1.0	11.6	-7.1
	EU-28	2.3	3.6	0.3	-0.2	7.3	-4.6
	USA	17.1	21.9	2.5	-1.5	11.3	-6.8
	Rest of the World	7.1	7.9	0.1	-0.1	1.5	-0.9
	world	35.6	47.5	4.5	-2.7	9.4	-5.7
Biodiesel	Brazil	0.9	1.1	0.1	-0.1	9.4	-6.1
	EU-28	3.2	4.5	0.3	-0.2	6.1	-4.0
	USA	1.5	1.9	0.1	-0.1	6.8	-4.4
	Rest of the World	4.6	3.8	0.1	-0.1	3.5	-2.3
	world	8.2	11.2	0.6	-0.4	5.6	-3.7

Global Biofuel Production

With the base oil price, global ethanol and biodiesel production are expected to reach around 53 billion and 13 billion gallons by 2023, respectively (Figure 3). Both productions will experience a 3 percent annual growth rate during the projection period. Rising oil prices is expected to boost global ethanol production by about nine percent, which is more than 4.5 billion gallons annually throughout the projection period compared to the base (Table 5). With lower oil prices, global ethanol production will decline by about six percent compared to the base. On the other hand, global biodiesel production could experience small changes, less than 6 percent compared to the base for high and low oil price.

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Figure 3. Global Biofuel Production, 2012-2023
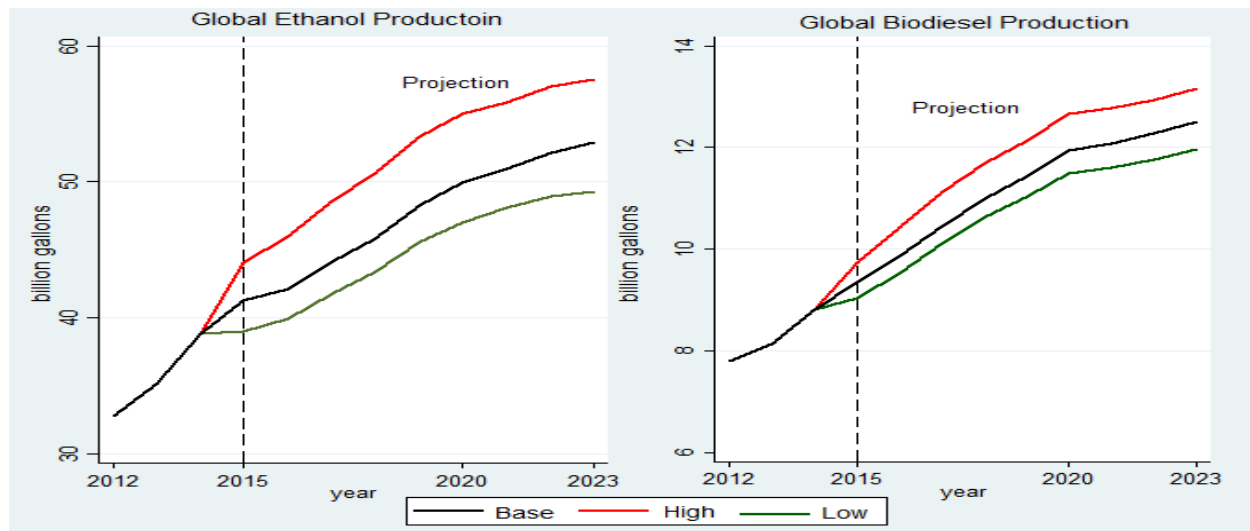
Reference prices

With the base oil price scenario, ethanol and biodiesel price will reach around $2.54 and $3.27 per gallon by the end of the projection period, respectively (Figure 4). Both prices will grow with an annual rate of 2 percent throughout the projection period while oil price annual growth rate is around 5 percent. Changes in oil prices are expected to have impacts on biofuels prices. It is projected that when oil prices are high, biofuel prices will rise more than 30 percent during the projection period compared the base. Low oil prices push biofuel reference prices down by about 18 percent per year, compared to the base. But both the increase as well the decrease in biofuel prices as a result of high and low oil prices, respectively, will subside in magnitude at the very end of the projection period.

