Chapter 8
The global impacts of US and EU biofuels policies

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1. Introduction

The major biofuels producers in the world are the US, EU, and Brazil. Figure 1 shows the global breakdown of biofuels production for 2006. The US and Brazil combine to produce three-fourths of global ethanol, and the EU produces three-fourths of global biodiesel. The US overtook Brazil in ethanol production, and global production now exceeds 50 billion liters. Biodiesel total production is much smaller.

In the US, Brazil, and the EU, the biofuels industries were launched with some combination of subsidies and mandates plus border protection. As production levels have grown and as oil prices have risen, all three are now switching in different degrees from reliance on subsidies to reliance on mandates. One reason is the government budget cost of subsidies, which increase as production increases. Mandates also have a cost, but it is paid by consumers at the pump assuming the biofuel is more expensive to produce than the petroleum based fuel it replaces. The consumer cost of a mandate is directly related to oil price. At low oil prices, a mandate can be expensive for consumers because high cost renewable fuel is mandated in lieu of a certain fraction of relatively lower cost petroleum. At high oil prices, the renewable fuel may even be less expensive than petroleum based fuels, so the cost can be much lower or zero.

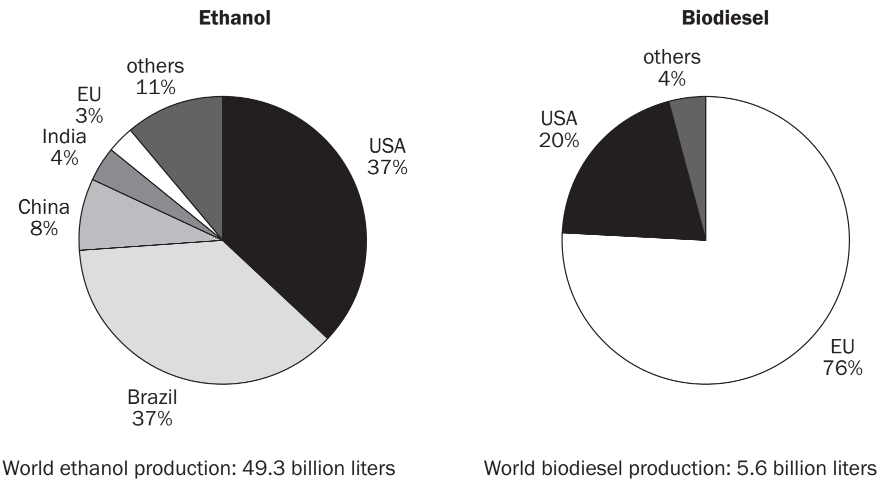
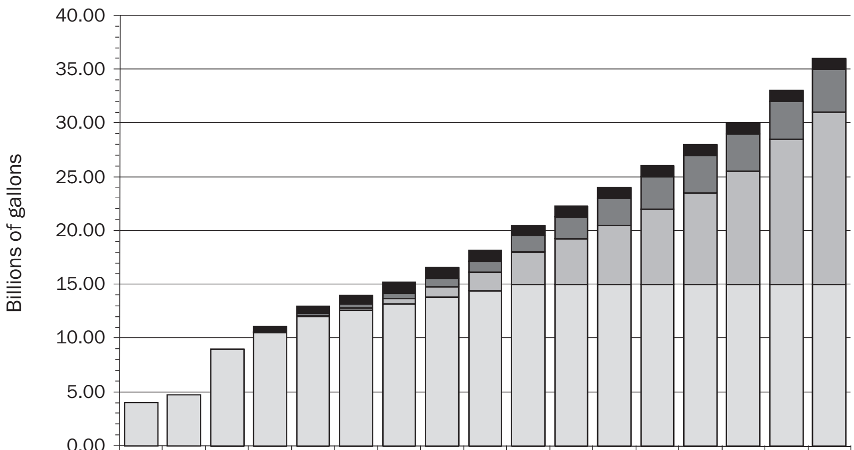


Figure 1. Global biofuels production, 2006. Data sources: Earth Policy Institute (2006), Renewable Fuels Association (2007), European Biodiesel Board (2007).

In Brazil, subsidies have been completely replaced with mandates. In the EU, subsidies are determined by each country. In essence, the EU sets a target level of renewable fuels, and each country decides how best to achieve that target. The original target was 5.75 percent renewable fuels by 2010. Most countries were well behind the pace needed to achieve that target. More recently a target of 10 percent by 2020 has been proposed. Given the recent food price and greenhouse gas controversies (more later), it appears the EU is backing away from that target. Germany has had relatively high levels of subsidies for biodiesel, but these have now ended. At present, the future directions for biofuels policies in the EU are uncertain.

