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Biofuel Incentives and the Energy Title of the 2007 Farm Bill

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Introduction

Given the increased interest in biofuels and other biorenewables, a separate Energy Title is being considered for the 2007 Farm Bill. The added benefits and costs of such government intervention need to be weighed carefully. The United States has conducted an interesting social experiment with ethanol over the last three decades. The federal government and some state governments have provided incentives to increase both corn grain ethanol production and consumption to improve local air quality, reduce greenhouse gas emissions, and provide a substitute fuel from renewable resource that could serve to improve energy security. The experiment was successful, but in large part because the price of crude oil increased. Pushing this experiment further will eventually lead the added costs to outweigh the added benefits. Further expansion is typically justified on grounds of moving to biomass-based ethanol, which is purported to have even greater environmental and development benefits. The simple breakeven analyses presented in this paper seriously question the potential of biomass ethanol as a sustainable biofuel source.

Ethanol and Other Biofuels

Biofuel is a liquid form of biomass that can be used as a fuel. It is a renewable energy source that can be used to substitute for petroleum imports, improve oxygenate levels and air quality, and reduce the amount of carbon dioxide released into the atmosphere.

The most commonly used biofuel is *ethanol*. In the United States, the primary feedstock for ethanol is corn grain. Eventually, biomass may be used to supplement corn grain as an ethanol feedstock, once cost-competitive enzymatic processes are developed for breaking the cellulose fibers in corn stover, grasses, and woody plants into component sugars. Other conversion processes are also under development, such as producing *bio-gas* or *bio-oil* and refining the product into a biofuel (such as *bio-butanol*). Optimistically, such technologies will not be available on a commercial scale before 2015.

The use of ethanol as a transportation fuel in the United States can be traced to Henry Ford's 1908 Model T, which was designed to run either on ethanol or gasoline. The use of ethanol as a fuel substitute increased during World War II, but decreased after the war when the available supply of crude oil increased and petroleum prices declined. The interest in ethanol as a transportation fuel was revived in the 1970s with oil supply disruptions from the Middle East. Incentive programs to encourage ethanol use began with the 1978 Energy Act and the road use tax credit on ethanol blended with gasoline. Ethanol demand increased with the Clean Air Act Amendments (1990s), which mandated the use of reformulated gasoline (RFG) and oxygenated fuels in regions with serious mobile source air quality problems. Other incentives were created in the late 1990s to assist ethanol producers facing high feedstock costs. These incentives were formalized and expanded in the Rural Development Title of the 2002 Farm Bill.

Adding ethanol raises the octane and oxygen levels of gasoline, making the engine run smoother and cleaner and reducing the demand for other additives or further gasoline refining. Ethanol is certified for use as a 10 percent mixture with gasoline in conventional gasoline engines and up to an 85 percent mixture of ethanol with gasoline (E-85) in "*flex fuel*" engines in the United States.

Large-scale U.S. commercial production of flex fuel vehicles began in 1997. Initially, the use of E-85 grew slowly because gasoline prices were sufficiently low that subsidized ethanol was not a cost competitive fuel substitute for gasoline. Lack of E-85 fueling stations (except in Minnesota, which provides incentives for E-85 fueling stations) has further hindered adoption, even when subsidized ethanol is more cost competitive.

Demand for ethanol has also increased because it serves as a substitute for another compound, methyl tert-butyl ether (MTBE), which raises the oxygen content of gasoline. In 2001, California discovered residues of MTBE in surface water. By 2005, twenty states had banned MTBE use. When the 2005 Energy Policy Act (EPAct 2005) did not include a producer waiver of liability for MTBE damage to water quality, the demand for ethanol as a substitute increased and MTBE use is being phased out.

Biodiesel is a liquid fuel with combustion properties similar to petroleum diesel fuel. It can be made from vegetable oil, animal fat, or recycled grease, through a transesterification process where methanol is used to convert base oil into methyl ester. In the United States, biodiesel is primarily produced from soy oil, animal fat, and waste cooking oil.

As an alternative fuel, biodiesel is used alone (B100) or in a blend with diesel fuel in formulations of 2, 5, or 20 percent biodiesel (B2, B5, and B20) without modifying conventional diesel engines. Adding biodiesel raises lubricity of ultra-low sulfur diesel (ULSD), preventing damage in older diesel engines. Since sulfur acts as a lubricant, lowering its content leads to a drop in lubricity of diesel fuel. ULSD is an EPA requirement under the Clean Air Act Amendments of 1990 to reduce harmful emissions from diesel fuel beginning in 2006. Currently, biodiesel is the only diesel fuel additive that meets the Health Effects Testing requirements of the Clean Air Act Amendments.[1]

The Costs and Benefits of Policy Intervention: A Qualitative Look

There are three main arguments for expanded biofuel production.

- Energy security. U.S. reliance on oil imports has been increasing as the economy has expanded. In 2006, approximately 60 percent of U.S. oil that was consumed was imported. Although about 30 percent of U.S. oil imports come from Canada and Mexico, a significant share of U.S. oil imports come from more unstable parts of the world. The federal policy perspective is that these "less reliable suppliers" create a threat to the U.S. economy and national security. Advocates of biofuel argue that substituting more "reliable" biofuel sources for imported oil will reduce the risk of foreign energy supply disruptions.
- Environmental quality. Since biofuels are derived from living plant matter, substituting them for petroleum could reduce the net amount of carbon dioxide and other greenhouse gases (GHG) released into the atmosphere. There are other environmental considerations regarding ethanol, as well. In addition to reducing GHG and carbon dioxide emissions, blending ethanol with gasoline reduces carbon monoxide and volatile organic compounds that are harmful local and regional air emissions. The Clean Air Act

[1] The Energy Policy Act of 2005 includes a tax subsidy similar to the ethanol tax subsidy for plant and animal oils used in biodiesel production. Virgin oils—that is, plant-derived oils not previously used—receive a $1.00/gal excise tax credit, and recycled plant oils and animal fats receive a $0.50/gal credit.

Amendments (1990) were designed specifically to address carbon monoxide and other harmful emissions, and mandated the use of reformulated gasoline (RFG) and oxygenated fuels in regions with serious mobile source air quality problems. Such air quality problems include smog and higher concentrations of carbon monoxide in urban areas, which have deleterious impacts on human health.

- Reduced federal budget exposure. Currently in the United States, the most competitive and predominant feedstock for biofuel production is corn grain. The derived demand for corn as a biofuel feedstock is closely linked to the price of crude oil (see discussion below). As the price of crude oil increases, the price that ethanol producers can afford to pay for corn increases. Higher corn prices result in reduced government commodity program payments to corn and soybean producers. Additionally, new job creation for rural biofuel production may ultimately reduce budget exposure in rural development programs. At the same time, every additional gallon of ethanol that is blended receives a $0.51 per gallon tax subsidy (the volumetric ethanol excise tax credit, or VEETC), which may offset any reduction in commodity program payments.

There are three questions to consider when making a case for government intervention. First, do the added benefits of government intervention into biofuel markets outweigh the added costs of intervention? Second, if the government intervenes in energy and biofuels markets, what are the economic arguments for intervention and what are more efficient and less distorting policy options for intervention? Third, what are the economic impacts of different forms of government intervention and what are the implications for biofuel and energy markets?

Calculation of the benefits and costs of government intervention in biofuel markets is complicated by the diverse nature of benefits. The three arguments considered above for government intervention are: improved energy security, environmental quality, and federal budget exposure. Although it is difficult to place a value on improved energy security, corn ethanol supplies less than 4 percent of the 142 billion gallons of gasoline currently consumed. All biofuels supply about 3 percent of the 200 billion gallons of motor fuel consumed.[2] Even if 14 to 15 billion gallons of biofuel were consumed in the United States by 2015, that would account for 10 percent of gasoline consumption and 6–7 percent of U.S. motor fuel consumption.

Using biofuel does reduce carbon dioxide and GHG emissions relative to petroleum and other fossil fuels. Estimates of reduction in GHG emissions from using corn-based ethanol rather than petroleum as a transportation fuel are about 12−13 percent (Farrell and others 2006; Hill and others 2007) and about 20 percent for carbon (Kopp 2006).[3] The actual reduction in GHG emissions from substituting corn-based ethanol as a transportation fuel may, in part, be offset by increased application of energy-based inputs in corn production in response to higher market prices for corn.

