The US Ethanol and Biofuels Boom: Its Origins, Current Status, and Future Prospects

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This article explains why we are experiencing a boom in ethanol and other biofuels, the current status of biofuels, and prospects for the future under different policy regimes. I argue that today's boom is in a sense an unintended consequence of a fixed ethanol subsidy that was keyed to $20-per-barrel crude oil, combined with a surge in crude oil prices—initially to $60 per barrel, and later doubling to $120 per barrel. Future prospects for corn ethanol depend on the crude oil price, the price of corn and distillers' grains, the market value of ethanol, plant capital and operating costs, and federal ethanol and biofuels policies. I examine the impacts of a wide range of policies for subsidies and renewable fuels standards. Policy choices will be absolutely critical in determining the extent to which biofuels targets are achieved and at what cost. However, if the price of oil remains above $100 per barrel, biofuels will continue to be produced even without government interventions.

Keywords: biofuels, ethanol, energy policy, renewable fuels

Renewable energy—especially biofuels—is a very hot topic in the United States and in many other countries around the world. Although governments have been promoting biofuels for a long time, the real boom began in 2005 and continues to the present. In this article I explore the history of biofuels, describe the current situation, examine alternative policies for the future, and consider issues that will be important in determining future prospects for biofuels. Although a wide variety of biofuels can be produced from agricultural resources, I focus mainly on ethanol.

Ethanol has been produced for fuel in the United States for at least 28 years. The subsidy provided in the Energy Policy Act of 1978 (10.6 cents per liter, or 40 cents per gallon) launched the industry. Between 1978 and today, the ethanol subsidy has ranged between 10.6 and 15.9 cents per liter (40 and 60 cents per gallon). See table 1 for the history of subsidies and other relevant aspects of federal policy. Today the federal subsidy stands at 13.5 cents per liter (51 cents per gallon; Tyner 2007a). The subsidy mechanism originally was a partial excise-tax exemption for the blended fuel, whereas now it is a tax credit for the entity that blends ethanol with gasoline. Throughout the almost three-decade history of ethanol production, the subsidy has been a fixed amount, invariant with oil or corn prices (Tyner and Quear 2006).

There are other federal subsidies in addition to the blended fuel tax credit, as well as state subsidies. Many states have complicated combinations of state subsidies, renewable fuel standards, producer incentives, and so on. For example, the current Minnesota producer tax credit is 5.3 cents per liter (20 cents per gallon) (Schumacher 2006). In fact, Koplow (2006) calculated the total subsidy available for ethanol in 2006 to range between 27.8 and 36.5 cents per liter of ethanol ($1.05 and $1.38 per gallon) or between 37.6 and 49.5 cents per liter of gasoline equivalent ($1.42 and $1.87 per gallon), with the conversion from Koplow based on fossil fuel displaced. Many would regard these figures as high, but they do demonstrate that the ethanol industry has been one with substantial subsidies.

Moreover, there is also a tariff on imported ethanol of 14.3 cents per liter (54 cents per gallon), plus 2.5 percent of the import value. This tariff was originally designed to offset the ethanol subsidy, which applies to both domestic and imported ethanol. When the tariff was originally enacted, the ethanol subsidy was also 14.3 cents per liter (54 cents per gallon). Congress wanted to subsidize domestic ethanol and not imported ethanol, so the import barrier was created. This import protection has very likely prevented lower-cost foreign ethanol from entering the country in the great volumes that might be possible without the tariff.

The crude oil price as measured by composite US refinery acquisition costs (*www.eia.doe.gov*) in nominal terms ranged between $10 and $30 per barrel between 1983 and 2003, except for a couple of short-term spikes (figure 1). Thus, for most of that two-decade period, the country had a fixed ethanol subsidy while the crude oil price was around $20 per barrel.

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Table 1. History of ethanol subsidy legislation.		
Year	**Legislation**	**Description**
1978	Energy Tax Act of 1978	$0.40 per gallon of ethanol tax exemption on the $0.04 gasoline excise tax.
1980	Crude Oil Windfall Profit Tax Act and the Energy Security Act	Promoted energy conservation and domestic fuel development.
1982	Surface Transportation Assistance Act	Increased tax exemption to $0.50 per gallon of ethanol and increased the gasoline excise tax to $0.09 per gallon.
1984	Tax Reform Act	Increased tax exemption to $0.06 per gallon.
1988	Alternative Motor Fuels Act	Created research and development programs and provided fuel economy credits to automakers.
1990	Omnibus Budget Reconciliation Act	Ethanol tax incentive extended to 2000 but decreased to $0.54 per gallon of ethanol.
1990	Clean Air Act amendments	Acknowledged contribution of motor fuels to air pollution–oxygen requirements for motor fuels.
1992	Energy Policy Act	Tax deductions allowed on vehicles that could run on E85.
1998	Transportation Efficiency Act of the 21st Century	Ethanol subsidies extended through 2007 but reduced to $0.51 per gallon of ethanol by 2005.
2004	Jobs Creation Act	Changed the mechanism of the ethanol subsidy to a blender tax credit instead of the previous excise tax exemption. Also extended the ethanol tax exemption to 2010.
2005	Energy Policy Act	Established the renewable fuel standard starting at 4 billion gallons in 2006 and rising to 7.5 billion in 2012. Eliminated the oxygen requirement for gasoline, but failed to provide MTBE legal immunity.
2007	Energy Independence and Security Act of 2007	Established a renewable fuel standard totaling 36 billion gallons (1 billion biodiesel) by 2022.