In the US, ethanol has been subsidized for 30 years (Tyner, 2008). The subsidy has ranged from 10.6 to 15.9 cents per liter, and is currently 13.5 cents per liter. The subsidy on maize ethanol will be reduced to 11.9 cents per liter on 1 January 2009, but a new subsidy of 26.7 cents per liter of cellulosic ethanol will be introduced (US Congress, 2008). In addition to the subsidy, in December 2007, the US introduced biofuel mandates in the Energy Independence and Security Act (US Congress, 2007). Figure 2 portrays the timing of the US mandate, called a Renewable Fuel Standard (RFS). The Renewable Fuel Standard (RFS) as amended in the 2007 Energy Independence and Security Act calls for 36 billion gallons of renewable fuels by 2022. The RFS is divided into four categories of biofuels: conventional, advanced, cellulosic, and biodiesel. The advanced category reaches 21 billion gallons by 2022 and includes cellulosic ethanol, ethanol from sugar, ethanol from waste material, biodiesel, and other non-maize sources. In other words, the advanced category encompasses both the cellulosic and biodiesel categories. Cellulosic ethanol as a sub-set of advanced reaches 16



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Biomass-based diesel				0.50	0.65	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Non-celulosic advanced				0.10	0.20	0.30	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	3.50	3.50	4.00
Celulosic advanced					0.10	0.25	0.50	1.00	1.75	3.00	4.25	5.50	7.00	8.50	10.5	13.5	16.0
Conventional biofuels	4.00	4.70	9.00	10.5	12.0	12.6	13.2	13.8	14.4	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0

Figure 2. US Renewable Fuel Standard (2007-2022). Source: Joel Valasco (pers. comm.).

billion by 2022, and biodiesel reaches 1 billion. The residual, likely to be sugarcane ethanol, amounts to 4 billion gallons by 2022. The way the standard is written, there is the total RFS requirement and the advanced requirement (with its sub-components specified separately) with the difference being presumed to be maize based ethanol. However, there is no specific RFS for maize ethanol. This residual, labeled conventional biofuels, reaches 15 billion gallons by 2015 and stays at that level. The residual is the only category that permits maize ethanol. However, it could also include any of the other categories of biofuels.

Associated with all the biofuel categories is a GHG reduction requirement. For maize based ethanol, the reduction must be at least 20 percent. For all advanced biofuels except cellulosic ethanol, the reduction required is 50 percent, and for cellulosic ethanol, it is 60 percent. Ethanol plants that were under construction or in operation as of the data of enactment of the legislation are exempt from the GHG requirement (grandfathered). The GHG requirements are to be developed and implemented by EPA. The EPA administrator has flexibility to modify to some extent the GHG percentages. S/he also has authority to reduce or waive the RFS levels.

In addition to the subsidy and RFS, the US also has a tariff on imported ethanol (Abbott *et al.*, 2008). The tariff is 2.5 percent *ad valorem* plus a specific tariff of 14.3 cents per liter of ethanol. With an ethanol CIF price of 52.9 cents per liter, the total tariff becomes 15.6 cents per liter. The rationale for the tariff was that the US ethanol subsidy applies to both domestic and imported ethanol. Congress clearly wanted to subsidize only domestically produced ethanol, so the tariff was established to offset the domestic subsidy. At the time the tariff was created, the domestic subsidy was also about 14.3 cents per liter (Tyner, 2008). However, the domestic subsidy was reduced to 13.5 and has now been reduced further to 11.9 cents per liter. Thus, today, the import tariff, as a trade barrier, goes far beyond the subsidy offset. The EU and Brazil also have import tariffs on ethanol. For Brazil, it is largely irrelevant since Brazil is one of the world's lowest cost producers of ethanol, so it is unlikely to import ethanol.

2. Ethanol economics and policy

The lowest cost ethanol source is ethanol from sugarcane. It is also the most advantageous from a net energy perspective. Brazil is the global leader in sugarcane based ethanol production, and has ample land resources to expand production. The US uses maize to produce ethanol. The cost of producing ethanol from maize varies with the price of maize. The value of the ethanol produced is a function of the price of crude oil since ethanol substitutes for gasoline. Figure 3 provides a breakeven analysis for maize ethanol at varying prices of crude oil and maize. The top line is the breakeven values with no government intervention and ethanol valued on an energy basis. The second line includes the 13.5 cent per liter subsidy. Prior to 2005, maize often ranged between \$80 and \$90 per mt. Without a subsidy oil would have had to be over \$60 for maize ethanol to be economic. However,

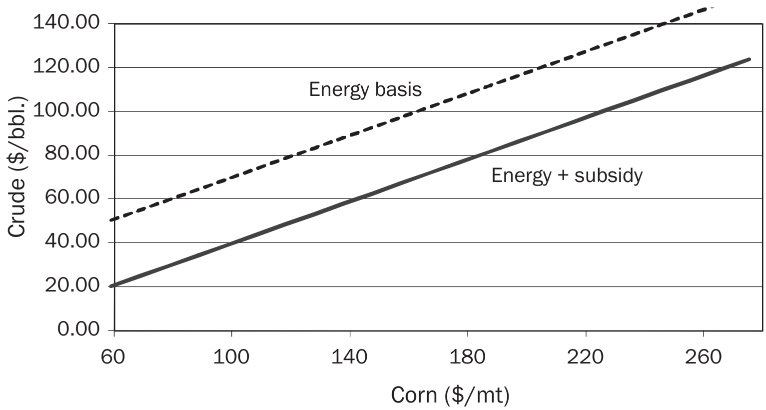


Figure 3. Breakeven ethanol prices with and without federal subsidy.

with the federal subsidy, maize ethanol was economic at around $30 crude. In addition to the federal subsidy, many US states also offered subsidies, so ethanol was attractive in the two decades prior to 2005 even though oil averaged $20/bbl. During that period It was not hugely profitable, but enough so to see the industry grow slowly over the entire period. Today with maize around $240/mt, the breakeven oil price is about $135 with no subsidy and $105 with a subsidy. The nature of a fixed subsidy is such that regardless of the maize price, the breakeven oil price difference with and without the subsidy is about $30/bbl. Or conversely, at $120 oil, the maize breakeven prices with and without subsidy are $270 and $207 per metric tonne, respectively.