Biomass-based ethanol—although currently not a competitive fuel source—could reduce GHG emissions by even greater amounts frequently estimated from 80 to over 90 percent (Hill and others 2007). Biomass production is purported to use significantly less fertilizer nutrients and biomass refineries to use significantly less natural gas than corn-

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[2] DOE, Energy Information Administration, Annual Energy Review 2005, tables 1.3 and 2.1A, July 2006, http://www.eia.doe.gov/emeu/aer/contents.html

[3] Greater reductions are referred to by Shelby (2007)—a 26 percent reduction in GHG emissions with corn-based ethanol and McCarl (2007) —43 percent reduction in carbon with corn-based ethanol used in their modeling efforts.

based ethanol plants. Yet we found no published studies that provide a comprehensive accounting of all the energy used and energy costs of producing ethanol and other biofuel from biomass resources. Notably, to get competitive biomass yields may require more fertilization than many biomass research studies have indicated. More importantly, harvesting, transporting, handling, and storing biomass are energy-inefficient operations, given current technology.[4]

The federal government has been spending $20 to 30 billion on annual farm program payments. If historically high corn and soybean prices prevail, only the direct and countercyclical payment components are anticipated for these two commodities, and some groups have proposed eliminating these payments as well. The decreased payments reduce federal government budget exposure (while also improving compliance with U.S. commitments under international trade agreements through the World Trade Organization). At the same time, every gallon of fuel ethanol receives the $0.51 tax subsidy (VEETC). In 2006, the VEETC effectively cost the government $2.5 billion. If the ethanol industry expands production to 14−15 billion gallons annually, the tax subsidy will increase to $7.0–$7.5 billion per year. This discussion implicitly assumes that there is an economic rationale for transfer payments to farmers (agricultural landowners) and ethanol producers. In reality, these issues are more political objectives than social welfare maximization objectives.

What are the costs of biofuel expansion? In addition to budget costs, biofuel expansion may involve a number of other costs. As corn acreage increases in response to higher corn prices and increased ethanol production, nutrient use and soil loss will likely increase. Corn acreage will be pushed to more erosion-prone soils, more erosive practices may be used in corn production, and the derived demand for fertilizer nutrients will increase. Nutrients and sediment from soil leaching and runoff are the two major sources of water quality deterioration originating in Midwest agricultural areas. Further, use of more nutrients and more erosive production practices will reduce or eliminate the GHG emission reduction associated with corn grain ethanol. The Conservation Reserve Program (CRP) was designed to remove highly erodible land from production to reduce soil erosion, lessen water quality damages, and provide enhanced wildlife and recreation benefits. Landowners receive annual payments for 10 years to retire qualifying lands. As the opportunity cost of maintaining land in the CRP increases (that is, the return from growing corn increases), many CRP contracts will not be renewed when they expire and water quality and wildlife benefits will be lost (Heimlich 2007; Kuminoff 2007).

Livestock groups have argued for releasing CRP acres under contract for corn production. Their rationale is that the increased corn supply will decrease corn prices and therefore drive down livestock feed costs. Although such an approach may have a small short-run impact on corn prices, in the longer run the price of gasoline and the VEETC are the major determinants of what ethanol producers can pay for a bushel of corn, and thus the price that livestock producers will have to pay for corn (Brester and Smith 2007).

A frequently cited benefit of the ethanol boom in the Midwest is rural development. The corn ethanol industry creates well-paying jobs in rural communities, which have local income and job multiplier impacts that ultimately lead to community development. It is argued that these community benefits may be further enhanced by local investment as opposed to outside investment (Miranowski and Andrian 2007). As

[4] Iowa State University, "Switchgrass Fact Sheet," Department of Agronomy, Ames (February 2007). www.agron.iastate.edu.

the industry grows, these potential benefits are becoming less significant for a number of reasons. First, earlier dry mill plants (2000) were smaller, employed more workers per unit of capacity, had a larger share of local investment, and had a minor impact on local corn markets and livestock feed costs. Today, new dry mill ethanol plants have increased annual production capacity from under 40 million gallons to over 100 million gallons. New plants employ fewer than 0.5 workers per million gallons capacity, whereas earlier plants employed up to 2.5 workers per million gallons capacity. Roughly 40 percent of ownership in older Iowa ethanol plants was local, but today relatively little investment in new plants is local (Miranowski and Imerman 2007). Recent reports place current majority Iowa ownership in Iowa ethanol plants at 34 percent.[5]

For the Midwest and the United States, the added benefits of ethanol industry expansion have exceeded the added costs of industry expansion to date. A 5 billion gallon corn ethanol industry has significant benefits relative to costs. The corn ethanol industry has demonstrated that biofuel can make a modest contribution in meeting air quality requirements, GHG emission reductions, improved energy security, and shifting farm program payments to ethanol tax subsidies. Such industry expansion can also bring about local economic development without destructive impacts on livestock industry growth and the quality of the rural landscape.

Continued expansion of the corn ethanol industry will add benefits, but eventually, the added costs will exceed added benefits. It is uncertain at what ethanol output level will the added benefits exceed the added costs. Additional expansion will create less new employment per unit of capacity and may eventually create a net job loss. Ethanol industry expansion and higher corn prices will disrupt livestock production activities and may displace more livestock employment than jobs created in the ethanol industry. Significant expansion of the biofuel industry will also lead to higher food prices and change trade flows, with the United States ultimately becoming a net importer of corn (El Obeid and others 2006).

Continued industry expansion may have environmental costs in addition to those mentioned above. Some local groundwater supplies may be drawn down and groundwater consumption may be disrupted in some areas. Although corn ethanol has helped meet certain Clean Air Act Amendment requirements, further expansion of the industry may contribute to decreased GHG emission reductions as more intensive production practices and more erosion-prone lands are used to produce corn.

Also, it is important to remember that all the current forms of government intervention in the ethanol (biofuel) market were in place before 2000. It was not a change in government biofuel or energy policy that caused the expansion after 2000. Rather, the important factor that is driving the future market for ethanol is the price of crude oil or gasoline. Ethanol is becoming the substitute fuel of choice. At current crude oil prices, ethanol processors can pay over $4 per bushel for corn and still break even. Under current and crude oil future market prices, the ethanol industry is in a position to support large-scale biofuel expansion.

On balance, do the benefits of biofuel incentives outweigh the costs? From an energy security perspective, ethanol can contribute only 10 percent to the gasoline fuel supply because the current fleet of automobiles is composed primarily of conventional gasoline engines. In 2006 the United States consumed about 142 billion gallons of

[5]Paula Lavigne, "As Industry Branches Out, Outside Investment Flows In," *Des Moines Register*, Sunday, April 29, 2007, p.3 ET. www.desmoinesregister.com.

gasoline.[6] If all the gasoline were blended with 10 percent ethanol, about 14 billion gallons of ethanol would have been used. To go beyond a 10 percent ethanol blend will require the necessary stock of flex fuel vehicles and readily available E85 fueling facilities in the United States. Currently, only 5 million flex fuel vehicles are on U.S. roads and less than a thousand fueling stations are offering E85.[7]

A more basic economic question needs to be addressed with respect to economic policy and the welfare impacts of biofuel incentives. If our policy objectives are to improve energy security and reduce dependence on foreign oil, reduce GHG emissions, and reduce federal budget exposure on farm commodity and rural development programs, what is the least distorting or least-cost approach to achieve these objectives? If our objective in energy and bioenergy policy intervention is to maximize social welfare, we must accomplish that in the most efficient way possible, considering all the social costs and benefits of intervention.

The economic response to the GHG emissions reduction objective would be a tax on petroleum and other fossil fuels equal to the marginal value of the negative externalities created by GHG emissions costs. Alternatively, we could establish a cap and trade system for carbon emissions and let the private sector pursue the least-cost way of achieving a given reduction in carbon emissions. By letting the private sector find the least-cost solution, resources would be allocated more efficiently in achieving the GHG emissions reduction. Our nation has not demonstrated the political will to tax petroleum and other fossil fuel sources or create a cap and trade system, except in the case of sulfur emissions from power plants. Similar provisions could be used in the case of energy security costs. A tax on petroleum and other fossil fuels would increase conservation, reduce imports, and improve energy security.

Historically, the United States has pursued a "cheap energy" policy through the use of extensive tax subsidies to the fossil fuel energy sector, including many provisions contained in Energy Policy Act of 2005. In the ongoing policy effort to maintain low petroleum fuel prices, petroleum prices do not serve as an effective signaling mechanism for alternative energy and biofuel markets to develop substitute fuels. Instead, policymakers have chosen selected fuel forms—such as ethanol and biodiesel, or electric cars in California—to receive tax subsidies and mandates in an effort to create a "more level playing field" relative to petroleum fuels.

Even if the nation chooses to pursue second best policy options, some second best options may be less inefficient than other options. For example, since there is not a "silver bullet" to solve the "energy problem," a more efficient solution would be to provide comparable tax subsidies to all forms of low carbon or renewable fuels, including hydrogen and nuclear energy. Alternatively, renewable fuel mandates could include all forms of renewable fuels and the market could determine which forms of renewable fuels would achieve the mandate at least cost. Such approaches would stimulate more efficient and competitive fuel forms to be developed and marketed, would encourage adoption of carbon reduction technologies in refining and processing petroleum and other fossil fuels,

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[6] DOE, Energy Information Administration, Annual Energy Review 2005, tables 1.3 and 2.1A, July 2006, http://www.eia.doe.gov/emeu/aer/contents.html.

