BIOFUEL TAXES, SUBSIDIES, AND MANDATES: IMPACTS ON US AND BRAZILIAN MARKETS

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Executive Summary

Future prospects for biofuels in the United States and Brazil depend on government policies, the prices of gasoline and feedstocks, and the ability of each country’s fleet of vehicles to use ethanol. Because trade barriers between the two countries are low, the prospects for biofuels in each country are dependent on what goes on in the other. To help sort out the complex web of interrelated markets and fuels requires a model of the markets in which the fuels are traded. In this paper we present an updated and expanded market model of biofuels in Brazil and the United States and use the model to help understand the economic impacts of the US biodiesel tax credit and a recent reduction in the tax on ethanol in Brazil.

The model looks ahead to the 2013/14 corn marketing year in the United States that begins on September 1, 2013. Crop acreage is assumed known and fixed. For 500 different yield levels of US corn and soybeans, Brazilian soybean, sugarcane and recoverable sugar yields, Argentine soybean yields, gasoline prices and demand for Brazilian exports, the model solves for market-clearing prices and quantities of US corn ethanol and biodiesel, Brazilian sugarcane ethanol, and world prices of corn, soybeans, soybean oil and meal, and sugar.

US biofuel mandates are a major driver of the market solutions. The competition between biodiesel and sugarcane ethanol to meet the US advanced mandate and the competition between sugarcane ethanol and corn ethanol to meet the US conventional mandate as well as ethanol demand in Brazil are what determine model solutions. The outcome of this competition is a set of equilibrium RIN (Renewable Identification Number) prices that reflect underlying biofuel supply and demand conditions.

The model is calibrated to USDA’s May 2013 WASDE projections and to Brazil’s latest CONAB projections. Both sets of projections indicate that corn and sugarcane supplies are likely to increase from recent levels, lowering the cost of producing ethanol. This lower cost helps to hold down conventional biofuel RIN prices, which still must be high enough to induce ethanol consumption beyond the 10 percent blend wall in the United States. In Brazil, more abundant sugarcane supplies will result in increased ethanol production and consumption, but because the demand for ethanol in Brazil is price elastic, market prices will not drop much from recent levels.

The biodiesel tax credit increases the competitiveness of US biodiesel relative to sugarcane ethanol. Thus, biodiesel production will likely exceed levels needed to meet the biomass-based diesel mandate and will result in lower imports of sugarcane ethanol. The decline in Brazilian ethanol exports decreases Brazilian domestic demand for imported US corn ethanol so the extent of two-way trade in ethanol is reduced under the tax credit. However, demand for ethanol in Brazil is strong enough, and the cost of producing corn ethanol will likely be low enough, to induce strong exports of corn ethanol to Brazil even with the tax credit. The strong demand for ethanol in Brazil due to its large fleet of flex vehicles is further boosted by the reduction in one of Brazil’s ethanol taxes. Because of the availability of corn ethanol, much of the ethanol consumption increase in Brazil caused by the lower tax is met by increased imports of US corn ethanol.
I. Introduction

The future of biofuels in Brazil and the United States would seem to be bright. In Brazil, potential ethanol demand far outstrips supply because the number of flex fuel vehicles has grown from about one million cars in 2005 to more than 18 million today. In the United States, demand growth is also set to outstrip available supplies because of rapidly growing mandates specified in the Renewable Fuels Standard (RFS). California’s low carbon fuel standard can also most readily be met by increasing the consumption of low carbon biofuels over the next five years.

Potential demand growth in both countries, however, will only result in additional supplies if the future outlook for biofuel prices is attractive enough to drive investment. In Brazil, ethanol production stalled in recent years because of a lack of investment in new and existing sugarcane fields and high world sugar prices, which makes sugar more profitable to produce than ethanol. In the United States, most growth in mandated biofuel use is for cellulosic and other advanced biofuels. Investment in cellulosic biofuel plants will not be able to generate enough production to meet scheduled mandates, and the most available advanced biofuel is sugarcane ethanol from Brazil. Although it is certain that available supplies of cellulosic biofuels will not keep up with the US mandates, there is uncertainty about how the mandates will change to reflect this reality. Adding to this policy uncertainty is the uncertainty about how US biofuel consumption can increase enough to meet even non-cellulosic mandate increases because ethanol consumption will need to move significantly higher than levels that can be supported by 10 percent blends. How the so-called E10 blend wall will be breached or even if will be breached is not yet settled. This uncertainty makes it difficult to justify the levels of investment needed today to meet tomorrow’s mandates.

Adding to the uncertainty facing the demand for biofuels is uncertainty caused by other government policies. In Brazil, the government has fixed the wholesale price of gasoline below the gasoline import price. Because ethanol is a substitute for gasoline, this gasoline subsidy decreases domestic Brazilian demand for ethanol. The Brazilian government recently announced a reduction in a tax that is assessed on ethanol when it
leaves the plant. This measure was taken to counteract the gasoline subsidy. In the United States, a $1.00 per gallon biodiesel demand subsidy in the form of a blenders tax credit is set to expire on December 31, 2013. Because biodiesel and sugarcane ethanol both qualify as advanced biofuels under the RFS, this subsidy reduces the demand for sugarcane ethanol and hence reduces the amount of ethanol that will be needed to meet RFS mandates.

We write this paper to meet two objectives. The first is to provide insight into how Brazil’s reduction in its tax on ethanol and the US biodiesel tax credit impact the markets for biofuels in both countries. The period that we examine is the upcoming US corn marketing year, which runs from September 1, 2013, to August 31, 2014. The second objective is to provide an intuitive explanation of how biofuels and the RFS affect the markets for corn, soybeans, and sugarcane through the market for Renewable Identification Numbers (RINs). This second objective is met by explaining how the economics of the RIN markets work and providing the data that is used to estimate and calibrate the key supply and demand drivers of these markets that underlie our empirical simulation model.

The basics of our model along with underlying data are provided in Section II. Section III shows how RIN supply curves are derived. Section IV explains how competition between biofuels to meet the mandates RINs works. Model results for the 2013/14 US marketing year are provided in Section V. Additionally, more detailed results are provided in appendices. Readers who do not mind their results coming from a “black box” model can just skip ahead to Section V and the appendices. Those who don’t trust black box model results can find detailed explanations of the important modeling assumptions and data that drive the results in Sections II, III and IV.

II. The Model

The basic model framework builds on the approach developed by Babcock, Barr, and Carriquiry (2010). The model solves for market-clearing prices and quantities of corn ethanol, sugarcane ethanol, corn, soybeans, soybean oil and meal, biodiesel, and raw sugar. Random exogenous variables are wholesale gasoline prices, US corn yields, soybean yields in the United States, Brazil, and Argentina, total recoverable sugar (TRS) production in Brazil, and sugar export demand facing Brazil. The model is a short-run model because
crop acreages are fixed. Model solutions are found for 500 sets of the stochastic exogenous variables which are drawn from distributions that reflect their degree of uncertainty over the 2013/14 US corn and soybean marketing. Thus, the average value of the 500 model solutions can be interpreted as expected prices and quantities. To put the model results into perspective it is important to understand the important supply and demand determinants and modeling approaches for each of the markets analyzed.