2.1. Impacts of alternative US ethanol policies

This breakeven analysis is from the perspective of a representative firm. We can use a partial equilibrium economic model to examine the fixed subsidy, a variable subsidy, and the RFS over a range of oil prices (Tyner and Taheripour, 2008a,b). The model includes, maize, ethanol, gasoline, crude oil, and distillers dried grains with solubles (DDGS). The supply side of the maize market consists of identical maize producers. They produce maize using constant returns to scale Cobb-Douglas production functions and sell their product in a competitive market. Under these assumptions, we can define an aggregated Cobb-Douglas production function for the whole market. In the short-run the variable input of maize producers is a composite input which covers all inputs such as seed, fertilizers, chemicals, fuel, electricity, and so on. In short run capital and land are fixed. The demand side of the maize market consists of three users: domestic users who use maize for feed and food purposes; foreign users, and ethanol producers. We model the domestic and foreign demands with constant price elasticity functions. The foreign demand for maize is more elastic than the domestic demand. The demand of the ethanol industry for maize is a function of the demand for ethanol.

The gasoline market has two groups of producers: gasoline and ethanol producers. It is assumed that ethanol is a substitute for gasoline with no additive value. The gasoline and ethanol producers produce according to short run Cobb-Douglas production functions. The variable input of gasoline producers is crude oil and the variable input of ethanol producers is maize. Both groups of producers are price takers in product and input markets. We model the demand side with a constant price elasticity demand. The constant parameter of this function can change due to changes in income and population. We assume that thegasoline industry is well established and operates at long run equilibrium, but the ethanol industry is expanding. The new ethanol producers opt in when there are profits. There is assumed to be no physical or technical limit on ethanol production – only economic limits.

The model is calibrated to 2006 data and then solved for several scenarios. Elasticities are taken from the existing literature. Endogenous variables are gasoline supply, demand, and price: ethanol supply, demand, and price; maize price and production; maize use for ethanol, domestic use, and exports; DDGS supply and price; land used for maize; and the price of the composite input for maize. Exogenous variables include crude oil price, maize yield, ethanol conversion rate, ethanol subsidy level and policy mechanism, and gasoline demand shock (due to non-price variables such as population and income). The model is driven and solved by market clearing conditions that maize supply equal the sum of maize demands and that ethanol production expands to the point of zero profit. The model is simulated over a range of oil prices between $40 and $140.

Figure 4 provides the results from this model simulation for maize price and Figure 5 for ethanol production. In each figure, the far left bar is the 13.5 cent fixed subsidy, the second is no subsidy, the third a subsidy that varies with the price of crude oil, the fourth the RFS alone, and the fifth the RFS in combination with the fixed subsidy (current policy). The variable subsidy is in effect only for crude oil prices below $70. The first thing to note from Figure 4 is that, just as was evident from the perspective of the firm, there is now a tight linkage between crude oil price and maize price. The basic mechanism is that gasoline price is driven by crude price. Ethanol is a close substitute for gasoline, so a higher gasoline price means larger ethanol demand. That demand stimulates investment in ethanol plants. More ethanol plants means greater demand for maize, and that increased demand means higher maize price. This is a huge change, as historically, there was very little correlation between energy and agricultural prices.

The $40 oil price represents the approximate price in 2004. The model accurately 'predicts' the ethanol production and maize price corresponding to $40 oil. That is, the 2004 model results are very close to the actual 2004 values. The ethanol production under no subsidy also accurately shows ethanol production beginning only when oil reaches $60 and then at a very low level. Of course, the RFS case has the ethanol production level at 56.7 bil. l., which is the level of the RFS in 2015, and the level modeled in this analysis. The numbers above the RFS bar in Figure 5 represent the implicit subsidy on ethanol ($/gal. ethanol) due to the