Source: North Dakota Chamber of Commerce 2006, Tyner 2007b.

That subsidy together with oil in the $10 to $30 range was sufficient to permit growth in ethanol production (figure 2) from about 1625 million liters (430 million gallons) in 1984 to about 12.85 billion liters (3.4 billion gallons) in 2004 (Tyner 2007b). In other words, production grew about 563 million liters (149 million gallon) per year. In 2004, the crude oil price began its steep climb to around $70 per barrel, and in recent months has topped $120 per barrel. This rapid increase in the crude oil price while the ethanol subsidy has been fixed led to a tremendous boom in construction of ethanol plants. Ethanol production in 2005 was about 14.8 billion liters (3.9 billion gallons), in 2007 it was around 24.6 billion liters (6.5 billion gallons), and it could surpass 41.6 billion liters (11 billion gallons) in 2008. Production will have grown about 8.9 billion liters (2.4 billion gallons) per year over that three-year period, compared with 563 million liters (149 million gallons) per year in preceding years. Thus, the combination of high oil prices and a subsidy keyed to oil at $20 per barrel has led to the ethanol boom.

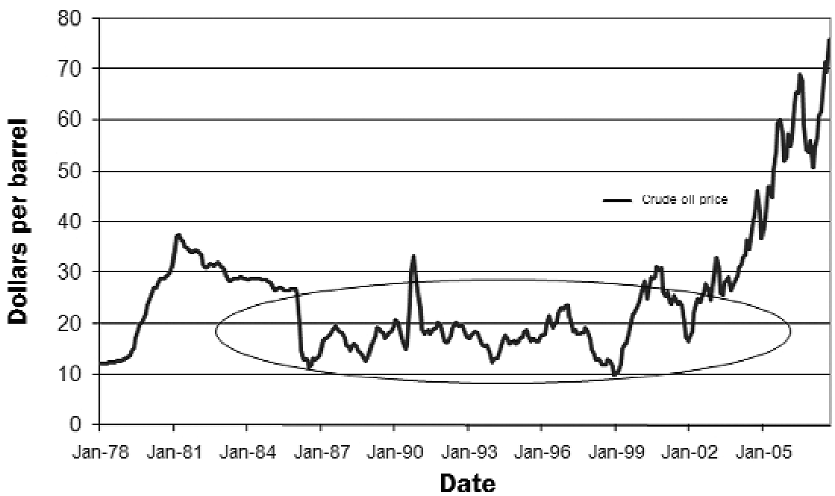

Figure 1. Composite refiner acquisition cost of crude oil, 1978 through September 2007 (Tyner 2007b).

One could even say that this corn ethanol boom was an unintended consequence of the fixed subsidy keyed to $20-per-barrel oil. No one could argue that a corn price of $157 per metric ton was the objective of the ethanol policy, yet that is about where matters stood at the end of 2007, and since then corn has surpassed $230 per metric ton. The rapid increase in corn prices led to 6.25 million additional hectares (ha) of corn being planted in 2007, which, in turn led to reduced soybean area and increased soybean prices. The run-up in commodity prices has spurred debate over the food-fuel issue and raised questions about the extent to which renewable fuels can be supplied from corn alone. Corn went from $87 per metric ton in early 2006 to $217 per metric ton or higher in two years—an increase of 150 percent. This rapid jump in price is also an unintended consequence of the current ethanol policy combined with the surge in oil prices.

