Biofuels, Energy-Security and Global-Warming Policy Interactions

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Within the past 5 years, there has been a significant movement in political consensus towards an energy future with a substantially larger renewable-energy component. One of the major drivers is the perception that importing over 60% of our oil reduces our national security. A recent estimate of the hidden cost of oil dependence amounts to about $3 per gallon of liquid fuel excluding multiplier effects (Copulos, 2007). This estimate includes incremental military costs, supply-disruption costs and direct economic costs. Many argue that energy security is a major issue that must be addressed in today's policy environment.

Another issue is global warming. The United States now acknowledges that global warming is real and that it is caused by human interventions. Over two dozen national and international corporations have joined forces with environmental groups to ask Congress to enact cap and trade policies as quickly as possible (US Climate Action Partnership, 2007). The link between biofuels and global warming is that biofuels, especially cellulosic-based biofuels, emit much less carbon dioxide into the atmosphere than conventional petroleum sources. While all biofuels provide net reductions in greenhouse-gas (GHG) emissions, cellulosic ethanol can, under certain production conditions, be carbon negative; that is, it actually sequesters carbon even after including the CO_2 released when the ethanol is used in vehicles. If we are able to enact cap and trade GHG policy in the near future, biofuels would receive a credit through the cap and trade system. In other words, the GHG-emissions reduction achieved by biofuels could be sold to other entities needing to purchase the reductions. However, we will assume here that the United States does not adopt a cap and trade system quickly, so other policy mechanisms will be needed to credit biofuels for their GHG-emission reductions.

So what we have with biofuels are two kinds of market failures, that economists call externalities:

- energy security, and
- GHG emissions linked to global warming.

Economists argue that externalities need to be "corrected" through taxes, subsidies or some form of regulation. While the nation may be paying an energy security cost of up to $3 per gallon for liquid fuels, consumers do not pay that cost at the pump. In other words, markets have no way of incorporating the energy-security cost into the market transaction. To correct that market failure, we must either put an additional, substantially higher, tax on petroleum fuels, subsidize alternatives to petroleum, or create fuel standards that require liquid fuel vendors to procure a certain percentage of their liquid fuels from domestic alternatives to petroleum. In the US political context, the tax route is very unlikely to happen, so we will focus in this paper on alternative fuel subsidies and fuel standards. Since our energy security is increased in direct proportion to the extent to which a domestic alternative displaces petroleum, we will focus on petroleum import displacement in this analysis.

Similarly, there is currently no market mechanism to "price" GHG-emission reductions achieved by biofuels. Thus, if we want to credit biofuels for that reduction, we will need to incorporate a GHG credit into our subsidy mechanism

In the rest of this paper, we will discuss and evaluate a set of alternative biofuel policies that could be designed to achieve the energy-security objective alone or the energy-security and GHG-reduction objectives together.

Ethanol Economics

Ethanol has been produced for fuel in the United States for almost 30 years. The industry launch was initiated by a subsidy of 40 cents per gallon provided in the Energy Policy Act of 1978. Between 1978 and today, the ethanol subsidy has ranged between 40 and 60 cents per gallon. The federal subsidy today is 51 cents per gallon. Throughout, the subsidy has been a fixed amount that is invariant with oil or corn price (Tyner and Quear, 2006).

Ethanol gets its value from the energy it contains and as an additive. It has value as a gasoline additive because it contains more oxygen than does gasoline (and, therefore, causes the blend to burn cleaner) and because it has a much higher octane (112 compared with 87 for regular gasoline). Historically, ethanol prices have been higher than those of gasoline because of the additive value and because of federal and state subsidies. It is interesting to portray these values in terms of the relationship between crude-oil price and the maximum a corn dry mill could afford to pay for corn at each crude price (Tyner and Taheripour, 2007).

Figure 1 displays the relationships between crude-oil price and break-even corn price on the basis of energy equivalence, energy equivalence plus additive value (assumed to be 35 cents per gallon for this illustration), and energy equivalence plus additive value plus the current federal blending subsidy of 51 cents per gallon. The energy equivalence line was done assuming a figure of 70%, slightly more than the direct energy equivalent.