[7] James M. Flamang, 2006, "E85: Flex-Fuel Vehicles: Are They Corny?" http:/www.valvoline.com/carcare/articlereviewer.asp?pg=dsm2006050185&cccid=3&scccid=6 (accessed 5/2/2007); U.S. Department of Energy, 2007, "E85 Stations in the United States," Alternative Fuels Data Center, Energy Efficiency and Renewable Energy. http://www.eere.energy.gov/afdc/infrastructure/e85_stations.cgi. (accessed 5/2/07).

and would encourage different fuel utilization technologies from improved internal combustion engines to electric and hydrogen powered vehicles. The alternative—having policymakers and the government "pick the winners"—is not an efficient alternative.

As a second best solution, Kopp (2006) argues, "Subsidies and mandates are better suited to commercialization, while policies focusing on R&D are better suited [to] pre-commercialization." More typically, both forms of incentives are provided to new technologies. For example, for the recent U.S. Department of Energy (DOE) grants to six cellulosic-ethanol biorefineries, grant recipients will receive up to $80 million each to research, develop, and commercialize cellulosic ethanol.[8] In addition, the VEETC provides a $0.51 per gallon tax subsidy to all fuel ethanol producers including cellulosic ethanol. In some cases, biomass production subsidies are being sought as well.[9]

In weighing various policy alternatives, it is useful to have a good understanding of recent biofuel market developments, and the basic demand and supply relationship in the biofuel market. The next section explores the recent explosion in ethanol and other biofuel production. The following section considers the underlying demand and supply relationships in the ethanol market and derives empirical estimates of short-run ethanol demand and supply and long-run equilibrium prices for corn and biomass feedstocks.

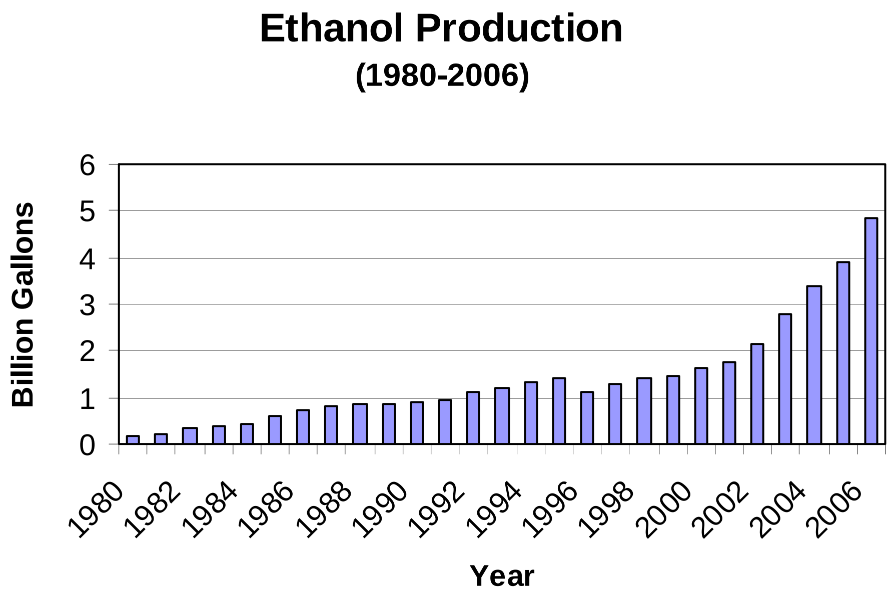
Recent and Projected Ethanol and Biofuel Production

Ethanol output has continued to expand every year since 1980—with the exception of 1995, when corn grain prices were at record levels (figure 1). Ethanol output has been expanding rapidly and by the end of 2007 is expected to exceed the 2012 Renewable Fuels Standard (RFS) of 7.5 billion gallons established in the 2005 Energy Policy Act.

[8] U.S. Department of Energy (DOE), "DOE Selects Six Cellulosic Ethanol Plants for Up to $385 Million in Federal Funding," February 28, 2007. http://www.energy.gov/news/4827.htm (retrieved March 22, 2007); Service (2007).

[9] Philip Brasher, "Likely Hurdles Include Storage, Harvesting," *Des Moines Register*, Sunday, March 18, p.4 ET. www.desmoinesregister.com.

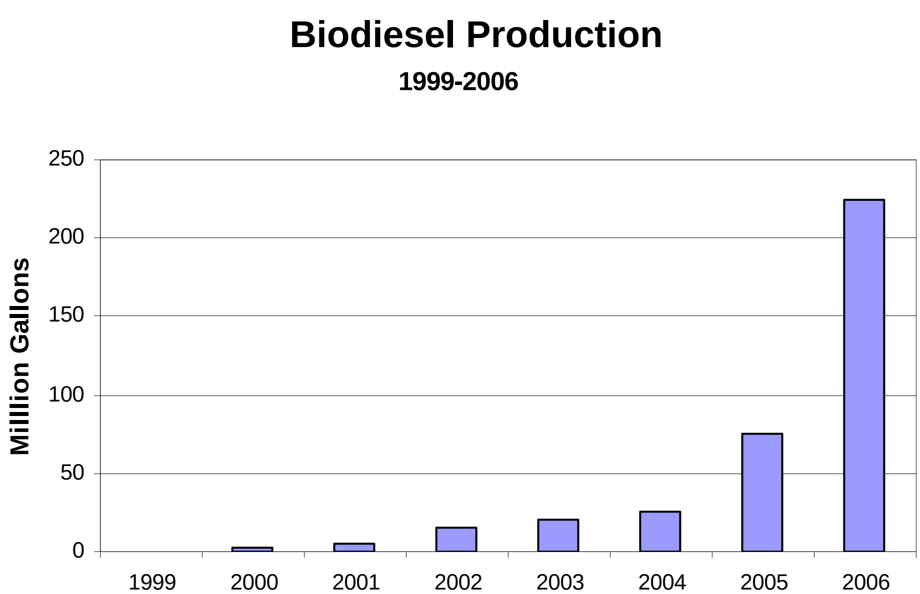
Figure 1.



Source: Renewable Fuels Association, "Industry Statistics: Historic U.S. Fuel Ethanol Production." http://www.ethanolrfa.org/industry/statistics/#A

Similar developments on a much smaller scale are occurring in biodiesel production, where capacity increased from 15 million gallons in 2004 to over 200 million gallons by the end of 2006. As illustrated in figure 2, biodiesel production has grown rapidly since 2000, but the potential for biodiesel expansion may be constrained to less than 1 billion gallons by availability of feedstock and the opportunity cost of shifting corn acreage to oilseed production.

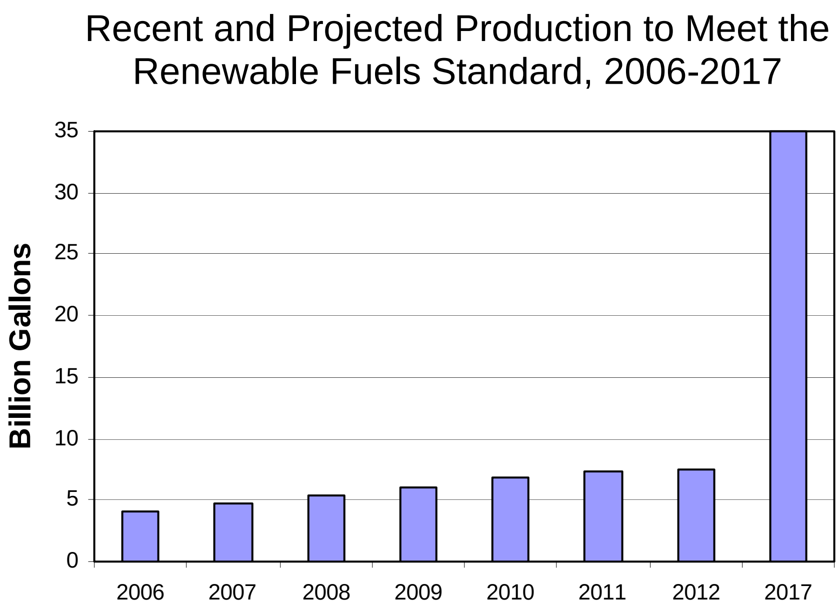
Figure 2



Source: Soy Stats, "Domestic Utilization: U.S. Biodiesel Consumption." http://www.soystats.com/2007/Default-frames.htm

Several incentives, including air quality regulations in the Clean Air Act Amendments, 1990, the phase out of MTBE without a liability waiver in the EPA Act of 2005, higher crude oil prices, state ethanol mandates, federal and state tax credits and other tax incentives, and federal and state grant and loan programs have played a part in the past expansion of the biofuel market. As noted in figure 3, the Renewable Fuels Standard is being outpaced by biofuel industry expansion, and thus the RFS is essentially becoming redundant. In his State of the Union Address, President Bush called for a 35 billion gallon renewable fuels mandate for 2017, with substantial quantities of biofuel derived from biomass feedstocks.[10] As the discussion that follows shows, achieving such a mandate may have significant economic costs and benefits associated with it.