This is not to say, however, that food prices will increase in like proportion. Corn is used primarily as animal feed, with the proportion varying by animal species. The poultry industry is facing the largest hit because corn constitutes about two-thirds of the poultry ration. The total cost of producing poultry meat and eggs had increased about 30 percent through

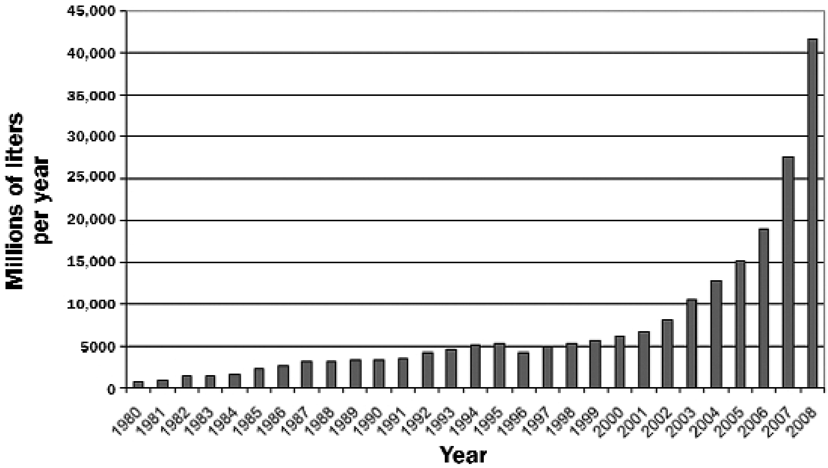

Figure 2. US ethanol production (millions of liters per year) from 1980 through 2008 (projected) (Tyner 2007b).

the end of 2007. It is unlikely, however, that all of this increase can be passed on to consumers. For other commodities, the cost increase is smaller, and it is substantially smaller for the total consumer food bill. Estimates made in 2007 put the increase in the consumer food bill attributable to corn ethanol at 1.1 to 1.8 percent (Tokgoz et al. 2007).

As indicated above, corn ethanol could reach between 42 billion and 45 billion liters (between 11 billion and 12 billion gallons) in 2008–2009. How much higher will it go, and what will be the determining factors? Most industry and agriculture experts (Tokgoz et al. 2007, Elobeid et al. 2007) and I think corn ethanol production will top out at around 57 billion liters (15 billion gallons). We expect a plateau at that level because pressures on corn prices would very likely render higher levels uneconomic. That level would constitute about 10.7 percent of US gasoline consumption by volume and about 7.3 percent on an energy-equivalent basis. The volumetric and energy-equivalent shares are different because ethanol contains about 68 percent of the energy of gasoline per unit of volume. Miles per gallon, at least in the short run, will be determined by energy content, so consumers are unlikely to be willing to pay more for ethanol than its energy equivalence to gasoline.

Several factors will determine where corn-based ethanol will top out. I discuss these determinants in the sections that follow.

The price of crude oil and gasoline. Over the medium term, the price of gasoline can be predicted from the price of crude oil. The econometric relationship is depicted in this equation (Tyner and Taheripour 2007): Wholesale gasoline price ($ per gallon) = (0.1076 + 0.03127) × crude oil price ($ per barrel). This relationship explains 93 percent of the variance in monthly gasoline prices.

The price of corn. Most of the analysis that has been done to date suggests that the demand for corn for ethanol will bid up the price of corn to the point that it no longer is profitable to invest in corn ethanol plants. One of the big unknowns for the price of corn is the global supply response to higher corn prices. In the United States, corn acreage went from 78 million to 92 million acres (32 million to 38 million ha) in just one year (2007) as a result of higher corn prices induced by the demand for corn for ethanol. If the demand for corn is met by a substantial global response, the corn supply might be able to keep up with the rising demand for corn-based ethanol. In economic modeling, such supply responses to large price changes are quite difficult to predict. Also, any short-term supply disruption (drought or flood) would very likely send corn prices up substantially and reduce ethanol production.

The price of ethanol. Historically, ethanol has gotten its value from its energy content and its additive value. The additive value derives from the fact that ethanol has much higher octane (112) than standard gasoline (87), and its oxygen content is higher than that of gasoline, so blends of ethanol and gasoline burn "cleaner" than does gasoline alone.

Gasoline has been required to have a certain percentage of oxygen (by weight) since passage of the Clean Air Act of 1990. The main sources of this added oxygen have been MTBE and ethanol, but MTBE was found to be quite toxic, and it contaminated ground water supplies. By 2005, it had been banned as an additive by 20 states. In the debate leading up to the Energy Policy Act of 2005 (PL 109-058), oil companies sought legal immunity from prosecution related to MTBE. They lost that battle, although they did succeed in eliminating the percentage-oxygen requirement. In May 2006, when the changes in the clean air rules were implemented, there was a huge increase in demand for ethanol as an additive; ethanol's price jumped to nearly $1 per liter ($3.78 per gallon).

By early 2008, however, there was sufficient ethanol in the market to satisfy the national demand for gasoline additives. Thus, the price of ethanol should revert to its energy value. If wholesale gasoline is $0.79 per liter ($3 per gallon), then, wholesale ethanol should be about $0.54 per liter ($2.04 per gallon), plus the subsidy (currently $0.135 per liter [$0.51 per gallon]).

