THE ECONOMIC EFFECT OF GOVERNMENTAL INCENTIVES ON THE ETHANOL FUEL MARKET

by

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(Under the Direction of Michael E. Wetzstein)

ABSTRACT

Rising gasoline prices and increased awareness of air quality problems, as well as heightened concern for homeland security have compelled Americans to reevaluate their views on alternative fuels. As an alternative fuel, ethanol is one of the more widely adopted fuels in the market today. Corn-based ethanol fuel may be domestically produced and is subsidized by the state and federal governments; however, there is currently limited research on the market for ethanol. For this study the market supply and demand for U.S. corn-based ethanol is estimated. The result from this estimation provides insights on the impacts current ethanol subsidy legislation has on the ethanol market. This analysis reveals that ethanol and methyl tertiary-butyl ether (MTBE) are close substitutes and that the federal subsidy for ethanol producers may no longer be warranted.

INDEX WORDS: Corn–Based Ethanol Fuel, Alternative Fuels, Subsidization, Panel Data, Fixed Effects Model, Tobit Estimation, Two-Stage Least Squares Regression

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CHAPTER 1

Introduction

Rising gasoline prices and increased awareness of air quality problems, as well as heightened concern for homeland security have compelled Americans to reconsider their views on alternative fuels. Over 60% of oil in the U.S. comes from foreign sources (Environmental Protection Agency). Alternative fuels provide an opportunity for the U.S. to, not only reduce this dependence, but to benefit the environment as well. Combustion of carbon-based fuels, such as gasoline and diesel, produce carbon dioxide as well as complex mixtures of compounds that lead to the formation of ground-level ozone. According to the EPA, carbon dioxide is responsible for one-half to two-thirds of our contribution to global warming. The development of emission control technologies and the establishment of inspection and maintenance programs have been implemented in an effort to reduce automobile pollution. However, each year more cars are on the road, traveling more miles (Energy Information Administration). The EPA states, “Some vehicle fuels, because of physical or chemical properties, create less pollution than do today’s gasoline. These are called ‘clean fuels’” (EPA, 1994).

Clean fuels, also known as alternative fuels, may be characterized by a number of factors including emissions, octane number, physical state, color, odor, power, range, and engine compatibility. Chemical compounds that may be emitted from fuel combustion are ozone, sulfur, carbon dioxide, carbon monoxide, nitrogen oxide, and soot. The octane scale for defining gasoline quality was developed in the 1920’s

(Britannica Online). Automotive gasolines generally range from an octane rating of 87 to 100. Fuels usually exist in one of two physical states: liquid or gaseous. Fuel power is measured in British Thermal Units (BTU). Range is a measurement of how many miles a vehicle may travel per gallon of fuel.

Emissions from clean fuels, such as biodiesel, natural gas, alcohol, and hydrogen, create as much as 90% less toxins and ozone-forming hydrocarbons than does conventional gasoline (EPA, 1994). Accumulation of carbon dioxide from fuel produced by biomass and natural gas is also less than conventional gasoline. The addition of new fuels in the market will provide consumers with more choices, thereby reducing dependence on imported oil.

Ethanol an Introduction

In the early 1980's, due to water contamination, lead was gradually being phased-out of the gasoline supply and was replaced by ethanol and MTBE (methyl tertiary-butyl ether) as the U.S.'s primary octane enhancers (EIA). In 2000, ethanol producers supplied 1.65 billion gallons of ethanol to the U.S. market, of which 45% was consumed in Minnesota, Illinois and Ohio (Price). Prohibitively high import tariffs effectively protect U.S. ethanol producers from imports. Usually ethanol is shipped by rail, barge or truck since ethanol's high solubility in water makes shipping by pipeline difficult (Price).

Ethanol is produced through a process of fermenting and distilling starch crops, such as corn, barley, and wheat that have been converted into simple sugars. In the U.S., corn is the predominant feedstock used to produce ethanol. Ethanol may also be produced from milo, barley, potatoes, cheese whey, and beverage wastes. Of the corn grown in the U.S., about 7% is used to produce ethanol while most of the rest is used for animal feed and consumer consumption (Price).

There are three types of ethanol plants: dry mill, wet mill, and cellulosic. Due to technology advancements, dry-mill ethanol plants have become more efficient and productive over the past two decades. In 2000, a dry mill produced 2.7 gallons of ethanol, 17.5 pounds of distillers dried grains (high-value feed product), and 17 pounds of carbon dioxide from one bushel of corn. While wet-mill ethanol plants are more expensive than dry-mill plants, they are both capable of producing byproducts including oil, fructose, sweeteners, and feed products. Because of various location constraints, wet mills are more likely to be owned by large agribusinesses, while dry mills are more likely to be owned by individual farmers (Price).

Cellulosic ethanol production (ethanol produced from cellulose) is a relatively new process. Cellulose is the molecule responsible for providing strength and support to trees and plants. The sources of cellulose that can be used to create ethanol are agricultural residues, wood waste, some types of municipal solid waste, and dedicated energy crops (crops grown specifically to produce ethanol) (Price). Cellulosic ethanol may be produced by hydrolysis: either acid or enzymatic. In the future, forest debris such as brush and small trees that are below pulping grade may be utilized in cellulosic ethanol production. Four cellulosic ethanol plants in the U.S. are currently in the planning stages (Price). In his report Price states, “If the technological hurdles can be overcome, cellulosic ethanol production may soon be economically viable on a commercial scale, offering the potential to produce large quantities of ethanol in many areas outside the Midwest" (p.42). He goes on to emphasize, "If commercial-scale cellulosic ethanol production is successful, ethanol plants could begin springing up all over the country, increasing competition, and reducing the need to transport such large quantities over great distances to serve those markets" (p.48). With transportation costs minimized, ethanol demand should increase.