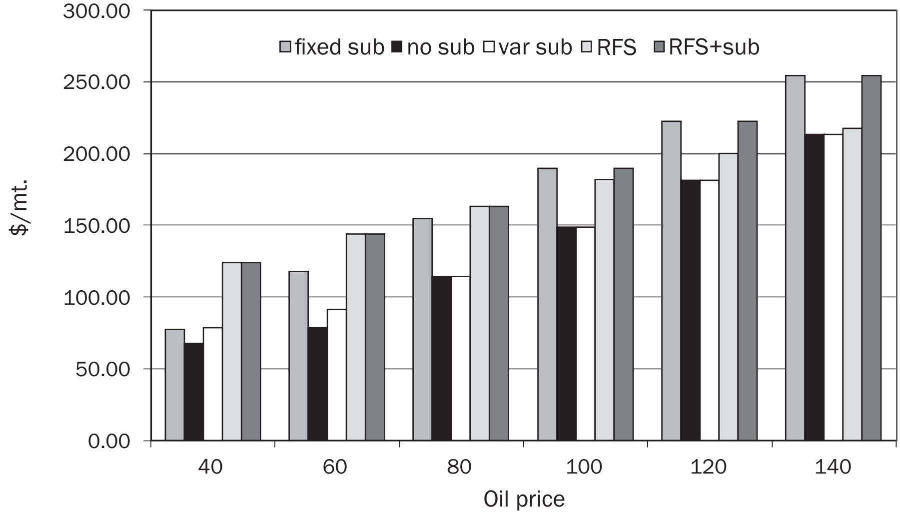


Figure 4. Maize price under alternative policies and oil prices.

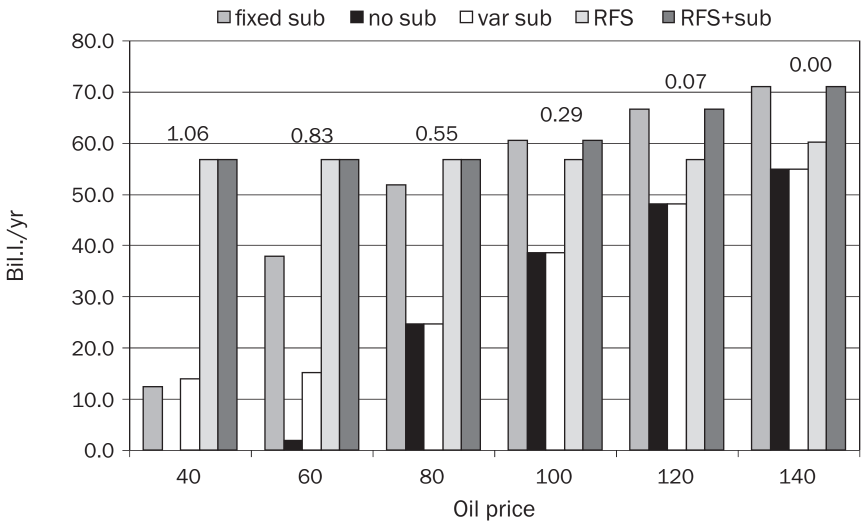


Figure 5. Ethanol production under alternative policies and oil prices.

RFS. It is also an implicit tax on consumers. The model follows the RFS rule, and 'requires' that the stipulated level of ethanol be produced. To the extent that the cost of ethanol is higher than the cost of gasoline, this higher cost gets passed on to consumers in the form of an implicit tax on consumers. Thus, a RFS functions very differently from a subsidy. The subsidy is on the government budget, whereas the mandate cost is paid by consumers directly at the pump. When oil is very inexpensive, the ethanol costs considerably more than petroleum. So the requirement to blend ethanol means consumers pay more at the pump than they would without the mandate. For \$40 oil, the implicit subsidy/tax is \$1.06/gal. or 28 cents per liter. The subsidy/tax falls to zero at \$140 oil. At \$140 oil, the mandate is no longer binding, and the amount of ethanol demanded is market driven – not determined by the mandate. Thus the RFS is a form of variable subsidy for the ethanol producer and variable tax for the consumer depending on the price of crude oil. Ethanol production stays at the RFS level of 56.7 bil. l. until oil reaches \$120. At that oil price and beyond the market demands more than 56.7 bil. l., and the RFS becomes non-binding.

The final bar is the current policy of RFS plus subsidy. Note that at low oil prices, the RFS production level is higher than that induced by the subsidy, and at high oil prices, the subsidy induces higher production than the RFS. If the RFS represents the intent of Congress with respect to level of ethanol production, the subsidy takes production well beyond that level at high oil prices.

Another important question that can be addressed using these model results is what proportion of the maize price increase is due to the oil price increase, and what proportion to the subsidy. If we start at the no subsidy case with \$40 oil, we have a maize price of \$67, which increases to \$181 when oil triples to \$120. If we add on the subsidy at \$120 oil, the maize price goes up to \$222. The total maize price increase is \$155, of which \$41 is due to the subsidy, and \$113 to the oil price increase. So roughly ¾ of the maize price increase has been due to higher oil prices, and ¼ to the US subsidy on maize ethanol. Even if the subsidy went away, maize prices would not return to their historic levels because of the new link between energy and agriculture. And if oil price went down, we would expect to see the maize price fall as well. As the oil price fell, gasoline would fall as would the price of ethanol. With lower ethanol prices, some plants could not produce profitably, so maize demand would fall and also the maize price.