Ethanol prices could also be constrained by infrastructure that is inadequate to transport the ethanol to market and to blend it at terminal markets. Ethanol and ethanol blends cannot be transported by pipeline; they must be shipped by truck, rail, and barge. The industry is already experiencing transport infrastructure bottlenecks, which also could effectively limit ethanol demand.

Gasoline consumption in the United States is about 530 billion liters (140 billion gallons). Today ethanol is marketed either in a 10-percent blend known as E10 or in an 85-percent blend called E85. At present, the distribution network for E85 is limited, and very few flex-fuel vehicles exist to use the 85-percent blend. Expansion of the market beyond the E10 saturation point will require greater availability of flex-fuel vehicles, and more service stations that can provide the E85 blend.

One thing that might prevent the ethanol price from dropping so quickly would be a change in the refining process to produce 84-octane gasoline, which could be blended with 10-percent ethanol to yield an 87-octane blend. Gasoline with 84 octane is less expensive to produce than 87-octane gasoline, so such a change is likely to occur if oil refiners become convinced that the price of ethanol will be lower than the price of gasoline on a volumetric basis over the longer term. To the extent that this change transpires, ethanol would retain an additive value up to 53 billion liters (14 billion gallons)—10 percent of gasoline consumption.

The value of a by-product of ethanol production: Distillers dried grains with solubles. When corn is used to make ethanol, about one-third ends up as ethanol, one-third as distillers dried grains with solubles (DDGS), and one third as carbon dioxide (CO_2). The DDGS is used as animal feed, particularly for ruminants (mainly dairy and beef cattle). Historically, the price of DDGS has been highly correlated with the price of corn and soybean meal. In recent years, the corn price has been more dominant in determining the DDGS price. In the summer of 2007, however, the huge quantities of DDGS on the market led to the DDGS price being lower than the value predicted from the historic relationship with corn. Since then, the corn-DDGS price relationship has been stronger. It is hard to say whether future DDGS values will follow corn prices closely or not, but the DDGS sales credit is an important factor determining overall ethanol economics. Also, new technologies employing fractionation (a separation process) produce by-products with improved nutritional characteristics, which could enhance the by-product credit.

Other capital and operating costs. The boom in construction of new plants has led to substantial increases in capital cost—about 80 percent, depending on the size of the plant. Some of this increase is due to shortages of key components such as stainless steel, but much of it is attributable to the insufficient capacity of engineering and construction companies to meet the demand for new plants. As the demand for new plant construction falls, I would expect the capital cost of new plants to come down. Ethanol-specific operating-cost items like enzymes also might come down a bit, but the major change we can expect would be a reduction in capital costs from today's peak.

Government policy. At this writing, government policy toward biofuels combines a fixed subsidy of 13.5 cents per liter (51 cents per gallon) with a renewable fuel standard (RFS) for corn ethanol that grows to 56.7 billion liters (15 billion gallons) in 2015. However, these policies are being challenged for a number of reasons. The policy chosen will be critical in determining the growth of both corn and cellulose ethanol.

Clearly, predicting the future growth of corn ethanol is precarious, given the high degree of uncertainty in all these factors. However, if oil stays above $100 per barrel, corn ethanol under normal conditions will be viable simply because of the energy demand for it as a substitute for gasoline. Because of the upward movement of corn prices, the upper limit is probably no higher than 57 billion liters (15 billion gallons) of ethanol from corn.

Cellulose-based ethanol

The hope for the future is ethanol derived from cellulosic feedstocks instead of, or in addition to, corn. Cellulosic feedstocks include corn stover, switchgrass, poplar trees, and any other raw material composed primarily of cellulose. According to the Department of Energy, it costs the equivalent of $102 per barrel to produce ethanol from cellulose. The US Department of Agriculture cites somewhat higher current costs of $123 per barrel (Collins 2007). The Department of Energy has a target price of $47 per barrel by 2012, assuming that needed successes in research and development are achieved. The Energy Independence and Security Act of 2007 (P.L. 110-140) also creates an RFS for "advanced biofuels," which is mainly seen as cellulosic ethanol. The level of the RFS is 75.6 billion liters (20 billion gallons) in addition to corn ethanol.

Ethanol economics

I can illustrate the most important drivers in the ethanol market with breakeven graphs. Figure 3 shows the breakeven point between crude oil and corn under two different scenarios (Tyner and Taheripour 2007): (1) There is no ethanol subsidy and ethanol is priced on an energy-equivalent basis with gasoline (indicated by the top line in the graph), and (2) the federal ethanol subsidy of 13.5 cents per liter (51 cents per gallon) is added (indicated by the second line in the graph).