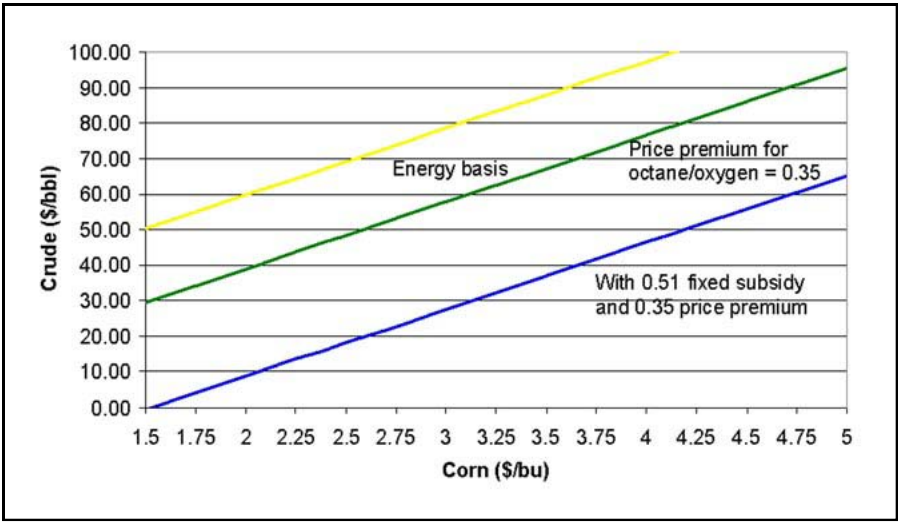

Figure 1. Breakeven corn and crude prices with ethanol priced on energy and premium bases plus a $0.51 ethanol subsidy.

Using Fig. 1, one can trace out the break-even corn price for any given crude-oil price. For example, with crude oil at $60 per barrel, the break-even corn price is $4.72 per bushel including both the additive premium and the fixed federal subsidy. This figure is for a new plant and includes 12% return on equity and 8% debt interest. If we consider an existing plant with capital already recovered, we add $0.78 per bushel to yield a break-even corn price of $5.50. It is important to note that additive value is currently 20 cents higher than the value assumed here, so ethanol producers can afford to pay another 53 cents per bushel under current market conditions, which are not likely to persist.

During the period 1984–2003, crude-oil prices ranged between $10 and $30 per barrel, with only one very short-term peak above $30. With crude-oil prices in that range, the fixed federal subsidy did not put significant pressure on corn prices. However, with crude oil today around $60, there is significant pressure on corn prices. During the past 3 years, ethanol investments in the United States have been highly profitable, with very short payback periods. This high profitability has attracted significant new investment in the industry and added substantially to corn demand. In just a few months, corn prices increased from about $2.25 to around $3.60 per bushel, an increase of about 60%. This leap is leading to an emerging opposition to ethanol subsidies on the part of animal agriculture, export markets, and other corn users. Some are also concerned about the $4 billion cost of the subsidy in 2007 that will grow rapidly as ethanol production increases.

Future Policy Alternatives

In essence, we are living an unintended consequence of the fixed ethanol subsidy. When it was created, no one could envision $60 oil; but today $60 oil is reality, and many believe oil prices are likely to remain high. So given this reality, what future federal policy options could be considered that would support the ethanol industry but provide less incentive for rapid growth in the industry leading to abnormally high corn prices? Several possible policy alternatives may be considered:

- Make no changes and let the other corn-using sectors (particularly livestock) adjust as needed.
- Keep the subsidy fixed, but reduce it to a level more in line with crude oil prices around $60.
- Convert from a fixed subsidy to one that varies with the price of crude oil.
- Construct a subsidy policy with two components:
  - a national security component (either fixed or variable) tied to energy content of the fuel, and
  - a component tied to GHG-emissions reductions of the liquid fuel.
- Provide higher subsidies for cellulose-based ethanol in hopes of accelerating development and implementation of that technology.
- Use an alternative fuel standard instead of subsidies to stimulate growth in production and use of alternative fuels.
- Use a combination of an alternative fuel standard and a variable subsidy