Figure 3



Source: Renewable Fuels Association, "Renewable Fuels Standard. http://www.ethanol.rfa.org/resources/standard/

Currently, the primary feedstock for ethanol is corn grain. Over 13 percent of the 2005 U.S. corn crop was used as ethanol feedstock, and over 25 percent of the 2009 corn crop could be utilized in ethanol production. Corn prices have nearly doubled in the last year alone and corn futures contract prices for deliveries into 2010 are over $4.00 per bushel. Public concerns are being expressed over the growing competition between food, feed, and fuel. Livestock producers are concerned over disruptions in livestock markets, humanitarian groups over potential increases in global food prices, malnourishment, and

[10]White House, *President Bush Delivers State of the Union Address,* January 23, 2007. http://www.whitehouse.gov/news/releases/2007/01/20070123-2.html (retrieved March 22, 2007).

hunger, and environmental interests over increased water quality and greenhouse gas emission problems.

The 2007 Farm Bill will be developed in an environment similar to the 1996 farm legislation, providing interesting challenges and opportunities to redirect commodity titles, as well as to redefine energy, conservation, and trade titles. We are entering this Farm Bill era with higher commodity prices, reflecting increased demand for corn grain for biofuel production. Farmers are receiving the same prices for corn grain that feeders and processors are willing to pay: that is, prices above target loan rates. Thus loan deficiency payments will not be required to make up the difference between market price and the target loan rate, and countercyclical payments will also decrease. The resulting reduced commodity program payments will reduce the federal budget exposure. However, various interest groups are hoping to redirect some of the anticipated budget savings to a redefined energy title.

Demand and Supply Analyses of the Biofuel (Ethanol) Market

Basic Ethanol Demand and Supply Relationships. Before evaluating the impacts of existing and proposed biofuel provisions of the Farm Bill Energy Title, it is useful to review the basic demand and supply relationships in the biofuel (ethanol) market. The discussion will focus on ethanol biofuel because the market is established, has been the beneficiary of government intervention at least since 1978, and has an established database for empirical observation. The market concepts and government interventions are easily extendable to biodiesel and other biofuel.

The determinants of ethanol demand include ethanol price, gasoline price, gross domestic product, and government regulations and incentive. Consider how different regulations and incentives impact the market demand for ethanol:

- Demand for ethanol as oxygenate. Government regulations such as the Clean Air Act Amendments beginning in 1995 required winter-time use of oxygenated fuels in 39 major regions that had not attained the carbon monoxide standard and year-round oxygenated fuels use in 9 regions that had severe difficulties attaining the ozone standard. These government requirements or mandates in large part determined the demand for oxygenated fuels. Because ethanol had a competitive substitute, MTBE, that could be used to meet the oxygenate requirement, the demand for ethanol was rather elastic. When MTBE was banned in several states and producer liability protection was not included in the Energy Policy Act of 2005, the demand for ethanol as an oxygenate had no close substitutes and the demand for ethanol as an oxygenate was essentially fixed (vertical) at any point in time, as depicted in figure 4.

- Demand for ethanol as octane enhancer. Legislation was passed in 1973 to completely phase out an octane enhancer, tetraethyl lead, in gasoline by 1995. Adding ethanol raises the octane level of unleaded gasoline without the use of other additives or the need for further gasoline refining. The widely used blend E10 (10 percent ethanol and 90 percent gasoline) raises the octane rating of unleaded regular gasoline by 2 points, to super unleaded gasoline, with an octane level of 89. Since conventional gasoline engines are certified to operate on E10 without modification, the demand for ethanol as octane enhancer is relatively elastic (figure 4).

- Demand for ethanol as a fuel substitute. When used in a conventional gasoline engine, a gallon of ethanol has approximately 67 percent of the Btu's of a gallon of gasoline.[11] By far the largest potential market for ethanol is as a fuel substitute for gasoline. Total ethanol production was 5 billion gallons in 2006, or less than 4 percent of the gasoline market. Even if all gasoline were blended with 10 percent ethanol (E10), the United States could currently use only about 14 billion gallons of ethanol per year. Thus the demand for ethanol as a fuel substitute is depicted as a horizontal line in figure 4. As the stock of flex fuel engines expands and the availability of E-85 fueling sites increases, ethanol could have a more significant market impact and the ethanol demand as a fuel substitute would then be more downward sloping.

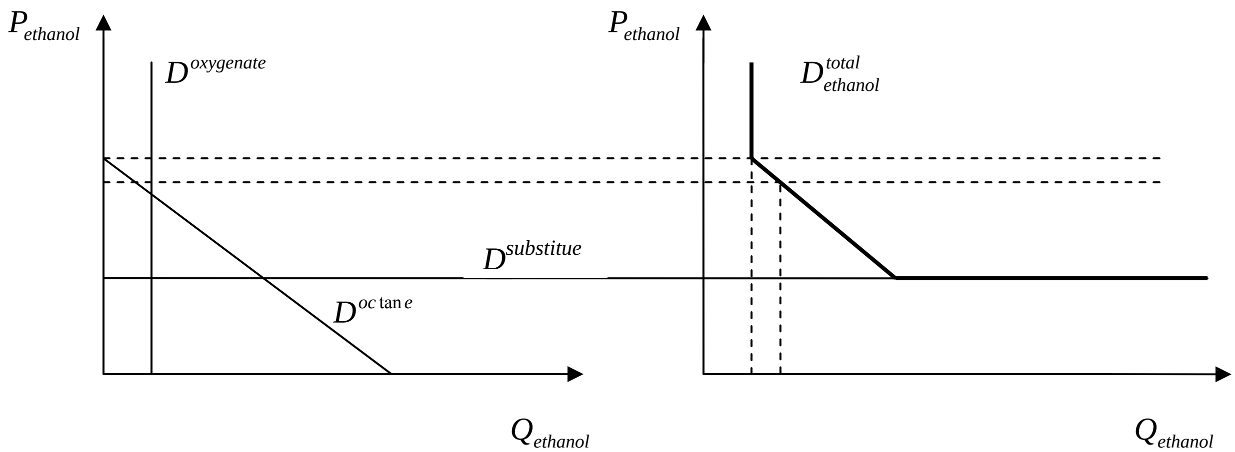


Figure 4: Total and Component Demands for Ethanol Biofuel

Source: Author's calculations.

The total demand for ethanol is shown as the bold line in figure 4. We are assuming that the demand for ethanol beyond environmental requirements, fuel standards, and use mandates is the derived demand for ethanol as a fuel substitute for gasoline. Although demand for ethanol as a fuel substitute is not quite perfectly elastic, we are assuming that the gasoline market will absorb up to 14 billion gallons of ethanol (that is, conventional gasoline engine constraint) at roughly 67 percent of the price of gasoline.

Ethanol supply is a function of feedstock cost, other input costs, output price, tax subsidies, investment incentives, and technology. How do biofuel incentives shift the supply curve?

[11] Flexible fuel engines can achieve 70 to 80 percent of gasoline's Btu value from ethanol because they are programmed to optimize the use of different fuel mixtures (Brown 2003).

- Ethanol tax credit. The volumetric ethanol excise tax credit (VEETC) is available to firms that blend ethanol with gasoline. The current tax credit is $0.51 per gallon ethanol blended. The $0.51 per gallon shifts the supply curve to the right. The perception of the ethanol industry is that most, if not all, of this tax credit is shifted backward to ethanol producers, and ultimately, to corn growers and landowners.[12]
- Investment incentives. A variety of incentive programs exist to stimulate investment in the biofuel industry. Such programs are available through the U.S. Department of Agriculture (USDA), Office of Rural Development, state economic development agencies, and local development efforts. The federal government makes grants and subsidized, guaranteed, and forgivable loans. State and local entities may use grants and loans, but also use tax abatement and infrastructure (such as roads, water) and employment incentives that are designed to promote local economic growth.

In an effort to evaluate the potential market impacts and the benefits and costs of government intervention in the biofuel (ethanol) market, we estimated an econometric model of the U.S. ethanol market. The model and results of the estimation are contained in the appendix to this paper.