**US Corn**

Corn supply in the 2013 marketing year equals beginning stocks plus the product of harvested acres and yield. Yield follows a beta distribution with a mean of 160 bushels per acre and a standard deviation of 14.5 bushels per acre.\(^1\) Harvested acres are fixed at 89.5 million acres, which is what USDA projects in its May, 2013 WASDE report. Beginning stocks are set at 759 million bushels. The cumulative distribution of US corn supply is shown in Figure 1. This chart shows the probability that beginning stocks plus production will be less than a given level. So for example, there is a 30 percent probability that supply will be less than 14 billion bushels. By contrast, supply in the 2012/13 marketing year was only 11.8 billion bushels. The probability that supply will be that low again is only 1.5 percent.\(^2\)

Non-ethanol corn demand consists of demands for feed, food, exports and storage. Demand curves for feed, food, and exports are assumed to be linear and calibrated to the corn prices and estimated use levels contained in USDA’s May WASDE projections. The mid-point of the projected range for corn prices for 2013/14 is $4.70 per bushel. The demand elasticities used to determine demand slopes and intercepts are -0.4 for feed demand, -0.065 for food demand, and -1.0 for export demand. Stock demand is specified as a non-linear function to account for stock-out conditions.\(^3\) Non-ethanol corn demand is shown in Figure 2.

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\(^1\) Trend yield for 2013 using 1980 to 2012 data is 157.25 bushels per acre. Using data from 1980 to 2010, trend yield is 163.21 bushels per acre, and using data from 1980 to 2011, trend yield is 161.65 bushels per acre. The 160 bushel per acre trend yield used here is a proxy for what trend yield would be if the weather variations were accounted for in estimating trend.

\(^2\) The probabilities of extreme high and low supply events are somewhat understated by Figure 1 because variability in planted and harvested acreage is not accounted for.

\(^3\) The demand function for ending stocks is \((1-\text{beta}	ext{c}	ext{d}	ext{i}	ext{f}(\text{min}(P\text{corn},8)/8,2.24644,1.65025))*3000+600.\)
Figure 1. Cumulative distribution of US corn supplies in 2013/14 marketing year

Figure 2. Non-ethanol corn demand in the United States
Corn Ethanol Supply

The amount of corn available to produce corn ethanol is simply corn supply, which is fixed once harvest is in, minus non-ethanol corn demand given by Figure 2. For a given corn supply, there is a unique combination of corn price and corn quantity available to produce ethanol. The amount of ethanol production equals the available corn for ethanol multiplied by 2.75, which is the number of gallons of ethanol that are assumed to be produced from each bushel of corn. The price of ethanol is found by assuming a zero economic profit condition in the industry and solving for the ethanol price that is needed to cover all production costs. Production costs are set at $0.50 per gallon plus the per-gallon cost of corn minus the value of distillers grains, which is set at 90 percent of the price of corn. Increases in corn ethanol production increase the ethanol industry’s use of corn, which necessitates a higher corn price to free up enough corn from non-ethanol uses. A higher corn price increases the cost of producing ethanol which requires a higher ethanol price to cover costs. Hence the corn ethanol supply curve slopes up.

Three ethanol supply curves are shown in Figure 3. Each supply curve corresponds to a different US corn yield. The effect of increasing corn production on ethanol supply can be measured in two ways. One way is to see how corn yield affects how much ethanol production will take place for a given price of ethanol. For example, if the price of ethanol received by plants is $2.00 per gallon then the plants will produce only 5 billion gallons if corn yield is 130 bushels per acre, 9.9 billion gallons if corn yield is 150 bushels per acre, and 14.8 billion gallons if corn yield is 170 bushels per acre. The second way of measuring the effect of corn production on ethanol supply is to see what price of ethanol is needed for a given level of production. The corn ethanol mandate rises to 14.4 billion gallons in 2014. To produce this quantity of ethanol will require a plant-received ethanol price of $1.96 per gallon with the corn yield of 170 bushels per acre, $2.45 per gallon with a corn yield of 150 bushels per acre and $2.97 per gallon if the corn yield is 130 bushels per acre.

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4 The zero-economic profit condition is a reasonable assumption in an annual model given that the corn ethanol industry has excess capacity and that it has shown an ability to produce large volumes of ethanol at relatively low margins since 2008.
Figure 3. US supply curves of corn ethanol in 2013/14 marketing years

US Ethanol Demand

In the fall of 2012, the Environmental Protection Agency (EPA) analyzed the impact on corn prices if requests for a waiver of the conventional biofuel mandate were granted. In their analysis EPA used a short-run demand for ethanol that was provided to them by the US Department of Energy. This demand curve is the curve in Figure 4 labeled “EPA demand curve.” The EPA demand curve is quite price insensitive at about 13.5 billion gallons, which is essentially where the E10 blend wall occurs. EPA also assumes that little E85 would be sold even if ethanol were priced at a 60 percent discount to gasoline. Furthermore, the EPA demand curve assumed that blenders would pay more than a 50 percent premium for ethanol if ethanol quantity dropped below 10 billion gallons.

The difficulty in estimating whether the EPA demand curve at low and high ethanol prices is reasonable is that there are no data to show what price discount would be required to induce owners of flex fuel vehicles in most parts of the country to fill up with E85 for the first time. There are also no data that shows what the quantity of ethanol demand would be if the price of ethanol rose about parity with gasoline now that refineries have been configured to produce 84 octane blendstock that when blended with 10 percent ethanol results in 87 octane regular blended gasoline.
In this study we assume that consumers, refineries, and blenders will be more responsive to price signals than EPA assumed in their waiver analysis. When the price of ethanol rises above gasoline, refineries will begin to have an incentive to use more gasoline and less ethanol. If the price of ethanol drops low enough relative to the price of gasoline, then owners of flex fuel vehicles (FFVs) will have an incentive to use E85 because the cost per mile traveled will be significantly less than with E10. The amount of price responsiveness that is added at the two ends of EPA’s demand curve shown in Figure 4 is the demand curve used in this study.

**Brazilian Ethanol Demand**

Brazilian fuel ethanol consumption consists of ethanol that is blended with gasoline to meet Brazilian blending requirements and pure ethanol that is used by owners of FFVs. The ethanol that is blended with gasoline is anhydrous (without water) ethanol. The pure ethanol that is consumed by FFVs and ethanol cars is hydrous ethanol that contains approximately five percent water. The modeling approach used here is to first specify the number of vehicles that will be driven in Brazil and the average consumption of fuel per
vehicle. The average consumption per vehicle is made a function of the weighted average price of hydrous ethanol and blended gasoline.\(^5\) Owners of FFVs choose whether to buy gasoline or E100 based on relative prices at the retail level. The model solves for the plant-received price of hydrous ethanol. The retail price of hydrous ethanol is specified by a mark-up equation. The wholesale price of gasoline equals the weighted average of the price of “neat” gasoline, which is known as gasoline A, and the wholesale price of anhydrous ethanol, which is a deterministic function of the plant-received price of hydrous ethanol. The retail price of blended gasoline, which is known as gasoline C, is specified by a different mark-up equation.\(^6\) The two key components of Brazilian ethanol demand for this analysis is the FFV demand for hydrous ethanol and the impact of Brazil’s regulation of the price of gasoline A.

Since 2006, mostly reliable data on annual hydrous ethanol consumption and the number of cars in the Brazilian fleet have been available. Because hydrous ethanol is only consumed in FFVs or ethanol cars—that can only run on ethanol—the proportion of the miles traveled by the FFV fleet that is accounted for by hydrous ethanol can be calculated. The scatter plot of red points in Figure 5 shows the relationship between this proportion and the retail price of hydrous ethanol relative to gasoline C from 2006 to 2012.