No Changes

Certainly, one option is to do nothing—to let the other corn-using sectors adjust to higher corn prices. But as can be seen from the results in the ethanol economics and sensitivity analyses sections above, that option could lead to substantially higher corn prices than we have seen historically. It certainly would lead to higher costs for the livestock industry (happening already) and ultimately for consumers of livestock products. It also would lead to reduced corn exports. The breakeven corn prices provided above are maximums the ethanol industry could pay to retain profitability. Whether these prices would be reached would depend on the rate of growth of the ethanol industry compared with the rate of growth of corn supply. The March planting intentions report revealed an expected 90.5 million acres for corn, an increase of 15% over 2006. With that report, the high corn prices moderated somewhat. However, we can certainly expect to see continued pressure on corn prices if no change is made in federal subsidy policy.

Lower Fixed Subsidy

Since the current pressure on corn prices comes from the combination of $60 oil and the 51 cent per gallon subsidy, one option would be to maintain a fixed subsidy but lower it to a level more in line with the higher oil price. Figure 2 depicts the corn breakeven prices with a 25 cent per gallon subsidy instead of the current 51 cent per gallon subsidy. The corn breakeven price for $60 oil becomes $3.90 instead of $4.72 under current policy. However, the fixed subsidy still has the disadvantage of not responding to possible future changes in oil prices. If oil fell to $40, the corn breakeven would be $2.84, and it would be $4.43 for $70 oil.

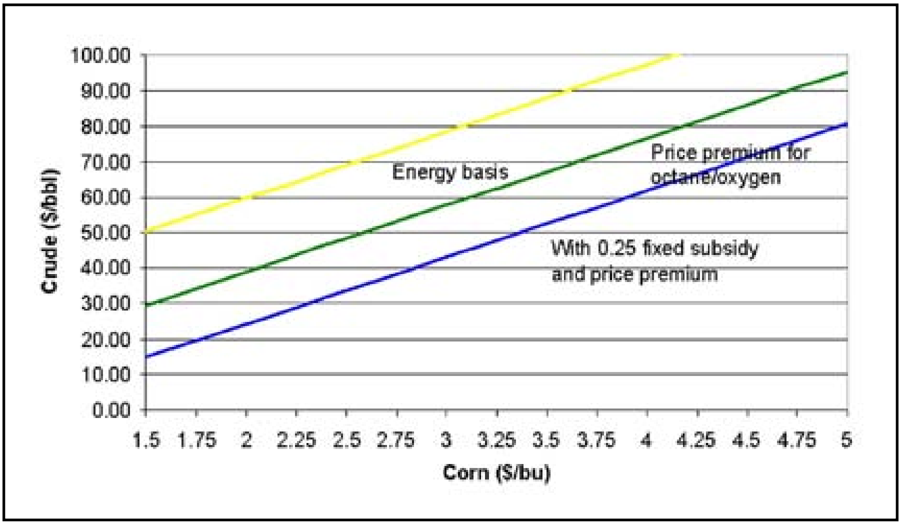

Figure 2. Breakeven corn and crude prices with ethanol priced on energy and premium bases plus a $0.25 ethanol subsidy.

Variable Subsidy

Both the current fixed subsidy and a variable subsidy are intended to handle the energy-security externality described above. 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 crude oil price falls.

We will illustrate the variable subsidy using $60 crude as the point at which the subsidy begins. That is, when crude is higher than $60, there is no subsidy, but some level of subsidy exists for any crude oil price lower than $60. In this illustration, we will use a subsidy change value of 2.5 cents per gallon of ethanol for each dollar crude oil falls below $60. Thus, if crude oil were $50, the subsidy per gallon of ethanol would be 25 cents. If crude oil were $40, the ethanol subsidy would be 50 cents per gallon. Therefore, for any crude-oil price above $40, the ethanol subsidy would be lower than the current fixed subsidy. For any crude price less than $40, the subsidy would be greater than the current fixed subsidy of 51 cents per gallon.