Even though our model performs reasonably well, the supply model is not useful in assessing Farm Bill initiatives designed to change the supply of biofuel. Given the dramatic expansion in the ethanol industry, changes in ethanol industry structure, and significant technology change over the last five years, a supply curve based on historical data is not reflective of current industry conditions and greatly underestimates the potential for expansion in supply. Instead of deriving the supply curve and estimating market equilibrium conditions from time series econometric analysis, we use an approach that has been adopted by previous studies that used breakeven analyses to evaluate long-run biofuel investment decisions and the potential for ethanol supply expansion under different assumptions of input, output, and incentive prices.[13]

Long-Run Equilibrium (Breakeven) Analysis for Corn-based Ethanol. Using a long-run equilibrium (breakeven) analysis, the basic question that we address is, "How much could a modern ethanol plant pay for a bushel of corn and still break even under current market, incentive, and cost assumptions in the long run?" Although this approach does not provide a direct estimate of long-run equilibrium ethanol quantity and price, it does provide the breakeven price for the last bushel of corn, taking all other ethanol supply costs into account. Additionally, since we have assumed that demand for ethanol as a fuel substitute is highly elastic within our range of consideration, we can implicitly derive the equilibrium price of ethanol from the price of gasoline and crude oil. We can then draw on results from a global agricultural model to determine the amount of corn available to the ethanol industry at the breakeven price, how related markets may adjust and be impacted, the "equilibrium" quantity of ethanol that would be supplied in the long run, and how related markets and trade-flows may be impacted (El Obeid and others 2006).

To determine the breakeven price of corn, we derive the market price for ethanol from gasoline and crude oil. We then add tax credits and octane benefits. Returns per gallon are multiplied by the conversion (yield) ratio to determine the returns per bushel.

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[13] See, for example, USDA, ERS (1988); Tiffany and Eidman (2003); Eidman 2005; El Obeid and others (2006).

Distillers dried grain solubles (DDGS) value is added and the operating and capital costs per bushel of corn are subtracted to determine the breakeven price that the biorefinery can pay for the last bushel of corn.

The following equation formalizes this relationship:

$$P_{corn} = Y_E\,[(P_{gas})\,(0.67) + V_O + T_{VEETC} - C_V - CK] + V_{DDGS} \qquad (6)$$

where

- P_{corn} = Price of corn grain per bushel
- Y_E = Ethanol yield per bushel corn
- P_{gas} = Price of gasoline per gallon
- V_O = Octane enhancement value per gasoline gallon
- T_{VEETC} = Volumetric ethanol excise tax credit
- C_V = Non-corn variable cost per gallon
- C_K = Capital cost per gallon
- V_{DDGS} = Value of DDGS per bushel of corn

We assume an ethanol yield of 2.8 gallons per bushel of corn; a $60 per barrel crude oil, which converts to a gasoline price of $2.10 per gallon;[14] octane value of $0.05 per gallon; VEETC of $0.51 per gallon ethanol blended; capital cost of $0.32 per gallon; non-corn operating cost of $0.50 per gallon;[15] and DDGS value of $1.02 per bushel of corn. Under these assumptions, the long-run equilibrium breakeven price for corn is $4.21 per bushel for a modern, 100 million gallon per year ethanol plant. This equation can be further manipulated to evaluate the sensitivity of the corn breakeven price to changes in the values of right-hand side parameters.

The Center for Agricultural and Rural Development (CARD) used a similar breakeven analysis in 2006 and calculated a $4.07/bu corn breakeven price (El Obeid and others 2006). The authors then perturbed the Food and Agricultural Policy Research Institute's global FAPRI model to determine how much corn would be utilized for ethanol feedstock at the long-run market equilibrium price and what adjustments would occur in domestic and national food, feed, and livestock markets. Although no timeframe was established to attain equilibrium, they projected that the United States would use more than 10 billion bushels of corn to produce more than 30 billion gallons of ethanol per year at long-run equilibrium.

Long-run Equilibrium (Breakeven) Analysis for Biomass Ethanol. A similar breakeven analysis per ton of biomass can be developed to evaluate incentive provisions for biomass feedstock and ethanol production. The breakeven approach in this case is viewed from the perspective of both the biomass processor and the biomass producer or supplier. First, what is the breakeven price that the biomass processor will pay for a ton of biomass to convert into biofuel? Second, what is the breakeven price that a biomass producer will accept for the last dry ton of biomass delivered to the ethanol plant? This approach can be used to compare the relative competitiveness of different biomass feedstock, including the opportunity cost of shifting cropping practices on agricultural

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[14] The Btu-equivalent factor of ethanol for gasoline is 0.667 (Brown 2003), or when gasoline is $2.10 per gallon (or crude oil is $60 per barrel), ethanol is valued at roughly $1.40 per gallon.

[15] To evaluate capital and operating costs, we analyzed a $200 million dollar plant with yield capacity of 100 million gallons of ethanol per year. Amortizing over 10 years at an interest rate of 10 percent yields capital costs of $0.32 per gallon. Operating cost was estimated to be $0.50 per gallon.

land and biomass research areas offering higher potential returns to investment in biomass-based fuels.

The following equation formalizes the biomass breakeven relationship for the biomass processor:

$$P_{pbiomass} = [(P_{gas})(0.67) + T_{VEETC} + V_O - C_K + C_V](Y_E) \quad (7)$$

where

$P_{pbiomass}$ = Price of biomass per dry ton
P_{gas} = Gasoline price per gallon
T_{VEETC} = Volumetric ethanol excise tax credit per gallon
V_O = Octane enhancement value per gasoline gallon
Y_E = Ethanol yield per dry ton of biomass
C_K = Capital cost per gallon
C_V = Operating cost per gallon

As an illustration, we calculate the breakeven price/ton for corn stover that the processor can pay. Using the same energy price assumptions as in equation 6—$60 per barrel expected crude oil price, $2.10 per gallon wholesale gasoline price, the $1.40 per gallon equivalent price of ethanol, continuation of the $0.51 per gallon VEETC—and an ethanol yield of 70 gallons per dry ton biomass (stover),[16] equals total revenue of $132 per dry ton of biomass.[17] Assuming the non-biomass cost (that is, capital and variable costs)[18] of converting corn stover to ethanol of $55 per ton, the plant would have net returns of $78 per ton. It is important to note that these cost estimates are based on engineering studies and are essentially synthetic data. These data should be a good indicator of the price that a commercial biomass conversion plant would be able to pay the producer for the last ton of biomass produced, harvested, stored, and delivered to the plant.

Table 1 provides the long-run equilibrium corn stover price for a series of crude oil prices with and without the tax credit.

Table 1. Long-run Corn Stover Breakeven Prices (dollars)

Crude oil price ($/barrel)	Gasoline price ($/gallon)	Ethanol price (without tax credit)	Ethanol price (with tax credit)	Stover breakeven without tax credit ($/ton)	Stover breakeven with tax credit ($/ton)
40	1.38	0.92	1.43	9.8	45.5
50	1.73	1.15	1.66	25.9	61.6
60	2.07	1.38	1.89	42	77.7

[16] Research and development studies suggest that alternative biomass feedstocks (such as switchgrass) and processing techniques may yield 85–95 gallons per ton in the future. See Aden and others (2002); Comis (2006).

[17] Without the VEETC, the plant could pay a breakeven price of only $42 per ton.

[18] Aden and others (2002). Other studies—including Gallagher and others (2003); Hamelinck, van Hooijdonk, and Faaij (2005); McAllon and others (2000); and Kaylen and others (2000)—have used other approaches to derive cellulosic ethanol production costs and considered alternative feedstocks.

70	2.42	1.61	2.12	58.1	93.8
80	2.76	1.84	2.35	74.2	109.9

Source: Miranowski and Irons (2007).

Table 1 demonstrates the importance of both continuation of the VEETC subsidy to cellulosic ethanol production and higher crude oil prices to the feasibility of biomass ethanol. The tax credit increases the price ethanol producers can pay for stover by \$36/ton over without the VEETC option. Every \$10 per barrel increase in crude oil prices increases the delivered price of stover by \$16 per ton.

From the perspective of the biomass feedstock producer or supplier, the breakeven price for the last dry ton of biomass delivered to the biomass processing plant is:

$$P_{fbiomass} = C_V + C_{ES} + C_{ST} + C_{land} \quad (8)$$

where

$P_{fbiomass}$ = Processor breakeven price per dry ton biomass delivered
C_V = Variable cost of biomass production per ton, including maintenance, nutrient, and harvesting cost
C_{ES}= annualized biomass establishment and seeding costs per ton
C_{ST} = storage, handling, and transport cost per ton biomass delivered
C_{land} = land opportunity cost in best alternative crop per ton of biomass delivered.

Obviously, if a market for biomass is going to exist:

$$P_{pbiomass} = P_{fbiomass}\,, \quad (9)$$

or the price that the processor is willing to pay per dry ton of biomass at the processing plant will have to equal the price that the farmer is willing to accept for a dry ton of biomass delivered to the biomass processing plant. The market will function only if both the supplier of biomass and demander for biomass can at least breakeven in a competitive market situation. If not, biomass will not evolve as a sustainable source of renewable fuel.