Because we have not observed price ratios greater than 0.7 or less than 0.5, we rely on survey data published by EPE (2013) to determine the response of FFV drivers to price ratios outside the range of data. The two data points we use to determine the relationship between fuel use and price are shown as triangles in Figure 5. The actual fuel use data show that when the average annual price of hydrous ethanol is 70 percent of the price of gasoline then approximately 23 percent of miles traveled in FFVs are fueled by hydrous ethanol. When the price drops to 50 percent of the price of gasoline then owners of FFVs use hydrous ethanol for about 80 percent of their driving. Because the proportion of hydrous ethanol used cannot fall below zero or rise above 100 percent, there are natural limits on the relationship between the price ratio and ethanol use. The portions of the solid line in Figure 5 that lie outside the fuel use data show the assumed relationship

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\(^5\) The demand elasticity of vehicle miles traveled with respect to the average price of fuel is assumed to be -0.04.  
\(^6\) The hydrous and gasoline retail markup equation were specified as linear functions of wholesale prices of each fuel and estimated using monthly price data from January 2003 to January 2011. The estimated ethanol markup equation is Retail Price = 0.35082 + 1.2086*Plant Price. The gasoline markup equation is Retail Price = 0.233 + 1.54*Wholesale Gasoline C Price.
Figure 5. Demand for hydrous ethanol by owners of FFVs in Brazil

where no data are available. If the price of ethanol rises above 115 percent of the price of gasoline, then it is assumed that hydrous ethanol consumption by FFVs falls to zero. Once the price of ethanol falls below 52 percent of the price of gasoline, then the remaining FFV owners begin to fill use hydrous ethanol linearly until 100 percent of miles traveled is fueled by hydrous ethanol.

Figure 6 shows the gasoline prices that are needed to understand the Brazilian ethanol market. Brazilian internal prices of gasoline are highly regulated. This regulation is made easier because the Federal government owns such a large share of Petrobras, the largest oil company in Brazil. The gasoline A price has not varied much from its current level of R$1.54 per liter since 2010. The difference between the gasoline A price and the Brazilian refinery price is tax. As world gasoline prices have increased over this time period, the Brazilian government has lowered taxes on Brazilian gasoline to reduce the cost of having to import gasoline at a higher price than it is sold for domestically. By reducing the tax on gasoline while holding it constant on ethanol, the Brazilian government has increasingly reduced the demand for ethanol. In an attempt to offset some of this reduced demand, Brazil’s government decided to reduce the tax on
wholesale ethanol by 12 reais cents per liter (R$ 0.12 per liter). The effect of the tax reduction is to lower the retail price of ethanol, thereby increasing the demand for ethanol, which will increase the price ethanol producers receive in Brazil. We assume that this tax reduction is made available to both domestically produced ethanol and imported ethanol.

**Brazilian Ethanol Supply**

Almost all Brazilian sugar refineries produce both ethanol and sugar. The amount of ethanol produced relative to sugar depends in part on which product generates more profits for the plant. Figure 7 plots the annual price of ethanol (expressed in R$ per liter) relative to the price of sugar (expressed in US$ per pound) against the proportion TRS used to produce ethanol. The equation of the best fit line is shown also. In general, as the price of ethanol increases relative to sugar, the greater is the proportion of TRS that is devoted to producing ethanol.

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7The order reducing the tax is Provisional Executive Order nº 613, decree number 7.997/13 released on May 8, 2013.
The quantity of TRS produced equals the product of sugarcane harvested and the average TRS expressed as a percentage of the tonnage of total harvest. Sugarcane harvested equals the product of area harvested and sugarcane yield. To make the analysis tractable we fix area harvested at 8.893 million ha in 2013/14 and 9.407 million ha for 2014/15. Sugarcane yield draws were multiplied by harvested area to obtain total sugarcane production in each year. The yield draws are assumed independent across the two years. The average production of sugarcane in the two years is 654 million tons in 2013/14 and 710 million tons in 2014/15. The average yield for 2013/2014 of 73.5 tons per ha is taken from CONAB’s forecast in April of 2013. Mean yield was increased by 1.3 tons per ha for 2014/15 because of a decline in the average age of Brazilian sugarcane fields due to increased investment in new and renewed fields. The standard deviation of yields was estimated from a regression of sugarcane yields in the state of Sao Paulo from 1990 to 2012 on a trend term and the average age of the fields. The standard deviation of the residuals from this regression was 1.40 tons per ha. Yields in 2013/14 are assumed
beta distributed with a mean of 73.5, a standard deviation of 1.4, a maximum of 77 and a minimum of 70.

Based on data from 1992/93 to 2011/12 TRS, expressed as a percentage of the tons of sugarcane harvested, averaged 13.8 percent in Brazil. The standard deviation of the percent TRS across these years is 0.33. Beta-distributed draws of TRS for 2013/14 and 2014/15 were obtained with a maximum value of 14.3 percent and a minimum value of 13.0 percent. These percent TRS draws were multiplied by total sugarcane harvest draws in each year to obtain million tons of TRS. To fit the Brazilian crop year into the US marketing year, a weighted average of the Brazilian total TRS draws were made with weights of 0.44 and 0.56 being assigned to 2013/14 and 2014/15 respectively. The resulting distribution of TRS in million tons is shown in Figure 8.

**Brazilian Sugar Demand**

Brazil is the world’s largest producer of sugar and the largest sugar exporter. The decision about how much ethanol to produce will therefore impact the world sugar price because more ethanol means less sugar will be produced. As a first step to modeling

![Figure 8. Distribution of Brazilian TRS for the 2013/14 US marketing year](image)
world sugar markets, here we specify a downward sloping demand curve for Brazilian sugar exports. The demand curve is a constant elasticity demand curve with a demand elasticity of -0.3. Demand is inelastic in the short run because world trade in sugar is thin and Brazil is by far the largest exporter. Sugar demand is calibrated so that Brazilian exports will total 28 million tons at a world sugar price of $0.18 per pound, which was the average futures price for sugar in the 2013/14 US marketing year in the middle of May, 2013. Sugar supply in other major producing countries is highly variable, and therefore so too is the export demand facing Brazilian sugar producers. To capture this variability the multiplicative constant in the export demand curve is varied by adding a mean-zero normal deviate with a standard deviation of 1.2.

The supply of sugar available for export equals the total supply of Brazilian sugar not used to produce ethanol less domestic sugar demand. The Brazilian domestic sugar demand curve is assumed deterministic and linear and equals 12 million tons at the $0.18 per pound price with a demand elasticity of -0.05. Sugar stock demand is a non-linear function of the world sugar price with stock out conditions happening at 100,000 tons if the 2013/14 price hits 33 cents per pound. Maximum storage is three million tons and occurs if the sugar price drops to eight cents per pound. The equilibrium world price is found where the quantity demanded of Brazilian sugar exports equals the available supply of exports.

**US Biodiesel Supply and Demand**

The US biodiesel supply curve is perhaps the most uncertain aspect of this analysis. The supply curve shows the quantity of biodiesel produced for any given biodiesel price. The biodiesel price must be sufficient to cover all variable costs of production and it must generate high enough returns for enough production capacity to be brought on line. The calculation of the price needed to cover incremental variable cost of making biodiesel from soybean oil is straightforward to calculate using soybean oil prices and variable cost data; however, the returns needed to induce biodiesel plant owners to turn on their plants is more difficult to determine as can be demonstrated in Figure 9. Plotted are monthly production and returns data since 2010.  

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8 Returns are calculated as the plant-received biodiesel price minus the cost of producing biodiesel from soybean oil. These returns are reported at http://www.card.iastate.edu/research/bio/tools/hist_bio_gm.aspx.
12 to annualize them. Although there is clearly an overall positive relationship between returns and production, it is also clear that the relationship is not constant across the three years. For example, in 2010, returns were low and so too was biodiesel production. But in 2012 returns were also low for some months but production was much higher than in 2010. In 2011 higher returns resulted in higher production levels in nearly a linear fashion. But production levels in 2012 were nearly as high with much lower returns.