Figure 3 illustrates the corn break-even price for different crude oil prices if this variable subsidy were in effect. In this case, the corn break-even price at $60 oil for a new ethanol plant would be $3.12 per bushel, compared to $4.72 with the fixed subsidy shown in Figure 1. With oil at $50, the corn break-even would be $2.90 for a new plant with the variable subsidy. $40 oil would support a corn price of $2.69 for a new plant and $3.47 for an existing plant with capital recovered. $70 oil would yield a breakeven corn price of $3.65 with no ethanol subsidy. So the variable subsidy provides a safety net for ethanol producers without putting inordinate pressure on corn prices.

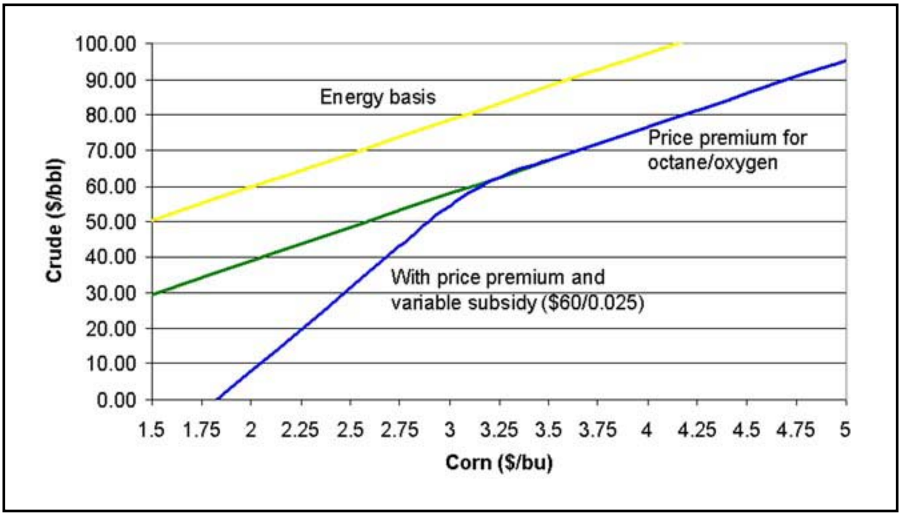

Figure 3. Breakeven corn and crude prices with ethanol priced on energy and premium bases plus a variable ethanol subsidy.

For any crude-oil price above $60, there is no ethanol subsidy with the variable system, so ethanol-plant-investment decisions are made based on market forces alone instead of being driven by the federal subsidy. For any crude price between $40 and $60, the variable subsidy is less than the fixed subsidy, thereby providing less incentive to invest and less pressure on corn prices, but maintaining a safety net. However, with the fixed subsidy, ethanol-plant-investment decisions continue to be heavily influenced by the government subsidy even at crude-oil prices that render ethanol very profitable in the absence of a subsidy.

Two-Part Subsidy

The two-part subsidy derives directly from the externality discussion provided above. For this illustration, we will construct the national security part of the subsidy based on energy content of the renewable fuel. Thus, ethanol from corn or cellulose would have the same energy-security subsidy since the energy content is the same, but biodiesel would have an energy-security subsidy 1.5 times larger since it has 150% of the energy content of ethanol. Similarly, biodiesel would have a larger GHG-reduction component than corn ethanol—but lower than cellulose ethanol—because of the differences in GHG-emission 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, we will assume it is fixed.

Hill *et al.* (2006) indicate that corn-based ethanol provides a 12% reduction in GHG (compared to gasoline), and soy biodiesel provides a 41% reduction (compared to diesel).