For our illustration, we calculate the breakeven price for corn stover per ton delivered to the stover processing plant. Estimated variable costs are \$45 per dry ton. Establishment and seeding costs and land opportunity costs are assumed at zero because corn grain is already harvested from the same land that provides stover. Transport costs are estimated from \$10−25 per ton within a 30-mile radius of the plant (DOE and USDA 2005; English and others 2006). Storage costs are estimated to average \$20−45 per ton. We use an average of \$48 per ton for storage and transport of stover. Thus the feedstock producer would require approximately \$93 per ton of dry stover.[19] Considering the breakeven estimates reported in table 1, it would take both \$70 per barrel crude oil and the VEETC for a market to develop for corn stover as a biomass feedstock in ethanol production using current technology.

[19]As noted above in footnote 8, POET (formerly Broin Cos.) estimate that they will have to pay farmers \$100 per ton to harvest, store, and deliver corn cobs, a component of corn stover, to their stover biomass processing plant in Iowa.

If the landowner grew another biomass crop, such as switchgrass, on Iowa corn acres, she would expect to incur an opportunity cost of $250/acre (estimated net returns to corn production per acre) in addition to other variable and fixed production costs (Hart and Babcock 2007).

Our conclusion is that corn stover—currently the least-cost biomass feedstock—is not competitive with corn grain as an ethanol feedstock at $60 crude oil prices. When corn grain is priced at over $4 per bushel and the VEETC is available to biomass ethanol, the crude oil price must increase to $70 per dry ton for corn stover to breakeven as an ethanol feedstock. Alternative biomass feedstocks are even less competitive alternatives at least in the Midwest where the opportunity cost of using land suitable for corn production is high. A case can be made for government research and development support in the early stages of new industry development, but continued support once the industry becomes established is not warranted unless the marginal social benefits—such as environmental gains—clearly outweigh the marginal costs incurred by society.

Impacts of Government Intervention of the U.S. Ethanol Market

We will use the ethanol market model developed above to address several policy questions with respect to biofuels:

- How important are tax incentives, environmental regulations, Renewable Fuel Standards (RFS), and supply incentives to the ethanol market, and what contribution do they make to energy security?
- How do the impacts of incentives and regulations change under different scenarios of petroleum prices, feedstock costs, natural gas prices, and co-product prices?
- How are producers and consumers impacted by these incentives, regulations, and mandates?

Numerous biofuel policy provisions are being considered for the 2007 Farm Bill. A USDA 2007 Farm Bill Theme Paper, “Energy and Agriculture,” provides a reasonably comprehensive list of suggested options currently being discussed for the Energy Title of the 2007 Farm Bill (USDA 2006):

Expand federal direct market intervention to support renewable energy:

- Raise the level of the Renewable Fuel Standard (RFS).
- Extend renewable energy tax credits to 2015 or later.
- Reduce biofuel tax credits when they are not effective in increasing biofuel supply or are not needed.
- Provide accelerated depreciation on renewable energy equipment and facility investment.
- Use more land enrolled in the Conservation Reserve Program (CRP) for biomass harvesting.
- Refocus the Commodity Credit Corporation (CCC) Bioenergy Program to support biomass used in bioproduct processing.

Expand federal indirect support for renewable energy:

- Expand the national cellulosic ethanol research initiative.

- Expand creative financial engineering to support development of the bio-based economy beyond grants, loans, and loan guarantees.
- Bridge the gap between federally-funded basic research and industry-funded applied research and development.

Other groups, including the Chicago Council on Global Affairs (2006, p. 9), in their report *Modernizing America's Food and Farm Policy: Vision for a New Direction, 2006,* have suggested more limited options:

The federal government should continue to support research on biofuels as a meaningful alternative to unreliable sources of fossil fuel. Current subsidies, in combination with support under the Energy Policy Act of 2005, are adequate to seed these new industries. Research should focus on new technologies to produce usable energy from cellulose or feedstock that can be grown on lesser quality land. Federal support programs must insist that as these biofuels industries mature and market conditions permit, companies benefiting from biofuel subsidies and import restrictions develop business models that ultimately accommodate a scaling back of such federal support to levels consistent with those given to other fuel production sectors.

We will first consider the biofuel direct market intervention provisions for the Energy Title of the 2007 Farm Bill.

Raise the Renewable Fuels Standard. Under the Energy Policy Act of 2005, Congress established the Renewable Fuels Standard (RFS), which requires that 7.5 billion gallons of biofuel be blended with gasoline and diesel fuel by 2012. Although rules and regulations are being promulgated, most market experts are predicting that the United States will surpass the RFS in 2008, given current biofuel production and capacity under construction. Proponents of the RFS are proposing that the 7.5 billion gallon RFS be raised to 15 billion gallons by 2012 or 2015.

It is difficult to assess the potential impact of a higher RFS for a number of reasons. First, it is unclear how or if the RFS would be enforced and at what level in the distribution system (blenders, wholesalers, retailers). Second, given the rapid expansion of ethanol and biodiesel industries, it is anticipated that ethanol and biodiesel production will approach 15 billion gallons by 2015 without a higher RFS.[20] The 10 percent ethanol blending constraint for conventional gasoline engines may serve as a limiting factor as the United States approaches 14−15 billion gallons of production.[21] Third, if the RFS is enforced and ethanol supplies do not expand as projected, then the market prices of ethanol and biodiesel could increase significantly. Under these circumstances, a 15 billion gallon RFS could seriously disrupt commodity markets, the livestock industry, and trade flow because it is difficult to anticipate a competitive biomass feedstock to relieve pressure on the corn and soybean markets. Fourth, if the excise tax subsidy, VEETC, is not continued, the breakeven price in equation 6 that ethanol plants can pay for corn decreases to about $2.70 per bushel. It will be highly unlikely that the United States will reach a 15 billion gallon Renewable Fuels Standard without government enforcement of the Standard.

[21] Ethanol interests are lobbying EPA to raise the blending constraint to 20 percent, but the auto industry is refusing to warrant internal combustion engines that use more than 10 percent blends.

Extend, reduce, or modify the Renewable Energy Tax Credit. The VEETC is set to expire in 2012 or at the end of the 2007 Farm Bill period. Current proposals include extending the tax credit until at least 2015 to avoid having the expiration coincide with the expiration of the 2007 Farm Bill. At the same time, concern is being expressed that further incentives are unnecessary to continue expansion of the ethanol industry, especially in periods of higher gasoline prices. In addition to proposals to extend the biofuel tax credit to 2015, there are competing proposals to reduce the biofuel tax credit, modify the tax subsidy to vary inversely with the price of gasoline, or eliminate the tax subsidy altogether.

First, extending the biofuel tax credit improves the cost competitiveness of biofuels relative to gasoline and diesel fuel as a fuel substitute. A recent CARD study employing a breakeven analysis and the FAPRI model concluded that the long-run corn-ethanol market equilibrium output would be three times higher with the tax incentive than without, although no time frame was specified (El Obeid and others 2006). If the objective is to increase biofuel as a share of transportation fuels—such as the "25 x '25" Initiative[22] to have 25 percent renewable fuels by 2025—then not renewing or eliminating the energy tax credit could reduce ethanol production capacity by as much as 20 billion gallons in the long run. Assuming that the excise tax subsidy is passed from blenders back to ethanol producers, and ultimately back to farmers and landowners in terms of what ethanol producers can pay for a bushel of corn, excise tax credits allow producers to pay approximately $1.50 per bushel more for corn than without excise tax credits.

Second, an inverse tax subsidy (that is, a variable tax subsidy inversely tied to crude oil/gasoline price) has also been proposed. The current VEETC is set at $0.51 per gallon regardless of the price of oil. Viewing ethanol as a fuel substitute, the current tax subsidy may lead to excess profits when oil prices are high and negative returns when oil prices are low. If an inverse tax subsidy were tied to the price of crude oil, say $51 per barrel crude oil and a $0.51 per gallon VEETC, for every $1 per barrel increase in crude oil price, the VEETC would decrease by $0.01 per gallon, and vice versa. If the price of crude oil increased to $61 per barrel, the VEETC would decrease to $0.41 per gallon. This would not only reduce firm and industry risk, but ensure net returns to firms in the biofuel industry. Essentially, an inverse tax subsidy sets an ethanol (biofuel) price floor and establishes expected returns irrespective of the price of crude oil. Further, if it is assumed that the excise tax credit is passed back to farmers and landowners in terms of what ethanol producers can pay for corn, a variable tax credit could essentially serve as an expected corn price floor, in lieu of other government payments.

Expand the Energy Title of the 2002 Farm Bill. Section 9006 of the 2002 Farm Bill established grant, loan, and loan guarantee programs to assist farmers, ranchers, and rural small businesses in purchasing renewable energy systems. From FY 2003 to FY 2005, USDA's Rural Development made available roughly $30 million for 119 biomass grants and loans and $10 million for two guaranteed loan programs (USDA 2006). Given the generally small magnitude of these grants and loans, they will have limited impact on investment and expansion of the biofuel industry. For example, if the capital cost of a 50 million gallon ethanol plant is $75 million and the loan is amortized over 10 years, a $1

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[22] "25x'25" is a bi-partisan coalition that is supported by several governors and states, as well as several U.S. Senators and Representatives. National and state partners include private companies, utilities, nongovernmental organizations, and rural groups. For more information, see www.25x25.org.

million grant would reduce the capital cost by $0.003 per gallon, or about $0.01 per bushel of corn.