Figure 6 displays the annual costs of the various policy options. Recall that the method of paying the costs is very different between the government subsidy and the RFS. The RFS is paid by the consumer at the pump, and the fixed and variable subsidies are paid through the government budget. The variable subsidy has no cost for oil above \$70 by design, and its cost at low oil prices is quite low. The cost of the fixed subsidy increases almost linearly with oil price. The higher the oil price, the higher the government subsidy cost. The RFS is exactly opposite. It has a high cost when oil price is low, and a very low or zero cost at high oil prices.

The US tariff on imported ethanol introduces a potentially greater distortion than does the subsidy or mandate. Since high oil prices directly lead to higher maize prices, maize ethanol becomes much more expensive. Sugarcane-based ethanol is less expensive to produce than maize ethanol at any oil price, but the gap widens at higher oil prices. So removal

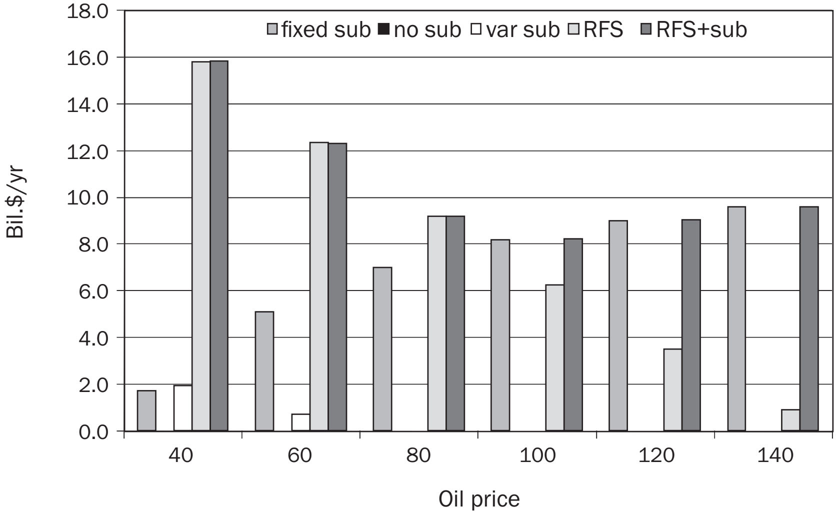


Figure 6. Costs of the policy alternatives.

of the tariff on imported ethanol would lead to the biofuel coming from the lowest cost source–sugarcane–which would reduce some pressure on maize prices and provide the United States with lower cost ethanol. Brazil has the potential to expand ethanol production substantially without increasing world sugar prices substantially, so imports down the road could be quite high.

However, the question is more complicated because it depends on the extent to which imported ethanol adds to total consumption and the extent to which it displaces maize ethanol. For the portion that displaced maize ethanol, each billion gallons of imports would displace about 358 million bushels of maize used for ethanol (Tyner and Taheripour, 2007). So you would get price impacts as the ethanol industry demanded less maize. The problem is figuring out how much would go to increase total consumption and how much to displace maize ethanol. In the United States, the limit of how much ethanol can be blended is called the blending wall (Tyner *et al.*, 2008). The blending wall is the maximum amount of ethanol that can be blended at the regulatory maximum of 10%. Currently, we consume about 140 billion gallons of gasoline (Energy Information Administration, 2008), so the max level for the blending wall would be 14 billion gallons of ethanol. However, for logistical reasons, the practical level is likely to be much lower, perhaps around 12 billion gallons. See Tyner *et al.* (2008) for a more complete analysis of this issue.

We already have in place or under construction 13 billion gallons of ethanol capacity. At present E85 is tiny, and it would take quite a while to build that market. There are only about 1,700 E85 pumps in the nation and few flex-fuel vehicles that are required to consume the fuel. It would require a massive investment to make E85 pumps readily available for all consumers, and a huge switch to flex-fuel vehicle manufacture and sale to grow this market. Without strong government intervention, it will not happen.

What options exist? The most popular among the ethanol industry is switching to E15 or E20 instead of E10. The major problem is that automobile manufacturers believe the existing fleet is not suitable for anything over E10. Switching to a higher blend would void warranties on the existing fleet and potentially pose problems for older vehicles not under warranty. In the US, the automobile fleet turns over in about 14 years, so it is a long term process. We could not add yet another pump for E15 or E20. The costs would be huge. So the blending wall in the near term is an effective barrier to growth of the ethanol industry. If a switch is made to an E15 or E20 limit for standard cars, some agreement would have to be reached on who pays for any vehicle repair or performance issues.

On the technical side, two options could emerge. One would be using cellulose through a thermochemical conversion process to produce gasoline or diesel fuel directly. Today this process is quite expensive, but the cost might be reduced over the next few years. A second option is to convert cellulose to butanol instead of ethanol, which is much more similar to gasoline. Without such a breakthrough, the EPA administrator likely will be forced to cap the RFS far below the planned levels.

Until we hit the blending wall, most of the imports likely would increase total consumption and not displace maize ethanol. However, we will probably reach the blending wall in 2009/10, at which point imports would likely displace domestic maize ethanol and thereby lower maize price.