What seems to be going on with these data is that in 2010 low production levels indicate that many biodiesel plants were idled. To induce owners of the plants to begin production requires high enough returns to cover switch-on costs of getting the plants operational. This is why margins of over $1.00 per gallon were needed to push production to about a billion gallons on an annualized basis. But once the plants were switched on in 2011, a billion gallons of annualized production was produced in 2012 at much lower margins. So the key question for this study is whether sufficient plants are

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9 Assuming that the demand for biodiesel is perfectly elastic, the data in Figure 9 trace out supply curves because the major shifter in supply is the price of feedstock which is accounted for in the calculation of margin.
operating to meet potential demand in the 2013/14 marketing year or whether margins need to be high enough to cover the costs of switching them on.

Monthly biodiesel production through March of 2013 lags the amount needed to meet 2013 biomass-based diesel mandates. This implies that currently-operating plants will need to ramp up production and/or additional production capacity will need to be brought on line. Either will require higher margins between April and September 1. Given that production increases in this time period, then the 2012 price quantity data would seem to be more applicable than the 2011 data for this study.

But the 2012 data are not adequate to identify the relationship between margin and production because the potential demand for biodiesel in the 2013/14 marketing year exceeds the highest production levels yet achieved by the US biodiesel industry. The key question for this study is what level of returns is needed to induce the industry to produce 1.6 billion gallons or 2.0 billion gallons in 2013/14? The supply response curve shown in Figure 9 is the one used in this study. It uses the 2012 data so that returns over variables costs need to be 43 cents per gallon to induce the industry to produce 1.28 billion gallons, which is the 2013 biomass-based diesel mandate. If returns rise to $1.00 per gallon, then the industry is assumed to respond by producing 1.85 billion gallons. The responsiveness of the industry declines at greater production levels to reflect capacity constraints.

Increases in biodiesel production will require increased amounts of soybean oil. The quantity demanded of soybean oil to produce biodiesel is a significant share of world soybean oil supplies so increased use of soybean oil to produce biodiesel will increase the price of soybean oil. This price response is why the model includes the soybean sector in the analysis. Of course not all biodiesel is produced from soybean oil. But because soybean oil is the most widely available feedstock approved by EPA for use as an advanced biofuel, we model all biodiesel produced in excess of 680 million gallons as coming from soybean oil. The first 680 million gallons of biodiesel is assumed to come from other feedstocks that include corn oil obtained from ethanol plant’s distillers grains, waste grease, inedible tallow, lard, and poultry grease.10

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10 No accounting for the differences in renewable diesel and biodiesel is made in this report. All fuel used to meet the biomass-based diesel mandate is referred to and modeled as biodiesel.
Biodiesel demand is assumed to be perfectly elastic at a discount to the wholesale price of diesel in the model. The discount is 8.65 percent plus 15 cents per gallon. The proportionate discount reflects the lower energy content of biodiesel. The fixed discount reflects extra handling and transportation costs of biodiesel relative to diesel.

**Soybeans, Soybean Oil, and Soybean Meal**

The key aspect of the soybean portion of the model, with respect to biofuels production, is the impact of expanded biodiesel production on the price of soybean oil. In the model, the world supply of soybeans is fixed once the realization of soybean yields in the US, Brazil, and Argentina occur; and thus, so too is the world supply of soybean oil because all soybeans are crushed. Soybean oil to produce biodiesel is obtained by diverting soybean oil from other uses. The total supply of soybeans plus the elasticity of demand for soybean oil for other uses are the two key factors that determine at what cost soybean oil can be bid away from other uses.

Soybean oil and palm oil are the two most widely traded and produced vegetable oils. The large market share of soybean oil lowers its demand elasticity. But the fact that other vegetable oils can substitute for soybean oil increases its elasticity. A more elastic demand implies a smaller price impact on soybean oil from expansion of US biodiesel production. The model’s relationship between the use of soybean oil to produce biodiesel and the market price of soybean oil is shown in Figure 10. For every 200 million gallons of biodiesel produced from soybean oil, the price of soybean oil increases by 3.2 cents per pound. Because it takes 7.6 pounds of soybean oil to produce a gallon of biodiesel, the cost of producing biodiesel in the model increases by about 24 cents per gallon for each 200 million gallons produced.

The supply curve of biodiesel combines the required margin increase and the feedstock price increase. The model’s supply curve when soybean yields in the United States, Brazil, and Argentina are at their mean levels is shown in Figure 11. The elasticity of supply of biodiesel at 1.2 billion gallons is approximately 2.0.

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Figure 10. Model’s relationship between the price of soybean oil and quantity of biodiesel produced from soybean oil.

Figure 11. US biodiesel supply curve at mean 2013/14 soybean yields.
III. RIN Supply Curves

Three categories of RINs currently trade. Conventional biofuel RINs are known as D6 RINs. D4 RINs are biomass-based diesel RINs. D5 RINs are generated by advanced biofuels. A fourth RIN category will begin trading once cellulosic biofuel production begins in enough volume. These RINs are used to meet three mandates. D4 RINs can be used to meet the biomass-based diesel mandate, the advanced biofuels mandate, and the conventional biofuels mandate. D5 RINs can meet the advanced mandate and the conventional mandate. D6 RINs can only meet the conventional mandate.12

Because of this hierarchy, the price of D6 RINs cannot be greater than the price of D4 and D5 RINs. If it was, then the cost of meeting the conventional mandate could be lowered by using D5 or D6 RINs. Similarly, the price of D5 RINs cannot be greater than price of D4 RINs. This means that D4 RINs will first be used to meet the biomass-based diesel mandate. They will then be in competition with D5 RINs for the advanced mandate. D5 RINs will first be used to meet the advanced mandated before competing with D4 RINs for the conventional mandate.

Corn ethanol can only generate D6 RINs because current law does not allow biofuels made from corn starch to generate D5 RINs. Sugarcane ethanol is the major biofuel that can generate D5 RINs. A variety of feedstocks are being used to produce biodiesel and meet the biomass-based diesel mandate.

The competition for meeting the advanced and conventional mandates takes place not on a price per gallon basis but rather on a RIN price basis. That is, mandates will be met at minimum cost by using the lowest-priced RINs. RIN prices are quoted on a dollar-per-gallon-of-ethanol basis because the RFS is expressed in ethanol equivalent gallons. Because biodiesel contains approximately 50 percent more energy per gallon than ethanol, each gallon of biodiesel generates 1.5 RINs. To see how this competition is modeled, first consider Figure 12, which shows how the biodiesel RIN supply curve is developed.

12 Throughout this paper the term “advanced mandate” refers to the portion of total advanced biofuels that is not met by RINS generated from biomass-based biodiesel.
Figure 12. Deriving the biodiesel RIN supply curve

Biodiesel RIN Supply

The Figure 11 biodiesel supply curve along with the biodiesel demand curve are the drivers of the biodiesel RIN supply curve, as is shown in Figure 12. Recall that a model assumption is that any quantity of biodiesel can be sold at a discounted diesel price so the demand curve in Figure 12 is flat. In this example the demand curve corresponds to a wholesale diesel price of $3.00 per gallon. The vertical difference between the biodiesel supply curve and the demand curve is the price-value gap that must be closed by the RIN price. As an example, in Figure 12 at the 2013 mandate level of 1280 million gallons, the plant price that is needed to cover the cost of producing 1280 million gallon is $4.75 per gallon. The value of this quantity of biodiesel in the market is $2.59 per gallon. Thus there is a price-value gap of $2.16 per gallon which will be covered by the price of RINs generated by biodiesel.