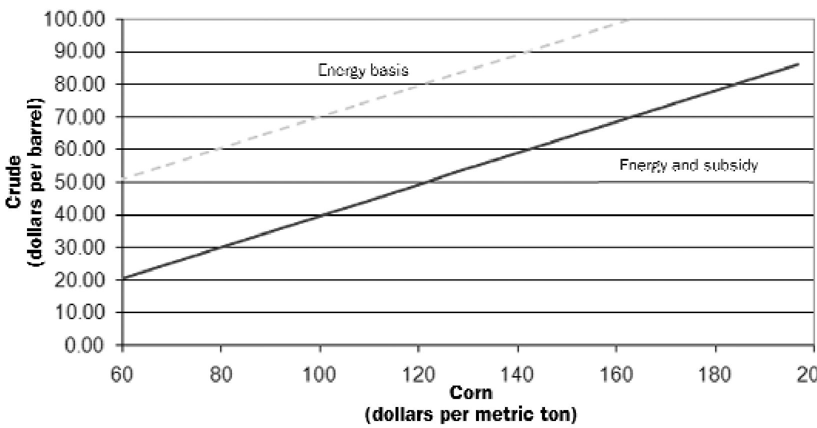

Figure 3. Breakeven prices of crude oil and corn with energy-equivalent pricing and with energy-equivalent pricing plus the federal ethanol subsidy.

All the assumptions and econometric estimations used in producing this graph are contained in the article by Tyner and Taheripour (2007). The econometric relationship between crude oil and gasoline price in the equation above (in "The price of crude oil and gasoline") is used to arrive at the gasoline price, and the ethanol price is then assumed to be 70 percent of the gasoline price without any subsidy. The prototypical ethanol plant has a capacity of 378 million liters (100 million gallons) at a capital cost of $0.48 per liter ($1.80 per gallon) of capacity. The plant is 60-percent debt financed at 8 percent and has 40 percent equity with a required return of 12 percent.

For $100-per-barrel oil, the energy and energy-plus-subsidy breakeven corn prices are $163 and $226 per metric ton, respectively. Even the no-subsidy price ($163 per metric ton) is nearly double historic norms (around $86 per metric ton). Thus, as long as oil prices remain very high, there will be a substantial demand for corn for ethanol regardless of the government policy option in place.

Policy alternatives

As indicated above, the fixed subsidy worked well as long as crude oil prices ranged between $10 and $30 per barrel. Also, until recently ethanol production levels were fairly low, so the subsidy cost was relatively low. However, moving toward 132 billion liters (35 billion gallons) as required for the RFS, the subsidy cost under the current policy would be about $18 billion per year. Depending on crude oil and corn prices, there could be periods when the subsidy makes ethanol very attractive, and other times when ethanol plants could lose money with the fixed subsidy. Perhaps most important, the current policy will not provide a bridge to cellulose ethanol. There are several possible policy alternatives that could be considered:

- Make no changes and let the other corn-using sectors (particularly livestock and exports) adjust as needed.
- Convert the fixed subsidy to one that varies with the price of crude oil.
- Construct a subsidy policy with two components: (1) a national security component (either fixed or variable) tied to the energy content of the fuel, and (2) a component tied to reductions in liquid fuels' greenhouse gas (GHG) emissions.
- Provide higher subsidies for cellulose-based ethanol in hopes of accelerating development and implementation of that technology.
- Use an RFS instead of subsidies to stimulate growth in production and use of alternative fuels.
- Use a combination of an RFS and a variable subsidy.

No changes. Certainly, one option is to do nothing—in other words, let the other corn-using sectors adjust to higher corn prices. But as the results in the section above on ethanol economics show, that option could lead to substantially higher corn prices than has been the case historically. It certainly would lead to higher costs for the livestock industry—this is already happening—and ultimately for consumers of livestock products. It also would lead to reduced corn exports. It is difficult to quantify the size of these adjustments in feed use and exports because the price changes are larger than recent historical experience. However, with corn use for ethanol going from less than 10 percent of the crop a few years ago to a quarter of the crop this year, it is clear that adjustments in these uses will occur.

Variable subsidy. Another option is a subsidy that varies with the price of crude oil and goes to zero at high crude prices. In designing a variable subsidy, there are two key parameters: the price of crude oil at which the subsidy begins, and the rate of change of the subsidy as the crude oil price falls. Assume, for example, that the subsidy ends when the price of crude oil is $75 or higher, but some level of subsidy exists for crude oil prices lower than $75. In this example, also assume a subsidy change value of 0.93 cents per liter (3.5 cents per gallon) of ethanol for each dollar that the crude oil price falls below $75. Thus, if crude oil were $60, the subsidy would be 13.9 cents per liter (52.5 cents per gallon), which is about the same as the current fixed subsidy. If the crude oil price were $40, the ethanol subsidy would be 23.1 cents per liter (87.5 cents per gallon). Therefore, for any crude oil price above $60, the ethanol subsidy would be lower than the current fixed subsidy. For any crude oil price less than $60, the subsidy would be greater than the current fixed subsidy.