3. Impacts of US and EU policies on the rest of the world

Our analysis of global impacts is done using the Global Trade Analysis Project (GTAP) model and data base. This work is based on Hertel *et al.* (2008). We begin with an analysis of the origins of the recent bio-fuel boom, using the historical period from 2001-2006 for purposes of model calibration and validation. This was a period of rapidly rising oil prices, increased subsidies in the EU, and, in the US, there was a ban on the major competitor to ethanol for gasoline additives (MTBE) (Tyner, 2008). Our analysis of this historical period permits us to evaluate the relative contribution of each of these factors to the global biofuel boom. We also use this historical simulation to establish a 2006 benchmark biofuel economy from which we conduct our analysis of future mandates.

We then can do a forward-looking analysis of EU and US biofuel programs. The US Energy Policy and Security Act of 2007 calls for 15 billion gallons of ethanol use by 2015, most of which is expected to come from maize. In the EU, the target is 5.75% of renewable fuel use in 2010 and 10% by 2020. However, there are significant doubts as to whether these goals are attainable. For this analysis, we adopt the conservative mandate of 6.25% by 2015 in the EU.

The starting point for our prospective simulations is the updated, 2006 fuel economy which results from the foregoing historical analysis. Thus, we analyze the impact of a continued intensification of the use of biofuels in the economy treating the mandates as exogenous shocks.[12] Ethanol exports from Brazil to the US grow in this simulation as well.

Table 1 reports the percentage changes in output for biofuels and the land-using sectors in the USA, EU and Brazil. The first column in each block corresponds to the combined impact of EU and US policies on a given sector's output (USEU-2015). The second column in each block reports the component of this attributable to the US policies (US-2015), and the third reports the component of the total due to the EU policies (EU-2015) using the decomposition technique of Harrison *et al.* (2000). This decomposition method is a more sophisticated approach to the idea of first simulating the global impacts of a US program, then simulating the impact of an EU biofuels program, and finally, simulating the impact of the two combined. The problem with that (rather intuitive) approach is that the impacts of the individual programs will not sum to the total, due to interactions. By adopting this numerical integration approach to decomposition, the combined impacts of the two programs are fully attributed to each one individually.

In the case of the US impacts (columns labeled Output in US), most of the impacts on the land-using sectors are due to US policies. Coarse grains output rises by more than 16%, while output of other crops and livestock falls when only US policies are considered. However, oilseeds are a major exception. Here, the production impact is reversed when EU mandates are introduced. In order to meet the 6.25% renewable fuel share target, the EU requires a massive amount of oilseeds. Even though production in the EU rises by 52%, additional imports of oilseeds and vegetable oils are required, and this serves to stimulate production worldwide, including in the US. Thus, while US oilseeds output falls by 5.6% in the presence of US-only programs, due to the dominance of ethanol in the US biofuel mix, when the EU policies are added to the mix, US oilseed production actually rises.

In the case of the EU production impacts (Output in EU: the second group of columns in Table 1), the impact of US policies is quite modest, with the main interaction again through the oilseeds market. However, when it comes to third markets – in particular Brazil (Output in Brazil), the US and EU both have important impacts. US policies drive sugarcane production, through the ethanol sector, while the EU policies drive oilseeds production in Brazil. Other crops, livestock, and forestry give up land to these sectors.

[12] Technically, we endogenize the subsidy on biofuel use and exogenize the renewable fuel share, then shock the latter. For simplicity, all components of the renewable fuels bundle are assumed to grow in the same proportion.

Table 1. Change in output due to EU and US biofuel mandates: 2006-2015 (%).

Sector	**Output in US**			**Output in EU**			**Output in Brazil**		
	USEU-2015	**US-2015**	**EU-2015**	**USEU-2015**	**US-2015**	**EU-2015**	**USEU-2015**	**US-2015**	**EU-2015**
Ethanol	177.5	177.4	0.1	430.9	1.3	429.7	18.1	17.9	0.2
Biodiesel	176.9	176.8	0.1	428.8	1.2	427.6	-	-	-
Coarse grains	16.6	16.4	0.2	2.5	0.8	1.7	-0.3	1.1	-1.4
Oilseeds	6.8	-5.6	12.4	51.9	1.2	50.7	21.1	0.6	20.5
Sugarcane	-1.8	-1.9	0.1	-3.7	0.0	-3.7	8.4	9.3	-0.9
Other grains	-7.6	-8.7	1.2	-12.2	0.1	-12.3	-8.7	-2.0	-6.8
Other agri	-1.6	-1.7	0.2	-4.5	0.0	-4.5	-3.8	-1.5	-2.4
Livestock	-1.2	-1.2	0.0	-1.7	0.1	-1.8	-1.4	-0.6	-0.7
Forestry	-1.2	-1.4	0.1	-5.4	-0.3	-5.1	-2.7	-1.0	-1.8

Note: Ethanol in the US and EU is from grains, and it is sugarcane-based in Brazil.

Table 2 reports changes in crop harvested area as a result of the biofuel mandates in the US and EU for all regions in the model. The simulation includes only the biofuels shock, and does not include population growth, income growth, trend yield increases, or anyother 'baseline' factors. It is designed just to isolate the biofuels impacts. Coarse grains acreage in the US is up by about 10%, while sugar, other grains, and other crops are all down. The productivity-weighted rise in coarse grains acreage is 10% (Table 3). This increase in maize acreage in the US comes from contribution of land from other land-using sectors such as other grains (Table 3) as well as pasture land and commercial forest land – to which we will turn momentarily.