A RIN supply curve shows the RIN price that corresponds to any quantity of RINs that will be generated by biofuel plants. If biodiesel RINs were expressed in biodiesel equivalent gallons, then the biodiesel RIN supply curve would go through a price of $2.16 at a quantity of 1280. If an obligated party wanted to buy one of these biodiesel-denominated RINs instead of a gallon of biodiesel to meet their mandate, it would cost $2.16 per gallon. But RINs are
expressed in ethanol equivalent gallons so that 1280 million gallons of biodiesel creates 1920 million RINs. Thus, the biodiesel RIN supply curve that corresponds to a $2.16 per gallon price-value gap goes through 1920 million RINs, not 1280 million RINs. This is shown in Figure 12. Now suppose that an obligated party wants to buy enough ethanol equivalent RINs to offset a $2.16 price-value gap of biodiesel. The obligated party must buy 1.5 ethanol-denominated RINs for each gallon of biodiesel that is being offset. The price of each of these RINs must be less than $2.16, otherwise the obligated party would be better off buying and blending a gallon of biodiesel than buying RINs. The price of ethanol-equivalent RINs is simply $2.16 divided by 1.5 or $1.44 per RIN. Thus, the biodiesel RIN supply curve expressed in ethanol-equivalent gallons goes through a price of $1.44 and a quantity of 1920 million as shown in Figure 12.

The $1.00 per gallon biodiesel tax credit is paid to blenders who buy a gallon of biodiesel and blend it with diesel. The tax credit increases the value of biodiesel from $2.59 per gallon to $3.59 per gallon in our example. With reference to Figure 12, the impact of the tax credit is to shift the biodiesel demand curve up by $1.00. This reduces the price-value gap of biodiesel from $2.16 to $1.16 per gallon of biodiesel. The shift up in the biodiesel demand curves shifts the biodiesel RIN supply curve down by $0.667 per RIN at all quantities. Thus instead of a $1.44 RIN price at 1920 million RINS, the D4 RIN price would be $0.77 per RIN. The $1.00 tax credit does not reduce the D4 RIN price by a dollar because it takes 1.5 D4 RINs to offset the per-gallon price-value gap of biodiesel. If the D4 RIN price fell by a full dollar to $0.44 per RIN instead of $0.77 per RIN, then the cost of offsetting the price-value gap of $1.16 per gallon of biodiesel though D4 RINs would only be $0.72. This is why the $1.00 tax credit per gallon of biodiesel translates into a reduction in RIN price of $0.667 per RIN. Both RIN supply curves are shown in Figure 13.

**Corn Ethanol RIN Supply**

The RIN supply curve of corn ethanol is derived similarly. At any quantity of ethanol, the RIN price is greater than zero if the ethanol price needed to cover production costs is
greater than the market value of ethanol at that quantity. With a 2013/14 yield equal to the trend yield of 160 bushels per acre, the supply curve of ethanol shown in Figure 14 results. The demand curve for ethanol in Figure 14 is derived at wholesale gasoline price of $2.70 per gallon. The RIN supply curve from corn ethanol is the vertical difference between the ethanol supply curve and the ethanol demand curve when the supply curve is above the demand curve. The price of RIN is zero when the demand curve is above supply. Thus, RIN prices for corn ethanol are zero until the mandate exceeds 13.3 billion gallons.\textsuperscript{13} The price of RINs rises sharply after 13.3 billion gallons because of the E10 blend wall. As illustrated in Figure 14, RIN prices for conventional ethanol will have to exceed $0.85 if ethanol consumption is to be pushed past 14 billion gallons with a corn yield of 160 and a gasoline price of $2.70, as in this example.\textsuperscript{14}

\textsuperscript{13} We can observe positive RIN prices even if the current difference between supply and demand is zero if traders expect RIN prices to rise in the future. This was the situation in the first part of the 2013 calendar year when RIN prices increased rapidly as the market became aware that RINs will be quite valuable in the future because of increased mandates. The ability to buy RINs today and bank them for use in the future is what can cause current RIN prices to be different than the vertical distance between current supply and demand curves. How the use of banked RINs impacts the model results is discussed in Section IV.

\textsuperscript{14} The US ethanol industry likely cannot produce much more than 15.5 or 16 billion gallons of ethanol even with all plants running at capacity. The ethanol supply curve and the RIN supply curve in Figure 14 would
Figure 14. Deriving the corn ethanol RIN supply curve

**Sugarcane Ethanol RIN Supply**

The final RIN supply curve to derive is for sugarcane ethanol. The sugarcane ethanol supply curve that is needed to derive the RIN supply curve is the ethanol export supply curve from Brazil to the United States. Export supply equals total supply minus domestic demand minus export demand facing Brazil from other countries. Figure 15 shows the export supply curve when TRS production of 95 million tons, total non-fuel ethanol use of 1.5 billion liters, non-US ethanol exports are 750 million liters, and the cost of transporting ethanol to the US from a sugar refinery in Brazil is $0.38 per gallon. As shown it is quite an elastic (flat) export supply curve because when the price of ethanol increases in Brazil, owners of flex vehicles readily switch from ethanol to gasoline.

Sugarcane ethanol qualifies as both a conventional biofuel and as an advanced biofuel. Thus it can compete with corn ethanol in the market for D6 RINs and with biodiesel for D5 RINs. In Figure 15, it is assumed that sugarcane ethanol generates D5 RINs that are used to meet the advanced mandate. Thus, the demand curve for imported...
sugarcane ethanol is the portion of the US ethanol demand curve that is in excess of the corn ethanol mandate. For 2013/14 if we fix the corn ethanol mandate at 14.2 billion gallons, then the demand curve for sugarcane ethanol is as shown in Figure 15.\textsuperscript{15}

**Advanced RIN Supply from Biodiesel**

There is one last step that is needed before showing how the model uses the RIN supply curves to solve for market-clearing quantities and prices. Biomass-based diesel has its own mandate that can only be met by biodiesel or renewable diesel. This mandate is at 1280 million gallons for 2013. Thus, the first 1280 million gallons of biodiesel produced will go to meet this mandate. Additional quantities of biodiesel can be produced to meet either the advanced mandate or even the conventional mandate. This means that the competition for the other mandates begins for biodiesel where its mandate lets off, that is, at 1280 million gallons. Figure 16 shows the RIN supply curve of biodiesel for quantities

\textsuperscript{15} If California refineries have a higher willingness to pay for imported sugarcane ethanol to meet their obligations under California’s low carbon fuel standard (LCFS), then their demand curve would be the appropriate demand curve to use to derive RIN values for sugarcane ethanol. No consideration of the possibility of such a higher willingness to pay is made in this study.
in excess of 1280 million gallons both with the $1.00 blenders tax credit and without it. These RIN supply curves are dependent on the assumed wholesale price of diesel and assumptions about soybean production. Altering either diesel prices or soybean supply will result in different supply curves.

IV. RIN Competition

The hierarchy of competition between RINs means that D4 RINs will first meet the biomass-based diesel mandate, then compete to meet the advanced mandate, and then compete to meet the conventional mandate. D5 RINs will first meet the advanced mandate and then compete to meet the conventional mandate. Thus, the price of D4 RINs can be found by looking at the biodiesel RIN supply curve in Figure 13. A 1280 million gallon biodiesel mandate is met with 1920 million D6 RINs. The price of these RINs in Figure 13 is $0.77 per gallon with the tax credit and $1.44 per gallon without it, when yields and gasoline prices are at their average levels.
Determining the price of D5 RINs needs to account for competition between sugarcane ethanol and biodiesel. Whichever fuel can generate lower-cost RINs will prevail in the competition. The cost or price of RINs is given by each fuel’s RIN supply curve. Figure 17 adds the sugarcane ethanol RIN supply curve from Figure 15 to the two biodiesel RIN supply curves from Figure 16.