Figure 4 illustrates the corn breakeven price for different crude oil prices if this variable subsidy were in effect. In this case, the corn breakeven price at the $75 crude oil price for a new ethanol plant would be $111 per metric ton, compared with the fixed subsidy value of $174 shown in figure 3. With the crude oil price at $60, the corn breakeven would be $100 per metric ton for a new plant with the variable subsidy. Oil priced at $40 would support a corn price of $87 per metric ton for a new plant—about the historical average corn price before the recent boom. Oil at $100 would yield a breakeven corn price of $163 per metric ton with no ethanol subsidy, whereas $100 oil with the fixed subsidy yields corn at $226 per metric ton. So the variable subsidy provides a safety net for ethanol producers without putting inordinate pressure on corn prices. Above the $75 crude oil price, ethanol investment decisions would be market driven.

Two-part subsidy. Economists argue for government intervention in markets in the presence of "externalities"—that is, factors that cannot be captured through market forces. At present, the two most commonly cited external factors in the oil marketplace are energy security and GHG emissions or climate change. The two-part subsidy is aimed at "correcting" these two market failures. For this illustration, I will construct the national security part of the subsidy on the basis of the energy content of the renewable fuel. Thus, ethanol from corn or cellulose would have the same energy security subsidy since they have the same energy content, but biodiesel would have an energy security subsidy 1.5 times larger because it has 150 percent of the energy content of ethanol. Similarly, biodiesel would have a larger GHG reduction component than corn ethanol, but the component would be lower than for cellulose ethanol because of the differences in GHG emissions reduction. The GHG component would be invariant with the price of crude oil, but the energy security part could be fixed or variable. In this illustration, assume it is fixed.

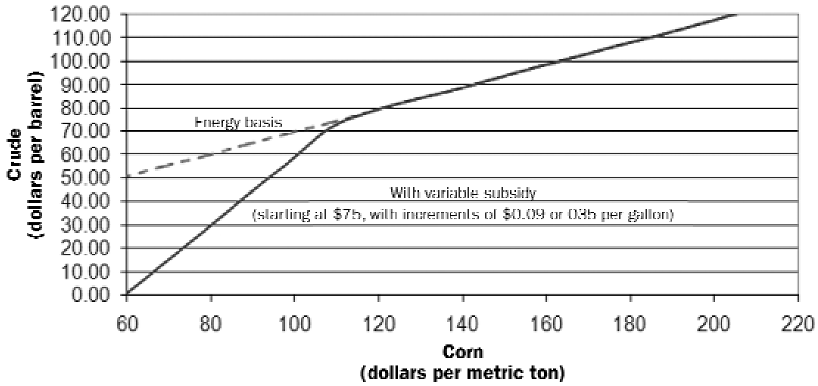

Figure 4. Breakeven prices of crude oil and corn with ethanol priced on an energy-equivalent basis with gasoline, with and without a subsidy that varies with the price of crude oil.

Hill and colleagues (2006) indicate that corn-based ethanol provides a 12.4 percent reduction in GHG (compared with gasoline), and soy biodiesel provides a 40.5 percent reduction (compared with diesel). Tilman and colleagues (2006) indicate that switchgrass can actually be carbon negative; that is, more carbon is sequestered than is released in combustion. For cellulose ethanol, they calculate a 275 percent reduction in CO_2 emissions, but the actual carbon balance depends on the production conditions. For purposes of this illustration, let us assume that cellulosic ethanol yields a 200 percent GHG reduction. Recent *Science* articles by Fargione and colleagues (2008) and Searchinger and colleagues (2008) have disputed the greenhouse reduction claims from biofuels, but the issue is still being hotly debated among scientists in the area. For this analysis, I use the percentage reductions from the literature.

I key the energy security component to energy value (that is, to the energy content of the oil displaced). The two-part subsidy is illustrated in figure 5. For this illustration, I keyed the base values for the national security component and the GHG component to yield a corn ethanol subsidy roughly equivalent to the current federal ethanol subsidy of 13.5 cents per liter (51 cents per gallon)—about 20 cents per liter (75 cents per gallon) for the national security component per unit of gasoline equivalent. I assumed a relatively high carbon price of $27.50 assumed to calculate the GHG credit. Soy diesel and gasoline were assumed to have the same energy level and ethanol two-thirds of that level. The resulting total subsidy values are 14 cents per liter (53 cents per gallon) for corn ethanol, 22 cents per liter (85 cents per gallon) for soy diesel, and 26 cents per liter ($1.00 per gallon) for cellulose ethanol. Clearly, these values are just illustrative to demonstrate that a two-part subsidy encompassing both the national security and GHG emissions externalities would be possible. Much more work would be needed to develop the subsidy mechanisms.