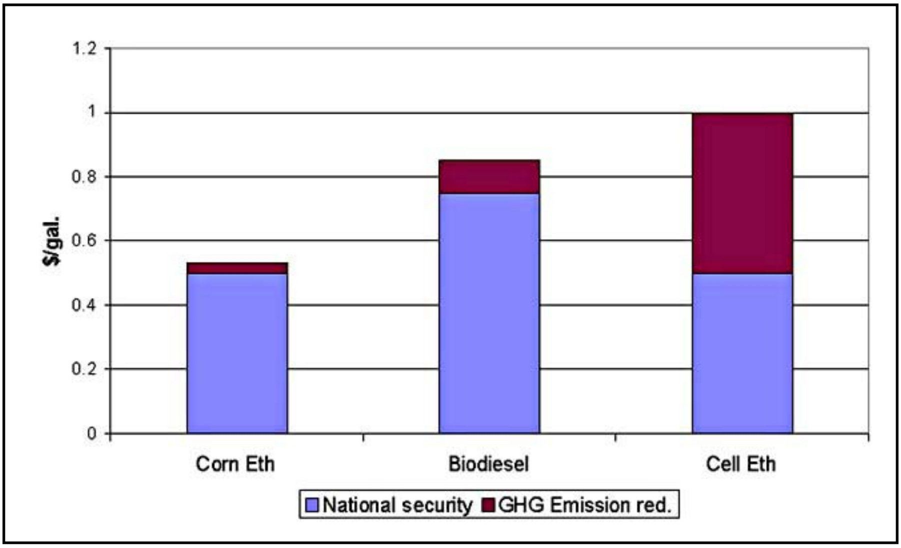

Figure 4. Two-part bioenergy subsidy.

Tilman, Hill, and Lehman (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% reduction in CO_2 emissions. Actual carbon balance depends on the production conditions. For purposes of this illustration, we will assume that cellulosic ethanol yields a 200% reduction in GHG. One could envision a GHG component of the subsidy keyed to an index. For simplicity, we will use these three percentage figures for the index values for corn ethanol, soy biodiesel, and cellulose ethanol respectively.

For the energy security component, we will key it to energy value, *i.e.* to the energy content of oil displaced. The two-part subsidy is illustrated in Fig. 4. For this illustration, we keyed the base values for the national security component and GHG component to yield a corn-ethanol subsidy roughly equivalent to the current federal ethanol subsidy of 51 cents. The base assumptions are 75 cents for the national-security component per gallon of gasoline equivalent and 25 cents per gallon for 100% reduction in GHG emissions.[1] The resulting total subsidy values are 53 cents for corn ethanol, 85 cents for soy diesel, and $1.00 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 to accomplish.

[1]For this illustration, a relatively high carbon price of $27.50 was 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.

Incentives for Cellulosic Ethanol

Clearly, incorporation of the GHG credit as in the two-part subsidy described above would help stimulate production of cellulosic ethanol. However, if that is not possible or deemed desirable, other cellulose-targeted incentives may need to be considered. Use of cellulose instead of corn would also reduce the implications of ethanol production for corn exports and animal feed. If the state or federal government wants to provide incentives for the industry to move towards 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 10–15 years. Companies then bid for the contract 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. So long as corn-based ethanol is highly 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 production. Thus, targeted incentives might be needed.

Alternative Fuel Standard

In his 2007 state-of-the-union message, President Bush proposed a relatively large alternative fuel standard of 35 billion gallons by 2017. That is roughly seven times current ethanol production. A fuel standard works very differently from a subsidy. It says to the industry that you must acquire a certain percentage of your fuel from alternative domestic sources. In the president's proposal, the sources could be renewable fuels, clean coal liquids or other domestic sources. With a fuel standard that is perceived to be ironclad, the industry is required to procure these alternative fuels no matter what their cost in the market. Most of the change in cost of the fuels is passed on to consumers, either through cheaper or more expensive fuel at the pump.[2] In other words, if crude oil is much cheaper than alternative fuels, consumers would pay more at the pump than they would in the absence of the standard. If it turns out that alternative fuels are eventually less expensive than crude oil, consumers would actually pay less at the pump. So, in a sense, an alternative fuel standard is a different form of variable subsidy—one in which consumers see a price at the pump different from that without the standard. For either a fixed or variable subsidy, the cost of the incentive is paid through the government budget. For a standard, consumers do not pay through taxes but pay directly at the pump.