Provide accelerated depreciation on renewable energy equipment. Providing special accelerated depreciation allowances on renewable energy equipment, similar to fiscal provisions for petroleum fuels in the Energy Policy Act of 2005, is another option. This provision would stimulate further investment in biofuels when the industry is profitable and in an expansionary phase. Yet without having specific details on such provisions, it is impossible to determine the potential impact of accelerated depreciation.

Use Conservation Reserve Program (CRP) land for biomass harvesting. Proposals in this area include: not renewing CRP contracts on working lands that can be used to produce biofuel feedstock; allowing biomass harvesting on CRP land, but with reduced CRP annual payments; and varying annual CRP payments tied to local cash rents to maintain land in the CRP base due to environmental and wildlife benefits.

If markets work, what is the role of the government in this situation? If corn is $4 per bushel, the opportunity cost of keeping land in the CRP is higher, and landowners will not renew the contracts unless they perceive sufficient non-monetary benefits to make up the difference between net returns from corn production and CRP rental payments. When markets do not work, who is the ultimate loser? Although estimating the costs and benefits is complicated, we use examples to illustrate. Not renewing CRP contracts on potential working lands that can be used to produce corn will cause a small increase in corn supply, may increase net returns to former CRP landowners who convert CRP lands to corn production, have a small impact on the supply of renewable fuels, and drive corn prices to the same long-run equilibrium market price estimated in the breakeven analysis using equation 6. Except for a possible small short-run impact on the cost of livestock feed, this proposal in the long run will leave livestock producers no better off in terms of feed costs and will increase soil erosion, decrease water quality, and destroy wildlife habitat. The small short-term benefits will be quickly offset by longer-term social and environmental costs.

With respect to the second proposal—allowing biomass harvesting on CRP land, but with reduced CRP annual payments—it is difficult to determine if there is any gain in social welfare. Under current technology, the U.S. DOE and USDA (2005) estimates that it costs about $35 per dry ton for harvesting, storing, and transporting biomass within a 30 mile radius of a processing plant. One dry ton of stover under current technology would yield about 70 gallons of ethanol and cost about $.50 per gallon on average for biomass harvesting, storing, and transporting within 30 miles of the biomass conversion plant. We have derived independent estimates in the range of $0.75 to 1.50 per dry ton range (Miranowski and Irons 2007). Further, there will be wildlife, erosion, and water quality costs associated with biomass harvesting. Additionally, the landowner wants to capture some rents to offset the reduction of CRP payments and cover the costs incurred in “producing” biomass (nutrients and soil, as well as foregoing the non-monetary benefits associated with CRP land).

Variable annual CRP payments tied to local cash rental values, or the opportunity cost of CRP land in its next best use, would be a way to retain land in the CRP and capture water quality and wildlife habitat values.

Redirect Commodity Credit Corporation (CCC) Bioenergy Program to support biomass. The CCC Bioenergy Program, which expired in 2006, provided CCC feedstock to ethanol plants in their first year of operation to reduce operating costs during the start-up period. The program has evolved into providing payments in lieu of commodity feedstock. The proposal is not to continue the program that expired in 2006, but rather to redirect payment to plants utilizing biomass feedstock in order to reduce feedstock cost in the infant industry. Such a proposal may make biomass feedstock more competitive and stimulate investment in biomass technologies during the industry's learning phase. At the current stage of lignocellulosic technology development, with a lack of sound cost data, it is difficult to evaluate the impact of such provisions on improving the biomass competitiveness with the starch fermentation process in ethanol production.

Expand federal indirect (research) support for renewable energy. Expanding research support for renewable energy, especially lignocellulosic conversion of agricultural residues and biomass crops, may have significant returns if directed to major bottlenecks in the biofuel production process from biomass feedstock. At the same time, equation 9 indicates that—with the exception of corn stover—biomass feedstock is far more costly to supply than biomass ethanol plants can afford to pay the suppliers. USDA and DOE already have a number of research programs directed at both basic and applied industry research, as does the biofuel industry, often in cooperation with universities. Although there is a strong public good argument for expanding these public research efforts, the large-scale economic feasibility of biomass feedstock is not within the near term. Finally, the case for more funding of technology transfer in order to get basic public sector research transferred to the private sector is less strong. In many university research facilities, industry, government, and university activities are already integrated, and the approach of choice may be to fund joint research and development efforts to reduce various production cost components. Along this line, several government grant programs available to universities for biofuel technology research already require industry participation as a condition of funding.

Conclusion

A basic question needs to be asked with respect to economic policy analysis. Is our energy and environmental policy objective to maximize social welfare or is it to transfer income between different groups and resource owners in society? If our objective in energy and environmental policy intervention is to maximize social welfare, we need to improve energy security and reduce dependence on foreign oil, reduce GHG emissions and other air quality issues, and reduce federal budget exposure on farm and rural development programs that accomplish that in the most efficient way possible. The objective pursued in this paper is to maximize net social benefits when considering all the social costs and benefits of intervention. If this is not our policy objective, economic benefit cost analysis has little to contribute.

The key findings of this policy analysis are:

- Ethanol and biofuels have made a contribution to improving energy security, reducing greenhouse gas and air quality emissions, and reducing federal budget exposure, especially recognizing that there is no single solution to the energy security, GHG emissions, or budget exposure problems.

- These social benefits have come at modest costs. However, the marginal costs of government incentives to expand biofuel use may be outweighed by the marginal costs in the future. We do not have sufficient benefit data to determine at what point in biofuel expansion will the marginal costs outweigh the marginal benefits.
- Even though expansion of corn-based ethanol may have important social costs, biomass feedstock has major economic and technical hurdles to overcome before it can be competitive with corn-based ethanol.
- The impact of raising the RFS depends on several factors. First, if the VEETC is retained, the nation will come close to producing and consuming 15 billion gallons of ethanol by 2012–15, assuming crude oil price stays at $60 per barrel or higher. Second, if the VEETC is not continued, biofuel use will likely be about 7.5 billion gallons and an enforced 15 billion gallon RFS will be needed to achieve that target. Further, going to biofuel mandates of 37 billion gallons in 2015 or even 36 billion gallons in 2022 will be costly. Marginal costs will exceed marginal benefits.
- Extending the VEETC will have costs in the area of $7 billion by 2015. Using a modified variable tax credit could reduce budget exposure (depending on the base level established), would insure within a range the price of ethanol and corn, but would still involve transfer payment to the ethanol and corn industry.
- Expanding the energy title of the 2002 Farm Bill to include additional rural development funding for biofuels would have a small impact on budget exposure but may have limited impact on biofuels expansion. First, the magnitude and nature of funding are not likely to have a major impact on current ethanol plant investment decisions, especially when much of the investment is coming from outside the community. Second, modern, large biofuel plants no longer have the employment potential of plants that were built before 2006 that were smaller and more labor intensive.
- Modification of the CRP is going to have few if any marginal benefits and could impose significant social costs on the environment and local amenities.

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Appendix for U.S. Fuel Ethanol Demand and Supply Model Estimation

There are three demands for ethanol: as a fuel substitute, as an octane enhancer, and as an oxygenate enhancer. To capture these effects, the ethanol demand function can be expressed as follows:

$$\ln Q_t^E = \alpha_D + \gamma_D \ln P_t^E + \beta_1 \ln P_t^G + \beta_2 \ln GDP + \alpha_1 CAAA_t + \varepsilon_t^D \quad (1)$$

where Q^E = U.S. fuel ethanol production per month (thousand gallons)
P^E = U.S. average monthly fuel ethanol rack terminal price (dollars/gallon)
P^G = U.S. average monthly gasoline retail sellers price (dollars/gallon)
GDP = U.S. seasonally adjusted monthly GDP (billions of chained 2000 dollars)
$CAAA$ = dummy accounting for the winter months (1 for November–April)

Corn grain is the most important variable cost component for ethanol production. Ethanol production from corn accounts for 94 percent of all the ethanol plant operations and corn cost accounts for as much as two-thirds of ethanol value, according to Tiffany and Eidman (2003). Ethanol production yields co-products, and we use co-product feed prices to capture this effect. We also introduce a time trend in an effort to capture the impact of time-dependent effects, including technological progress and government regulations. Ethanol supply can be formally expressed as follows:

$$\ln Q_t^E = \alpha_S + \gamma_S \ln P_t^E + \beta_3 \ln P_t^C + \beta_4 \ln P_t^{CGF} + \alpha_2 t + \varepsilon_t^S, \quad (2)$$

where Q^E = U.S. fuel ethanol production per month (thousand gallons)
P^E = U.S. average monthly fuel ethanol rack terminal price (dollars/gallon)
P^C = U.S. average monthly corn price (dollars/bushel)
P^{CGF} = U.S. average monthly corn gluten feed price (dollars/short ton)
t = time trend accounting for possible technological progress and/or accumulated effects of government CAAA regulations (1995, $1995+\frac{1}{12}$, $1995+\frac{2}{12}$, …, $2006+\frac{5}{12}$).