Incentives for cellulosic ethanol. Incorporation of the GHG credit as described in the two-part subsidy described above would obviously help stimulate the production of cellulosic ethanol. However, if incorporating the GHG credit is not possible or deemed desirable, other cellulose-targeted incentives could be considered, keeping in mind that using cellulose for ethanol production would ameliorate the problems associated with using corn—namely, reduced corn exports and higher costs for animal feed. If state or federal governments want to provide incentives for the industry to move toward cellulose sources instead of corn, then targeted incentives might be appropriate. One method would be what is called a reverse auction. In that approach, the government requests that firms supply some fixed quantity of cellulosic ethanol for the next 10 to 15 years. Companies then bid for the contract

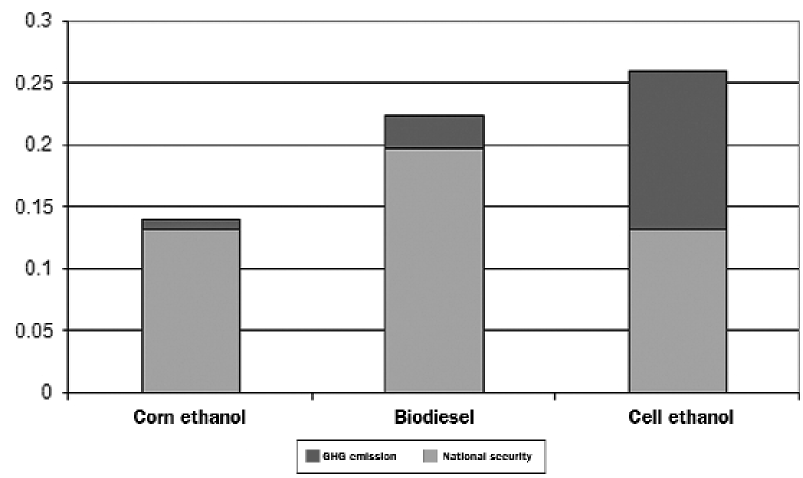

Figure 5. Illustration of a two-part subsidy with the two parts being based on contribution to energy security and contribution to reduction in greenhouse gas emissions (Tyner 2007b).

to supply the ethanol, with the lowest bidder winning the contract. Another option would be to provide a tax credit to cellulose processors for each dry ton of cellulose converted into fuels. With either of these alternatives, the government could assist in launching the cellulose-based industry. But so long as corn-based ethanol is profitable, it will be difficult to stimulate investment in cellulose technology, because it is much more uncertain and at present more costly than corn-based ethanol technology and production. Thus, targeted incentives might be needed to bridge to cellulose-based production.

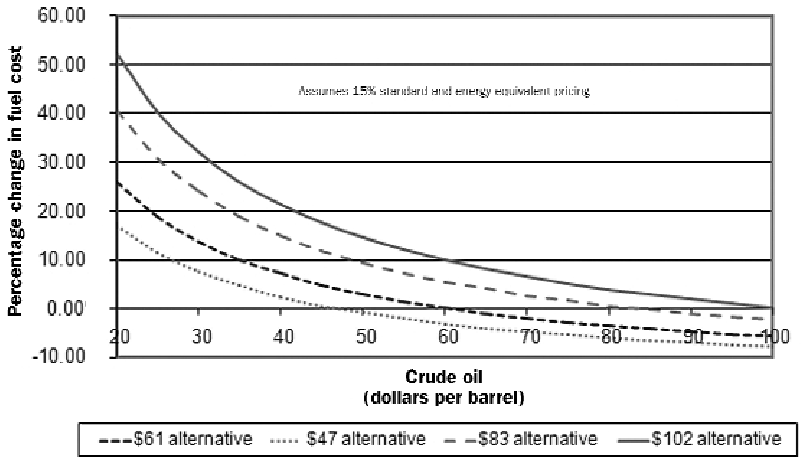

Figure 6. Illustration of the impacts on consumer fuel purchases of a renewable fuel standard of 15 percent under different assumptions of cost of renewable fuel alternatives and crude oil (Tyner 2007b).

Renewable fuel standard. In December 2007, Congress passed and the president signed legislation that included an RFS of 132 billion liters (35 billion gallons) of ethanol by 2022. That is roughly four times the amount of current ethanol production. A fuel standard works very differently from a subsidy. It tells the liquid fuels industry that it must acquire a certain percentage of its fuel from renewable sources. With a fuel standard that is perceived to be ironclad, the industry is required to procure these renewable fuels no matter what their market cost. Most of any change in the cost of fuels—either upward or downward—is passed on to consumers at the pump. In other words, if crude oil is much cheaper than renewable fuels, consumers pay more than they would in the absence of the standard. If it turns out that renewable fuels are less expensive than crude oil, however, consumers pay less at the pump, and the standard would not be binding. In a sense, then, a renewable fuel standard is a sort of variable tax, one in which consumers see a different price at the pump than they would without the standard. For either a fixed or variable subsidy, the cost of the incentive is paid through the government budget. For an RFS, consumers do not pay through taxes but pay directly through higher pump prices, especially when oil prices are lower.