Figure 4. Biofuels Reference Price, 2012-2023

Figure. Ethanol and Biodiesel prices ($/gallon), Base, High, and Low oil price projections, 2012-2023
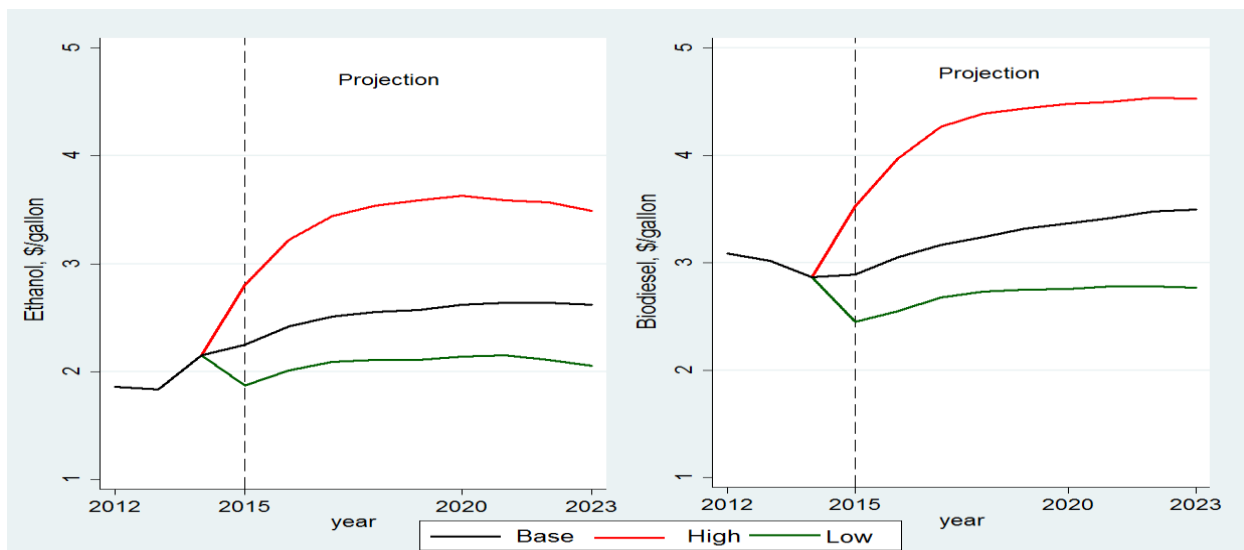
Sensitivity analysis

The standard yield equation in PEATSim, which includes lagged yield and lagged prices, was modified to also include expected production cost. The elasticity for production costs is assumed to be 30% of the elasticity for lagged producer prices, as assumed in Eq (7). To evaluate the sensitivity of this assumption, projections are derived when assuming the elasticity on production costs is 10 or 50 percent of the elasticity for lagged prices. The results indicate that the percentage change for the reference price for high and low oil price compared to the base are stable for the price of biofuels in any of the elasticities used (Table 6). Hence, the original assumption for using a 30 percent of the value long-run elasticity of yield to market prices to yield cost elasticity is a reasonable one which remains stable when tested for a wide ranges of values.

Table 6. Change in reference prices with alternative yield cost elasticity assumptions, 2015-2023 average,

	High oil price			Low oil price		
	Elasticity applying to production costs in the yield equation					
	10%	30%	50%	10%	30%	50%
Biodiesel	31.3	31.3	31.3	-17.7	-17.7	-17.7
Ethanol	35.2	35.2	35.2	-18.3	-18.3	-18.3

Conclusion

The potential impacts of energy price shocks on production feedstocks and biofuels are investigated using the dynamic multi-region, multi-commodity PEATSim model. The impacts of the EIA's 2014 base, low, and high oil price projections are analyzed with the aid of petroleum price–production cost transmission elasticities for major crops across countries and regions. Impacts on input costs, area harvested, yield and production, along with corresponding changes in reference prices for the projection years 2015-23 are reported.

Due to its high cost transmission elasticities, Brazil will experience wide ranging changes in average input costs. In the advent of higher energy prices, Brazil will increase its ethanol production by nearly 11 percent but with lower petroleum prices, it will decrease ethanol production by about seven percent compared to the base. As a result, sugarcane production, which is the major feedstock for Brazilian ethanol, will rise about 30 million tons annually to offset rising oil prices and fall about 18 million tons annually in the event of lower oil prices compared to the base.

US corn and soybean production will experience slight changes, while U.S. ethanol and biodiesel production will rise 11 and seven percent, respectively, between 2015 and 2023 with high oil prices. In the event of lower oil prices, US ethanol and biodiesel production will fall over the projection period by seven and four percent, respectively, compared to the base values. With annual average production of around 4.5 billion gallons of biodiesel throughout the projection period, in terms of absolute change, biodiesel production in EU will significantly respond to change in oil prices. EU will increase about 300 million gallons for high but decrease about 200 million gallon of biodiesel for low oil price scenario compared to the base.

The results reported here need more caution when applying for policy formulation for the following reason. Oil prices also have immediate impact on marketing costs and can also impact capital inputs and producer decisions to invest in yield enhancing technology. Future research can address these and related agriculture and energy sector issues. Such work would provide a more complete picture of the scope and magnitude of energy price shocks on world agricultural markets.

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