Assuming the ethanol market clears, the quantity demanded will equal the quantity supplied:

$$Q_E^D = Q_E^S = Q_E, \quad (3)$$

where Q_E = U.S. monthly fuel ethanol production (thousand gallons).

Because we are using a system of simultaneous equations where ethanol price P_E and quantity Q_E are endogenously determined, neither the demand nor the supply equation satisfies the assumptions of the classical regression model. Therefore, we use an instrumental variable/two-stage least squares approach to estimate the ethanol market model. Additionally, the system of equations is complete, there are no identification problems, and all coefficients can be estimated.

The results of our estimation are as follows for the demand equation:

$$\ln \hat{Q}_t^E = -4.842314 - 0.8917864 \ln \hat{P}_t^E + 1.05638 \ln P_t^G + 2.543392 \ln GDP + 0.1544298 CAAA_t \quad (4)$$

t-value (-2.08) (-2.25) (3.59) (7.49) (3.75)

For the supply equation, the results are:

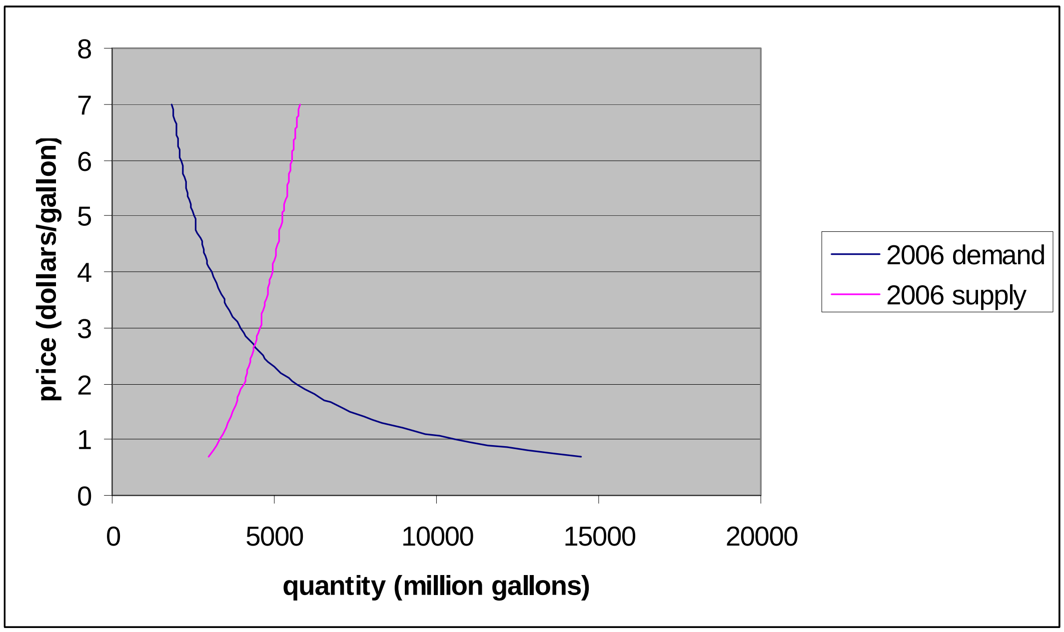
$$\ln \hat{Q}_t^E = -226.6933 + 0.2862548 \ln \hat{P}_t^E - 0.3594913 \ln P_t^C + 0.2793837 \ln P_t^{CGF} + 0.1188042t. \quad (5)$$

t-value (-12.81) (2.42) (-2.45) (2.32) (13.56)

As can be seen, the coefficients of the demand and supply equations all possess the correct signs and all coefficients are significantly different from zero at a high level of confidence.

The 2006 estimated demand and supply curves are plotted as in figure A-1.

Figure A-1. Ethanol Demand and Supply Estimates, 2006



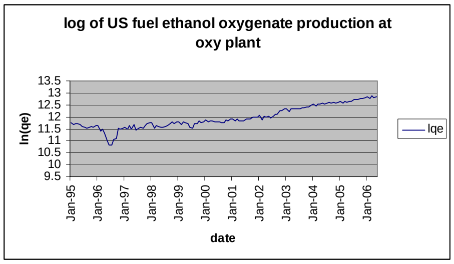
Source: Miranowski and Aukanagul (2007).

The demand for fuel ethanol and the supply of fuel ethanol are estimated based on the following information obtained from the USDA National Agricultural Statistics Service, DOE Energy Information Administration, U.S. Bureau Economic Analysis, Oxy-fuel News Price Reports, and Renewable Fuel News Price Reports.

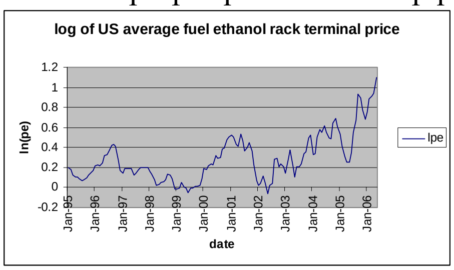
Data

- U.S. fuel ethanol oxygenate production at oxy plant (thousand gallons)

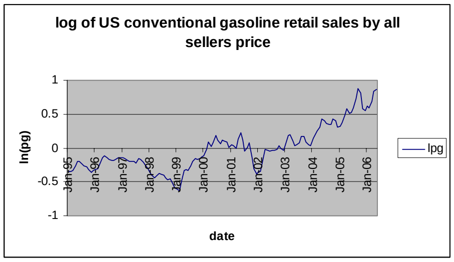
(monthly, Jan. 1995–May 2006)
http://tonto.eia.doe.gov/dnav/pet/hist/m_epooxe_yop_nus_1m.htm



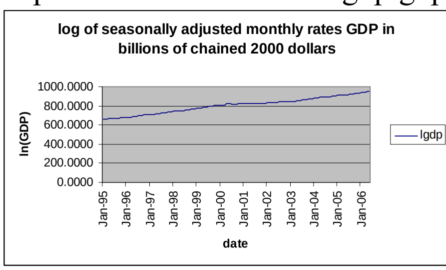
- U.S. average fuel ethanol rack terminal price (dollars/gallon) (monthly, Jan. 1995–May 2006)
http://proquest.umi.com/pqdweb?RQT=318&pmid=32874&cfc=1
http://proquest.umi.com/pqdweb?RQT=318&pmid=68404



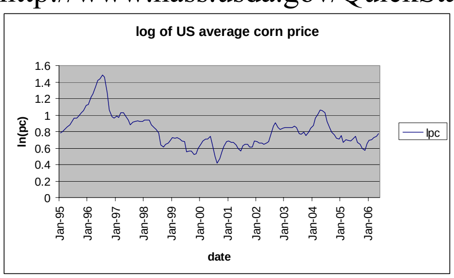
- U.S. conventional gasoline[23] retail sales by all sellers price (dollars/gallon) (monthly, Jan. 1995–May 2006)
  http://tonto.eia.doe.gov/dnav/pet/hist/d160600002m.htm



- U.S. seasonally adjusted annual rates GDP (billions of chained 2000 dollars) (quarterly, 1995Q1–2006Q2)[24]
  http://www.econstats.com/gdp/gdp__q1.htm



- U.S. average corn price (dollars/bushel) (monthly, Jan. 1995–May 2006)
  http://www.nass.usda.gov/QuickStats/PullData_US.jsp



- U.S. corn gluten feed price (dollars/short ton) (monthly, Jan. 1995–May 2006)
  http://www.ers.usda.gov/Data/feedgrains/FeedGrainsQueriable.aspx

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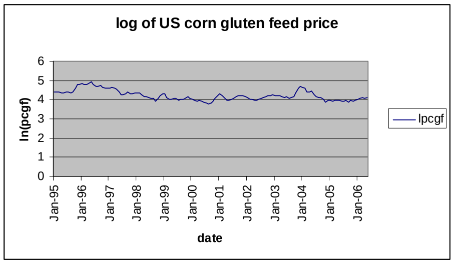
[23] Conventional gasoline excludes oxygenated or reformulated gasoline. See the following Web site for more details: http://tonto.eia.doe.gov/dnav/pet/TblDefs/pet_pri_refmg2_tbldef2.asp.

[24] Since the U.S. monthly GDP cannot be obtained, the quarterly value at an annual rate is divided by twelve to get the average monthly value. This average monthly value is then used for each month in the quarter.


log of US corn gluten feed price
ln(pcgf)
6
5
4
3
2
1
0
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
date
lpcgf