When biodiesel receives a tax credit, the lowest-priced advanced RINs are from biodiesel. Until RIN prices rise to $1.37 in Figure 17, sugarcane ethanol cannot compete with biodiesel for the advanced mandate with the tax credit. Biodiesel RINs reach $1.37 at a quantity of 634 million RINs. So if the advanced mandate is above 634 million gallons, some sugarcane ethanol will be imported to meet the advanced mandate. The part of the mandate that exceeds 634 million gallons will be shared by sugarcane ethanol and biodiesel. If the mandate is greater than 634 million gallons with the tax credit in place then the price of D5 RINs will equal the price of D4 RINs because biodiesel will be used to meet both mandates.

Without the tax credit, initially the low-cost source of advanced RINs is sugarcane ethanol. This is true until the price of sugarcane ethanol RINs rise above $1.44. This

![Figure 17. Advanced RIN supply curves](image)
occurs at a quantity of 340 million RINs. If the advanced mandate is greater than 340 million gallons then sugarcane ethanol and biodiesel will both meet the mandate and the price of D5 and D4 RINs will be equal. If the advanced mandate is lower than 340 million gallons and there is no biodiesel tax credit, then the price of D5 RINs will be less than the price of D4 RINs.

Figure 18 shows how the exact mix of sugarcane ethanol and biodiesel is determined when biodiesel has the advantage of the tax credit. The aggregate RIN supply curve to meet the advanced mandate is found by adding the number of RINs from sugarcane ethanol to the number of RINs from biodiesel at each RIN price. As discussed above, no sugarcane ethanol RINs will be supplied in Figure 18 until the price of RINs rises above $1.37. This means that the aggregate RIN supply curve equals the biodiesel RIN supply curve for RIN prices below $1.37. For higher prices, both biodiesel and sugarcane ethanol will provide addition RINs so the aggregate supply curve is greater than either individual supply curve as shown.

Figure 18. Derivation of the aggregate RIN supply curve and using it to determine equilibrium mix of biofuels to meet to a mandate
The exact mix of fuels that will be used to meet the advanced mandate is easily found. In Figure 18 the mandate is assumed to be 1000 million gallons of ethanol equivalent fuels. At this mandate the RIN price that is needed to generate 1000 RINs is given by the aggregate RIN supply curve. In this example, it is $1.43 per RIN. At this price both sugarcane ethanol and biodiesel will be used to meet the mandate. Each individual fuel’s RIN supply curve is used to determine the amount of each fuel that will be used. At a $1.43 RIN price, 300 million gallons of sugarcane ethanol will be imported to meet the mandate, and biodiesel will be used to generate 700 million RINs. The quantity of biodiesel that will be produced to generate this number of RINs is 467 million gallons. Thus in this example, a total of 1,747 million gallons of biodiesel will be produced. The biomass-based diesel mandate will be met with 1280 million gallons and the remainder will contribute towards meeting the advanced mandate.

The same kind of competition can occur in meeting the conventional ethanol mandate. It might be assumed that corn ethanol would meet the entire conventional mandate but the sharp increase in RIN prices for corn ethanol for quantities of RIN in excess of 13.5 billion suggests that biodiesel RINs could compete with corn ethanol. Note that RIN prices for corn ethanol exceed $0.80 for quantities in excess of 14 billion gallons and that biodiesel RIN prices with the tax credit in Figure 18 are $1.43. This means that there is the possibility that biodiesel with the tax credit could compete with corn ethanol in the conventional RIN market even after both the biomass-based diesel and advanced mandates are met. In this case, the price of D4, D5, and D6 RINs would all be equal.16

Most of the explanatory charts in this section and the previous section are applicable to just a single future. In reality we do not know what corn, soybean, or sugarcane yields are going to be and we do not know what gasoline prices are going to be. Each possible outcome of these random variables will change crop prices, the cost of producing biofuels, RIN prices and the equilibrium mix of biofuels that will meet the advanced mandate. To account for the wide range of possible future outcomes the model is solved 500 times for 500 sets of random variables. The distributions of the random variables reflect the information that is available when the model was calibrated so that the average

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16 Irwin and Good suggest that equality of RIN prices between corn ethanol, biodiesel, and sugarcane ethanol is likely due to the difficulty of increasing consumption of ethanol in the United States because of the E10 blend wall.
of the 500 model solutions can be interpreted as the expected outcome. But it is also useful to examine the model outcomes for different levels of the random variables. In the next section, average results across the 500 model solutions are presented. For those interested, results by quintiles are reported in the appendices in the form of charts. So, for example, equilibrium corn prices for the next marketing year are presented for the lowest 100 corn yields, the second lowest 100 corn yields, the 100 middle corn yields, the second-highest set of 100 corn yields and the highest 100 corn yields. This allows the reader to see what happens to corn prices (and all other variables of interest) if the random variables are higher or lower than their average values.

As discussed earlier, the purpose of this paper is to provide insight into the impacts of the biodiesel tax credit and Brazilian ethanol tax rates. But the model can just as easily be used to provide estimates of the impact other policies, such as alternative mandate levels. All that is needed is to specify how a particular policy affects the underlying supply and demand curves and then re-solve the model. The next section presents model solutions for the two policies considered here. The section begins with a discussion of the mandate levels used in the analysis.

V. Model Results

The RIN supply curves developed in the previous section show the importance of the level of the mandates on RIN price levels. Table 1 shows mandate levels for calendar years 2013 and 2014. The 2013 mandates are the latest proposed mandates from EPA although some believe that the volumes could still be subject to change. The 2014 biomass-based diesel mandate has not been determined. Throughout this analysis we assume that it will stay at its 2013 level. Total advanced biofuel mandates are as they were written into law by Congress. Other advanced mandates are simply equal to total advanced minus the biomass-based diesel mandates. The 2013/14 marketing year average is the weighted average of the calendar year 2013 and 2014 mandates with a one-third weight being given to 2013. Two key uncertainties for this analysis regarding mandates are whether EPA is going to reduce the advanced mandate for 2014 and the number of banked conventional RINs that are going to be used in the 2013/14 marketing year.
<table>
<thead>
<tr>
<th>Description</th>
<th>2013</th>
<th>2014</th>
<th>2013/14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Renewable Fuel</td>
<td>16.55</td>
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<td>Conventional Biofuel</td>
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<td>Total Advanced Biofuel</td>
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<td>Biomass-Based Diesel gallons</td>
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<tr>
<td>ethanol equivalent gallons</td>
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<tr>
<td>Other Advanced</td>
<td>0.83</td>
<td>1.83</td>
<td>1.50</td>
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Even though cellulosic biofuels has a mandate, the lack of production has led EPA to waive nearly all of it. To date, however, EPA has kept the total volume of advanced biofuels constant. If EPA does this again in 2014, then the portion of the advanced mandate that can be made by sugarcane ethanol or biodiesel in excess of the biomass-based diesel mandate increases significantly by one billion gallons. If instead EPA were to reduce the total advanced volume by the cellulosic volume, then the other advanced portion would stay constant at 0.83 billion gallons, assuming that the biomass-based diesel mandate stays constant. Whether the 2013/14 weighted average mandate used in this analysis is 1.5 billion gallons or 0.83 billion gallons is primarily important for the amount of ethanol that will be mandated because, as shown in the previous section, high levels of ethanol assumption can only be consumed if the ethanol price is heavily discounted to consumers. These heavy discounts will be accomplished by high RIN prices.