Figure 6 illustrates the functioning of an RFS. Each of the lines represents a cost for renewable fuels. The lowest line is the Department of Energy target for cellulosic ethanol ($47 per barrel of crude oil equivalent), and the highest renewable fuel cost shown in this graph is $102 per barrel—the Department of Energy estimate of the cost of producing ethanol from cellulose today. The horizontal axis is the cost of crude oil, and the vertical axis is the percentage change in consumer fuel costs compared with the no-standard case. Clearly, with low alternative fuel costs or high crude oil costs (or both), consumers see little or no change in the cost of fuel. But with high costs of alternative fuels (current state of technology) or low crude oil prices, consumers could see significantly higher pump prices. It is likely that the current cost of producing cellulosic ethanol would be higher than the Department of Energy estimate, which predates recent oil price and construction cost increases.

If we want to achieve both energy security and global warming objectives through a standard, then it would be appropriate to partition the standard, with a higher fraction being allocated to cellulose-based fuels. The 2007 legislation does that, with 43 percent of the standard going to corn and 57 percent to advanced biofuels, including cellulose. This approach could achieve results similar to those of the two-part subsidy described above.

Renewable fuel standard plus a variable subsidy. In the event that crude oil prices turned out to be quite low, consumers could see significantly higher prices at the pump with a standard than without one. One option to limit consumer exposure would be to combine a variable subsidy with a fuel standard. Essentially, there would be no subsidy unless crude

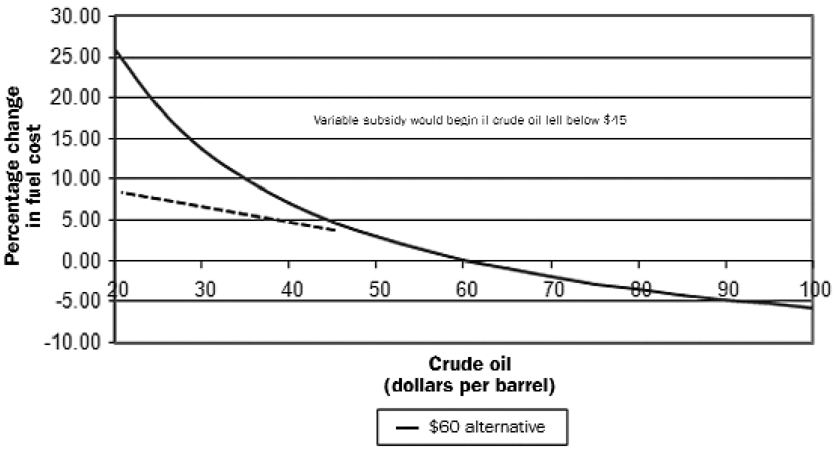

Figure 7. Illustration of a renewable fuel standard combined with a variable subsidy that begins at $45 per barrel of oil (Tyner 2007b).

oil prices fell below some predetermined level, say $70. Then a variable subsidy would kick in, which would limit the price increase consumers would see at the pump in the event of a strong drop in oil prices. In a sense, it is a form of risk sharing—with low oil prices, the government budget would take part of the hit instead of consumers taking all of the hit at the pump. This option is illustrated in figure 7. The horizontal axis is the crude oil price, and the curve represents a $60 alternative fuel cost. The line on the left that begins at $70 for crude oil illustrates the impact of the variable subsidy combined with the fuel standard.

Conclusions

The current ethanol boom in the United States has been driven by ethanol policy and the recent run-up in oil prices. In this article we have reviewed the factors that will determine the extent to which the corn ethanol boom continues or peters out. It is likely that the rapid growth of corn ethanol will cease, and under most assumptions, corn ethanol will peak around 57 billion liters (15 billion gallons). Beyond that level, it is likely that the price of corn will be high enough to choke off further growth in the industry.

I have also reviewed a wide range of future policy options and explained the impact that these alternatives might have on producers and consumers. Clearly, the policy path that is chosen is absolutely critical in determining (a) the extent to which renewable fuel targets are met, and (b) the costs that government and consumers must pay. Nonetheless, if oil prices remain above $100, there will continue to be energy production from agriculture even if all government subsidies and mandates go away. We have entered a new era in which agriculture supplies not only food, feed, and fiber but also fuel.

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