From Table 2, we see that US oilseeds acreage is up slightly due to the influence of EU policies on the global oilseeds market. However, this marginal increase is dwarfed by the increased acreage devoted to oilseeds in other regions, where the percentage increases range from 11 to 16% in Latin America, and 14% in Southeast Asia and Africa, to 40% in the EU. If the EU really intends to implement its 2015 renewable fuels target, there will surely be a global boom in oilseeds. Coarse grains acreage in most other regions is also up, but by much smaller percentages. Clearly the US-led ethanol boom is not as significant a factor as the EU oilseeds boom. Sugarcane area rises in Brazil, but declines elsewhere, and other grains and crops are somewhat of a mixed bag, with acreage rising in some regions to make up for diminished production in the US and EU and declines elsewhere.

From an environmental point of view, the big issue is not which crops are grown, but how much cropland is demanded overall, and how much (and where) grazing and forestlands are converted to cropland. These results are very sensitive to the productivity of land in the pasture and forest categories compared to cropland. We recognize that more work needs to be done on certain land categories such as idled land and cropland pasture in the US and the savannah in Brazil. Therefore the numerical results reported here must be taken as only illustrative of the results that will be available once the land data base is improved. Table 3 reports the percentage changes in different land cover areas as a result of the EU and US mandates. Furthermore, as with the output changes in Table 1, we decompose this total into the portion due to each region's biofuels programs. From the first group of columns, we see that crop cover is up in nearly all regions. Here we also see quite a bit of interaction between the two sets of programs. For example, in the US, about one-third of the rise in crop cover is due to the EU programs. In the EU, the US programs account for a small fraction of the rise in crop cover. In other regions, the EU programs play the largest role in increasing crop cover. For example, in Brazil, the EU programs account for nearly 11% of the 14.2% rise in crop cover.

Where does this crop land come from? In our framework it is restricted to come from pastureland and commercial forest lands, since we do not take into account idle lands, nor do we consider the possibility of accessing currently inaccessible forests. The largest percentage reductions tend to be in pasturelands (Table 3, final set of columns). For example, in Brazil,

Table 2. Change in crop harvested area by region, due to EU and US biofuel mandates: 2006-2015 (%).

Region	**Crops**				
	Coarse grains	**Oilseeds**	**Sugarcane**	**Other grains**	**Other agri**
USA	9.8	1.6	-5.7	-10	-2.7
Canada	3.5	16.9	-3.2	-2.6	-1.6
EU-27	-2.3	40	-7.4	-15.1	-6.1
Brazil	-3.2	16	3.8	-10.9	-5.1
Japan	10.7	7.6	-0.7	0.8	-0.1
China-Hong Kong	1.2	8.2	-0.6	-0.5	-0.5
India	-0.7	0.9	-0.7	0.5	-0.2
Latin American energy exporters	1.8	11.3	-2.3	-0.2	-0.8
Rest of Latin America & Caribbean	1.7	11.5	-1.6	-0.6	-0.3
EE & FSU energy exporters	0.5	18.1	-0.6	0.4	-0.5
Rest of Europe	2.3	10.5	0	1.8	0.4
Middle Eastern North Africa energy exporters	4	8.6	-0.9	2.5	-0.4
Sub Saharan energy exporters	-0.8	13.7	0	2.3	1.2
Rest of North Africa & SSA	1.5	14.2	-0.4	1.1	1.1
South Asian energy exporters	-0.5	3.7	-0.9	-0.6	-0.1
Rest of high income Asia	3.7	6.1	-0.1	-0.2	0
Rest of Southeast & South Asia	-0.2	2.9	-0.8	0	-0.1
Oceania countries	3.9	17.2	-0.6	-1.3	0.3

Note: These results are solely illustrative of the kinds of numerical results that are produced by the analysis. They are not definitive results.

we estimate that pasturelands could decline by nearly 11% as a result of this global push for biofuels, of which 8% decline is from EU mandates alone. The largest percentage declines in commercial forestry cover are in the EU and Canada, followed by Africa. In most other regions, the percentage decline in forest cover is much smaller.

Our prospective analysis of the impacts of the biofuels boom on commodity markets focused on the 2006-2015 time period, during which existing investments and new mandates in the US and EU are expected to substantially increase the share of agricultural products (e.g. maize in the US, oilseeds in the EU, and sugar in Brazil) utilized by the biofuels sector. In

Table 3. Decomposition of change land cover by EU and US biofuel mandates (with Sensitivity Analysis): 2006-2015 (% change).