The model used here is a one-year annual model. Thus it cannot directly account for how the incentive to bank or borrow RINs affects RIN prices. The RIN prices calculated by the model are simply the current year’s vertical distance between the supply curve for a biofuel and its demand curve. Thus, the mandates that are used in our model should reflect the actual volumes of biofuels consumed in the year. For biodiesel and sugarcane ethanol, the only divergence between the Table 1 mandates and the actual volumes that will be consumed will be if obligated parties decide to build their bank of advanced RINs by blending more of these biofuels than they are required to do because the current bank of advanced RINs is empty. Given the high RIN prices that we see today and the uncertainty about the future of the RFS, it is unlikely that obligated parties will build their bank of these RINs, so it is safe to assume that the mandated volumes will be consumed.
But the bank of ethanol RINs is not empty. As of the beginning of 2013 there were approximately 2.4 billion banked conventional RINs available. Some portion of these RINs will be used to meet the 2013 mandate if current trends continue. But given continued growth in the conventional mandate, it is likely that obligated parties will not want this bank to go to zero at the end of 2014. If we assume that the stock of banked RINs will total one billion at the end of calendar year 2014, and that banked RIN use will be constant for all months in 2013 and 2014, then 700 million banked RINs will be used for each 12 month period. This means that in the 2013/14 marketing year, the level of the conventional mandate that will be met by actual consumption of ethanol will be 13.5 billion gallons.

Average results across the 500 model solutions are reported in Table 2 for the United States and Table 3 for Brazil. The first column of results are baseline results which assumes that the $1.00 per gallon US biodiesel tax credit is extended through the 2013/14 marketing year and that Brazil maintains its R$0.12 per liter reduction in the tax on hydrous ethanol. The second column of results assumes that the US biodiesel tax credit is not in place for the 2013/14 marketing year. Thus, subtracting the column 2 results from the column 1 results shows the impact of the tax credit. The third column of results assumes that the Brazilian ethanol tax reduction is not in place. Thus, the impacts of the tax reduction can be seen by subtracting the column 3 results from the column 1 results.

**Baseline Results**

Before discussing the impacts of the two policies analyzed, it is useful to examine the baseline results. In the United States, the combination of an average yield of 160 bushels per acre, harvested acreage of 89.5 million acres, and beginning stocks of 759 million bushels implies total corn supplies of more than 15 billion bushels. This much corn combined with USDA’s corn demand projections implies much lower corn prices and an abundance of corn to produce ethanol. Ethanol production averages 15.9 billion gallons, well in excess of mandated consumption levels. The excess production is exported. In Table 1 the US ethanol supply price averages only $1.80 per gallon. With an average wholesale gasoline price of $2.69 per gallon this means that US ethanol production costs will only be about 67 percent of the gasoline price. So even if ethanol
Table 2. Results for the United States

<table>
<thead>
<tr>
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<th>Baseline</th>
<th>No Biodiesel Tax Credit</th>
<th>No Brazil Tax Reduction</th>
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<tbody>
<tr>
<td>Ethanol Quantities (billion gallons)(^a)</td>
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<tr>
<td>Production</td>
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<td>Exports</td>
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<td>Consumption</td>
<td>13.88</td>
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<td>Ethanol Prices ($/gal)</td>
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<tr>
<td>Demand Price</td>
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<td>1.30</td>
<td>1.35</td>
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<tr>
<td>Supply Price</td>
<td>1.80</td>
<td>1.83</td>
<td>1.74</td>
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<td>Biodiesel Production (million gallons)</td>
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<td>1,330</td>
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<td>Biodiesel Prices ($/gal)</td>
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<td>Demand Price</td>
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<tr>
<td>Supply Price</td>
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<td>RIN Prices ($/gallon-ethanol-equiv.)</td>
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<tr>
<td>Conventional (D6)</td>
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<td>0.39</td>
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<tr>
<td>Advanced (D5)</td>
<td>1.16</td>
<td>1.28</td>
<td>1.11</td>
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<td>Biodiesel (D4)</td>
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<td>Corn Price ($/bu)</td>
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<td>Soybean Complex Prices</td>
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<tr>
<td>Soybean ($/bu)</td>
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<td>10.52</td>
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<tr>
<td>Soybean oil ($/lb)</td>
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<td>Soybean meal ($/ton)</td>
<td>284.98</td>
<td>297.15</td>
<td>286.40</td>
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\(^a\)Production and consumption quantities are anhydrous-equivalent gallons of ethanol.

Table 3. Results for Brazil

<table>
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<th>Baseline</th>
<th>No Biodiesel Tax Credit</th>
<th>No Brazil Tax Reduction</th>
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</thead>
<tbody>
<tr>
<td>Ethanol Quantities (billion gallons)(^a)</td>
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<tr>
<td>Production</td>
<td>8.39</td>
<td>8.41</td>
<td>8.37</td>
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<tr>
<td>Fuel Consumption</td>
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<td>Ethanol Prices ($/gal)</td>
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<td>Plant Price ($/gal)</td>
<td>2.07</td>
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<td>Retail Price ($/gal)</td>
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<td>Share of TRS to Ethanol</td>
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<tr>
<td>Sugar Production (million tons)</td>
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<td>39.71</td>
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<td>Sugar Exports (million tons)</td>
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<td>World Sugar Price ($/lb)</td>
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<td>0.211</td>
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</table>

\(^a\)Production and consumption quantities are hydrous-equivalent gallons of ethanol.
\(^b\)Prices expressed in SUS per gallon of hydrous ethanol. An exchange rate of 2 reais per dollar is used.
is priced at its energy value (as it is in Brazil) there will be ample demand for US ethanol at this cost of production.\textsuperscript{17}

With regards to biodiesel, production averages 30 percent over the biomass-based diesel mandate. This extra production is used to meet a large share of the advanced mandate, displacing imported sugarcane ethanol. Because both imported sugarcane ethanol and biodiesel are used to meet the advanced mandate in almost all of the model outcomes, the average D4 RIN price is equal to the D5 RIN price.

**Biodiesel Tax Credit Results**

The biodiesel tax credit increases the competitiveness of biodiesel relative to sugarcane ethanol, and imports of sugarcane ethanol to meet the US advanced mandate decline by an average of 510 million gallons. Because more Brazilian ethanol is consumed in Brazil, the tax credit reduces US ethanol exports to Brazil by an average of 300 million gallons; although, US exports to Brazil in the baseline case are projected to average more than they have ever been in the past at 2.36 billion gallons. Relatively low corn prices combined with continued high gasoline prices and an elastic export demand set the stage for the US to be a major ethanol exporter across all three scenarios. The drop in demand for US ethanol exports decreases US production a small amount (300 million gallons) and the price of corn drops by an average of 8 cents per bushel. The biodiesel tax credit reduces US consumption of ethanol so the US ethanol demand price is 9 cents per gallon higher under the tax credit. The drop in ethanol production due to adoption of the tax credit reduces the ethanol supply price by 3 cents per gallon so the conventional RIN price is reduced by 12 cents per gallon because of the biodiesel tax credit.

The tax credit increases biodiesel production by an average of 324 million gallons. This increased production increases the soybean price by 24 cents per bushel, soybean oil prices by about 5 cents per pound, and reduces the soybean meal price by $12 per ton. Because the tax credit increases the biodiesel demand price by $1.00 per gallon of biodiesel, the biomass based diesel RIN price is decreased because of the tax credit. The difference in RIN price of

\textsuperscript{17} No capacity constraint was imposed on US ethanol production in the model. If the industry cannot produce in excess of 15.5 or 16 billion gallons, then average US exports will be cut and the price of corn will drop. This will create profits for the industry and an incentive to add capacity.
22 cents per gallon of ethanol equivalent is less than the full amount of the tax credit because the supply price of biodiesel is 68 cents higher due to higher feedstock costs and higher required margins needed to produce that additional biodiesel.18

A combination of biodiesel and sugarcane ethanol met the advanced mandate in 491 of the 500 model solutions. The other nine were met solely with biodiesel. Thus, the D5 and D6 average RIN prices are approximately equal at $1.16 per gallon. Without the tax credit, 278 of the 500 model solutions had imported sugarcane ethanol meeting all of the advanced mandate. Thus, without the tax credit the average D4 RIN price is 10 cents higher than the average D5 RIN price.