Figure 5 illustrates the functioning of an alternative fuel standard. The two lines represent $40 and $60 crude oil. The horizontal axis is the cost of the alternative fuel (unknown at this point), and the vertical axis is the percentage change in consumer fuel cost compared to the no-standard case. Clearly, in the left side of the graph with low alternative fuel costs, consumers see little or no change in fuel cost. But with high costs

[2]Recent studies of the demand elasticity for gasoline (Hughes *et al.*, 2006) conclude that it is very low (–0.03 to –0.08) and is lower than in previous time periods. With very low demand elasticity, most of the price change due to supply shifts would be passed on to consumers.

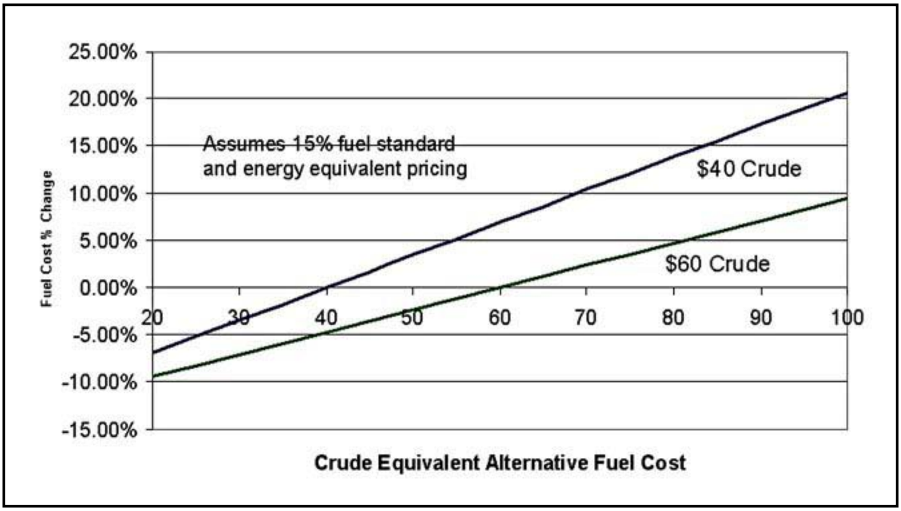

Figure 5. Fuel-cost change from fuel standard.

of alternative fuels (current state of technology), consumers could see significantly higher pump prices. 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 cellulose-based fuels.

Alternative Fuel Standard Plus Variable Subsidy

In the event that crude-oil prices turn out to be quite low, consumers could see significantly higher pump prices than without a standard. One option to limit the consumer exposure would be to combine a variable subsidy with a fuel standard. Essentially, there would be no subsidy unless crude-oil prices fell below some predetermined level, say $45. Then a variable subsidy would kick in, which would limit the price increase consumers would see at the pump. In a sense, it is a form of risk sharing so that in the event of very low oil prices, the government budget would take part of the hit instead of pump prices. This option is illustrated in Figure 6. In this case, the horizontal axis is crude-oil price, and the curve is done for a $60 alternative fuel cost. The line on the left side that begins at $45 crude illustrates the impact of the variable subsidy combined with the fuel standard.

Conclusions

Ethanol has been subsidized in the United States since 1978 from 40 to 60 cents per gallon. Currently the subsidy is 51 cents per gallon, and combined with $60 oil, ethanol production has become highly profitable. This profitability has stimulated a huge increase in ethanol production capacity with 6 billion gallons of new capacity under construction as of January 2007. This increase in production is increasing corn demand and prices. Under the current policy, ethanol producers could still invest profitably in new produc-