	Crop cover				
	USEU 2015	US 2015	EU 2015	Confidence interval (95%)	
				Lower	Upper
US	7	4.7	2.3	3.5	10.8
Canada	11.3	2.9	8.4	4.7	18.0
EU-27	14.3	0.9	13.4	8.0	20.7
Brazil	14.2	3.5	10.7	7.0	21.5
Japan	1.3	0.5	0.8	-0.1	2.7
China-Hong Kong	1.9	0.5	1.4	-0.5	4.3
India	1	0.1	0.9	-0.6	2.7
Latin American EEx.	6.2	2.1	4.1	1.6	10.9
Rest of Latin Am.	5.5	1.5	4.1	1.3	9.9
EE & FSU EEx.	4.6	0.9	3.7	0.1	9.1
Rest of Europe	6.8	1.3	5.5	2.1	11.5
Middle Eastern N Africa EEx.	1.7	0.4	1.2	0.2	3.2
Sub Saharan EEx.	6.9	1.6	5.3	1.7	12.1
Rest of North Africa & SSA	9.9	2.1	7.8	3.3	16.6
South Asian EEx.	-0.2	0	-0.2	-0.9	0.5
Rest of high income Asia	0.1	0	0	-0.1	0.2
Rest of Southeast & South Asia	1.2	0.2	1	-0.3	2.7
Oceania countries	6.6	1.5	5.1	1.6	11.7

the US, this share could more than double from 2006 levels, while the share of oilseeds going to biodiesel in the EU could triple. In analyzing the biofuel policies in these regions, we decompose the contribution of each set of regional policies to the global changes in output and land use. The most dramatic interaction between the two sets of policies is for oilseed production in the US, where the sign of the output change is reversed in the presence of EU mandates (rising rather than falling). The other area where they have important interactions is in the aggregate demand for crop land. About one-third of the growth in US crop cover is attributed to the EU mandates. When it comes to the assessing the impacts of these mandates on third economies, the combined policies have a much greater impact than just the US or just the EU policies alone, with crop cover rising sharply in Latin America, Africa

Forest cover					Pasture cover				
USEU 2015	US 2015	EU 2015	Confidence interval (95%)		USEU 2015	US 2015	EU 2015	Confidence interval (95%)	
			Lower	Upper				Lower	Upper
-1.7	-1.3	-0.5	-2.6	-0.9	-4.9	-3.2	-1.7	-7.3	-2.6
-6	-1.6	-4.4	-9.2	-2.8	-4.4	-1.1	-3.4	-6.9	-2.1
-7.3	-0.5	-6.8	-10.4	-4.3	-5.6	-0.4	-5.3	-7.8	-3.5
-1.7	-0.5	-1.2	-2.5	-0.9	-10.9	-2.7	-8.3	-15.8	-6.1
-0.8	-0.3	-0.5	-1.8	0.2	-0.4	-0.2	-0.3	-0.8	-0.1
0.1	0	0.2	-0.2	0.5	-2	-0.4	-1.6	-4.1	0.1
0	0	0	-0.4	0.4	-1	-0.1	-0.9	-2.4	0.3
-2	-0.8	-1.2	-3.3	-0.6	-4	-1.3	-2.7	-6.8	-1.2
-0.3	-0.3	0	-1.5	0.9	-5	-1.1	-3.9	-8.3	-1.7
-0.8	-0.2	-0.5	-3.6	2.0	-3.6	-0.6	-3	-6.0	-1.2
-0.7	-0.3	-0.4	-2.0	0.7	-5.7	-0.9	-4.8	-9.2	-2.3
-0.9	-0.2	-0.6	-1.7	0.0	-0.8	-0.2	-0.6	-1.4	-0.2
-3.4	-0.8	-2.6	-6.3	-0.5	-3.2	-0.7	-2.5	-5.1	-1.2
-3.4	-0.8	-2.6	-5.8	-1.1	-5.8	-1.1	-4.6	-9.2	-2.4
0.5	0.1	0.4	-0.2	1.2	-0.3	-0.1	-0.2	-0.5	0.0
0.1	0	0.1	0.0	0.2	-0.1	0	-0.1	-0.3	0.0
0	0	0	-0.3	0.2	-1.1	-0.2	-0.9	-2.5	0.2
-2.4	-0.6	-1.8	-4.0	-0.8	-3.9	-0.8	-3.1	-6.8	-1.0

and Oceania as a result of the biofuel mandates. These increases in crop cover come at the expense of pasturelands (first and foremost) as well as commercial forests. It is these land use changes that have attracted great attention in the literature (e.g. Searchinger *et al.*, 2008) and a logical next step would be to combine this global analysis of land use with estimates of the associated greenhouse gas emissions.

4. Conclusions

This paper examines US ethanol policy options using a partial equilibrium model and US and EU options using a global general equilibrium model. The partial equilibrium results clearly illustrate the new linkage between energy and agricultural markets. Prices of agricultural commodities in the future will be driven not only by demand and supply relationships for the agricultural commodities themselves, but also by the price of crude oil. Ethanol from maize and sugarcane can be produced economically at high crude oil prices. The US policy interventions have enabled the ethanol industry to exist and grow over the past 30 years. Today the government interventions continue to be important, but the new added driver is high oil prices.

When one examines the US and EU policies together, one sees clearly that the impacts are felt around the world. Trade and production patterns are affected in every region. The results presented here are very preliminary, but they serve to illustrate how the analysis can be used to estimate global production, trade, and land use impacts of US and EU policies.

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