In Brazil, the biodiesel tax credit lowers the plant price of ethanol by two cents per gallon because of the drop in demand for Brazilian ethanol. From Table 2, ethanol exports to the United States drop by 510 million gallons as biodiesel takes a larger share of the advanced mandate. This drop in exports reduces the demand for U.S. imports. The net effect on ethanol consumption in Brazil is a decline of 180 million gallons. Because the price of ethanol is largely unchanged in Brazil, the impact of the biodiesel tax credit on sugar production, exports and world prices is small.

**Brazil Tax Reduction Results**

The decision by Brazil to reduce the tax on ethanol is an attempt to offset the negative effects on ethanol demand from Brazil’s policy of holding down gasoline prices below world market levels. Thus, the effect of the tax reduction is to increase the demand for ethanol. From Table 3, the average effect of the tax reduction (found by subtracting column 3 results from column 1 results) on Brazilian ethanol prices is to increase the plant price of ethanol by 9 cents (US) per gallon. Part of the tax reduction is passed along to consumers in the form of lower retail prices, which decrease by 12 cents per gallon. This reduction in retail price increases ethanol consumption in Brazil by 1.07 billion gallons (about 14 percent). As shown in Table 2, a large portion of this increased consumption is accounted for by the large change in imports from the United States, and

18 To see where the $1.00 tax credit goes, on a gallon of ethanol equivalent basis, $1.00 of biodiesel is $0.67 per gallon of ethanol. The 68 cents per gallon of biodiesel change in the biodiesel supply price is 45 cents per ethanol-equivalent gallon. The change in RIN price is 22 cents per gallon of ethanol. Thus, the sum is 67 cents per gallon.
a smaller portion is accounted for by a drop in ethanol exports to the United States. This shows how the tax reduction makes Brazil a more attractive place to sell ethanol, whether it is produced in the United States or Brazil.

The tax reduction in Brazil increases US ethanol production by an average of 790 million gallons (5.2 percent). Because average US exports increase by about this amount and US imports from Brazil decrease, less ethanol is consumed in the United States. This drop in consumption increases the ethanol demand price by 4 cents per gallon. However, because the Brazilian tax reduction increases US ethanol production, the US supply price of ethanol increases by 6 cents per gallon because of higher corn prices. Thus conventional RIN prices increase by an average of 2 cents per gallon. Because the biodiesel tax credit is assumed to be in place in both the baseline set of results and in the results with no Brazil tax reduction, both biodiesel and sugarcane ethanol are used to meet the advanced mandate. Because the price of Brazilian ethanol increases due to the tax reduction, the cost of importing sugarcane ethanol increases so the D5 and D6 RIN prices increase by an average of 5 cents. Because the tax reduction increases the demand for biodiesel, the average price of soybean oil increases by 0.6 cents per pound, the price of soybean meal decreases $1.42 per ton, and the price of soybeans increase by an average of 3 cents per bushel.

The increased price of ethanol in Brazil because of the tax reduction causes Brazilian refineries to tilt slightly more towards ethanol and away from sugar. Brazilian sugar production drops by an average of 150,000 tons, almost all of which comes out of the export market. Thus world sugar prices average 0.8 cents per pound higher (3.8 percent) with the tax reduction in place than without it.

VI. Concluding Remarks

To understand biofuels markets in the United States and Brazil requires understanding feedstock markets, government policies, and consumer demand for fuel. And, because direct trade barriers in biofuels are low, it is important to consider how changes to policies in one country affect biofuels in the other. Recent biofuel policy changes in Brazil and the United States are analyzed with an objective of fostering greater understanding of the important factors that affect biofuel markets in the two countries. The re-introduction of the $1.00 per gallon biodiesel tax credit in the United States at the
end of 2012 increases the demand for biodiesel and reduces the demand for imported sugarcane ethanol. Thus less sugarcane ethanol will be imported to meet the advanced biofuel mandate in the United States. On May 8, 2013, Brazil decreased the tax on ethanol. This reduction increases the demand for ethanol in Brazil, making it more attractive place to sell ethanol, whether it be domestically produced or imported.

A stochastic simulation model provides estimates of the market impacts of these two policy changes for the upcoming 2013/14 US corn marketing year that begins on September 1, 2013. The results demonstrate how ethanol trade links the US and Brazilian markets even though the total volume of trade between the two countries is low relative to total production and consumption. The results also demonstrate how US mandates link ethanol and biodiesel markets because biodiesel is allowed to meet its own mandate, the mandate for other advanced biofuel, and even the conventional mandate. Sorting out the net effects of these policy changes across both countries and across fuels requires a detailed model of each key market. Because a model is only as good as the assumptions and data that underlie it, it is important to be transparent about the assumptions and the data used to parameterize the supply and demand curves that make up the model. Because the model used in this analysis is updated often, interested readers who disagree with assumptions used or who have better data are welcome to share their insights and data.

Finally, as with all model-based projections of future price levels, one should take care when viewing the exact level of prices being projected. If one or more parts of the model calibration differs significantly from current market conditions, then the model projections may be quite different from current price levels as indicated by futures markets. Or if the set of prices and quantities to which the model is calibrated are flawed then so too will be the projected prices levels from the model.\(^{19}\) Less sensitive to the exact model calibration are the differences in price levels across different policy scenarios or across different levels of the exogenous stochastic variables that include yields, gasoline price, and world demand for Brazilian sugar exports.

\(^{19}\) For example, there are three aspects of the May WASDE projections that some feel may be open to question. Projected corn feed use seems high given the drop in the number of cattle on feed. Projected corn exports seem low given historic export levels and the level of projected corn production that is possible. And the projected soybean crush spread at more than $2.00 per bushel seems high.
Appendix A. Results Conditional on US Corn Yields

Figure A1. Impact of corn yield on corn price: Baseline policies.

Figure A2. Impact of corn yield on conventional RIN price: Baseline policies
Figure A3. Impact of corn yield on ethanol net exports: Baseline policies

Figure A4. Impact of corn yield on US ethanol consumption: Baseline policies
Figure A5. Impact of corn yield on US ethanol supply and demand prices: Baseline policies

Figure A6. Impact of corn yield on advanced and biomass diesel RIN prices: Baseline policies
Appendix B. Results Conditional on US Gasoline Prices

Figure B1. Impact of gasoline price on conventional RIN price

Figure B2. Impact of gasoline price on biomass diesel RIN price
Figure B3. Impact of gasoline price on advanced RIN price

Figure B4. Impact of gasoline price on biodiesel production
Figure B5. Impact of gasoline price on soybean oil prices
Appendix C. Results Conditional on Brazilian Production of TRS

Figure C1. Impact of TRS production on world sugar price

Figure C2. Impact of TRS production on Brazilian sugar exports
Figure C3. Impact of TRS production on Brazilian ethanol production

Figure C4. Impact of TRS production on Brazilian ethanol price received by plants
Appendix D. Results Conditional on World Demand for Brazilian Sugar

Figure D1. Impact of sugar export demand shock on world sugar price

Figure D2. Impact of sugar export demand shock on Brazilian sugar exports
Figure D3. Impact of sugar export demand shock on Brazilian ethanol production

Figure D4. Impact of sugar export demand shock on Brazilian ethanol price
References