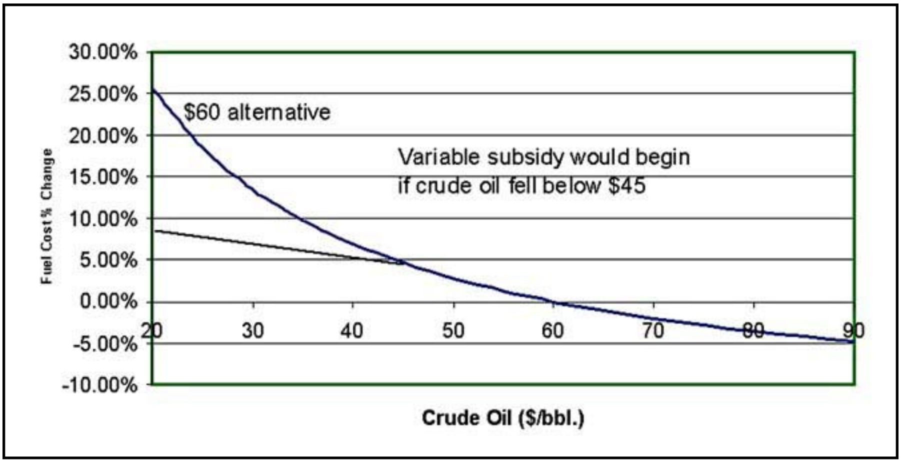

Figure 6. Cost of a fuel standard with a variable subsidy.

tion with a corn price as high as $4.72/bu. Other assumptions could yield substantially higher corn prices.

One option, clearly, is to make no change in current policy. With this alternative, the other corn-using sectors such as livestock production and corn exports would be forced to make the needed adjustments. Less corn would be used in these sectors, and prices for all livestock products likely would increase.

If government is interested in reducing upward pressure on corn prices, alternatives to the current fixed subsidy of 51 cents per gallon could be considered. One option would be to lower the fixed subsidy. This alternative would reduce the pressure on corn prices but would still provide ethanol subsidies under higher oil prices when they are not needed. It is also invariant to underlying market conditions.

A second option would be a subsidy that varies with the price of crude. The option evaluated in this paper provided no subsidy for crude oil price above $60, and a subsidy that increased 2.5 cents per gallon for each $1 that the price of crude is below $60. This option yields a breakeven corn price for $60 oil of $3.12 per bushel compared with $4.72 under the current policy.

If we want to correct both the energy-security and global-warming market failures, we can adopt a two-part subsidy that combines credits for energy security with credits for reductions in GHG emissions. That option would provide a greater incentive for cellulose-based ethanol. If it is not attractive, other cellulose-targeted incentives could be considered.

Instead of continuing subsidies, another policy path would be to switch entirely to alternative fuel mandates. The mandate approach takes the cost of stimulating production and use of alternative fuels off the government budget and, instead, puts it directly on the pump price of liquid fuels. If we want to consider both the energy-security and global-warming dimensions, then it would be appropriate to partition the standard between corn and cellulose-based ethanol. If the risk of high pump prices in the face of possible low oil prices is deemed unacceptable, another policy choice would be an alternative fuel mandate combined with a variable subsidy that kicks in at very low oil prices. In that way, higher pump prices could be avoided if oil prices were quite low.

It is clear that much work is needed in delineating the impacts of alternative policy pathways. This paper attempts to illustrate some of the alternatives that will need to be considered.

References

Copulos MR (2007) The Hidden Cost of Imported Oil—An Update. The National Defense Council Foundation. http://www.ndcf.org.

Hill J *et al.* (2006) Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proceedings of the National Academy of Sciences of the USA 103(30) 11206–11210.

Hughes JE *et al.* (2006) Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand, CSEM Working Paper 159. Berkeley: University of California.

Tilman D *et al.* (2006) Carbon-negative biofuels from low-input high-diversity grassland biomass. Science 314 1598–1600.

Tyner WE Quear J (2006) Comparison of a fixed and variable corn ethanol subsidy. Choices 21(3) 199–202.

Tyner WE Taheripour F (2007) Future biofuels policy alternatives, presented at the Farm Foundation/USDA Conference on Biofuels, Food, and Feed Tradeoffs, April 12–13, 2007, St. Louis, MO. http://www.farmfoundation.org/projects/documents/Tynerpolicyalternativesrevised4-20-07.pdf.

US Climate Action Partnership (2007) A Call for Action–Consensus Principles and Recommendations from the U.S. Climate Action Partnership, A Business and NGO Partnership, http://www.us-cap.org.

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Recent publications include "U.S. Ethanol Policy – Possibilities for the Future," Purdue Extension Publication ID-342, 2007; "Comparison of A Fixed and Variable Corn Ethanol Subsidy," *Choices* 21(3) 2006; and "Economics of Ethanol," Purdue Extension Publication ID-339, 2006.