Illinois is both the largest consumer and largest producer of ethanol. It is also the chief exporter of ethanol to other states. Other exporting states include: Nebraska, Iowa, Tennessee, North and South Dakota, and Kansas. Of the ethanol importing states, Ohio is the largest, followed by California, Wisconsin, Washington, Colorado, and Oregon (Price).

In the current market, ethanol is mixed with gasoline in the form of an E10 blend (10% ethanol, 90% gasoline) (Alternative Fuels Data Center). Another blend, E85 (85% ethanol, 15% gasoline), has gained favor in recent years. Flexible fuel vehicles (FFVs) are vehicles capable of running on either gasoline or E85. The three largest U.S. automobile manufacturers sell approximately 250,000 FFVs each year at no added cost to the consumer. The Ford Motor Company recently funded the construction of 50 retail gasoline stations that offer E85 in Minnesota. Eighteen states including Minnesota currently offer E85 at participating gasoline stations. Increased availability of E85 and competitively priced FFVs increased ethanol demand by 2 million in 1998 (Price).

There are many benefits to ethanol use over gasoline use. Ethanol is an alcohol-based, colorless liquid fuel with a characteristic odor. It is also a renewable resource that contributes no net carbon dioxide to the atmosphere. In 1990, a mandate was issued by the Clean Air Act Amendments (CAAA) that required specific regions of the U.S. to use cleaner burning fuels during winter months. Ethanol is a clean-burning fuel that reduces smog and carbon monoxide. When blended with gasoline, it increases octane and improves the emissions quality of the gasoline. It has an octane rating of over 100 compared with gasoline's highest octane rating of 90. E85 vehicles demonstrate a 25% reduction in ozone-forming emissions (AFDC). Besides E85 and E10, ethanol blends, known as "gasohol", may be successfully used in all types of vehicles with engines requiring gasoline; therefore there are zero fixed costs associated with switching to this fuel. Due to increased technological efficiency, Price states that, "Ethanol now has an estimated 30 percent net energy benefit relative to the energy it takes to grow, harvest, and process the corn used to produce it " (p.48). The federal government as well as many state governments encourages ethanol production and use through subsidies and tax incentives. Ethanol is gaining favor not only in the U.S. but in other countries around the world as well. Ethanol made from sugar cane is the primary automotive fuel in Brazil (AFDC).

Despite the numerous benefits of ethanol usage, there are serious drawbacks that must be considered. Currently, ethanol is more expensive than gasoline (EPA). It has a much smaller BTU per gallon than gasoline, meaning it has less power, and it has slightly less range than gasoline (Pimentel, EPA). Because ethanol is alcohol-based, it can be corrosive to some metals, gaskets, and seals. The addition of ethanol to gasoline increases fuel vapor evaporative emissions and ethanol-air mixtures are explosive in the ambient temperature range (EIA, Alternatives) (Table 1.1).

Table 1.1. Ethanol Advantages and Disadvantages

Advantages	Disadvantages
• Renewable • Reduces smog, carbon monoxide, and ozone forming emissions • Blends may be used in all types of gasoline engines • Domestically produced • Contributes no net carbon dioxide into the atmosphere • Government support via subsidies and tax incentives	• More expensive than gasoline • Smaller BTU per gallon • Has slightly less range than gasoline • It can be corrosive to some metals, gaskets and seals • Ethanol-air mixtures are explosive in the ambient temperature range

Brazil

Brazil is among the world's largest producers, consumers, and exporters of sugar (Bolling and Suarez). One of the primary derivatives of Brazil's sugar cane industry is ethanol fuel. Ethanol produced from sugar cane has been used as a fuel additive in Brazil since 1903, primarily as a means to insulate their sugar market from international fluctuations (Ames). Motivated by rising oil prices in 1975, Brazil's government initiated the Proálcool program (Ames). According to Ames, "The program consisted of a package of incentives for ethanol producers, and subsidies to lower the price of ethanol for consumers" (pg. 2). The program marketed a fuel of 22% ethanol blended with gasoline. This was followed by the addition of pure ethanol in 1979. Currently, Brazil is the world's largest ethanol producer with 65% of their sugar cane used for ethanol production. Ethanol fuel meets 40% of Brazil's fuel demand. However, "… diminishing government incentives, industry deregulation, and a reluctance of automakers to manufacture automobiles that run on pure ethanol… has lead to a decline in the ethanol market in recent years" (Ames, pg.2). Today, Brazil is looking for opportunities to export more of its ethanol fuel in response to this decline (Ames).

There is limited research available on the market for ethanol; therefore there is a lack of information needed for assessing the financial incentives for ethanol use. Assessing these incentives will result in more efficient and effective policies concerning alternative fuels. Since the primary fuel of choice in the U.S. is gasoline, research on alternative fuels, such as ethanol, has not been analyzed to the extent necessary to provide efficient subsidy levels. To determine the effectiveness of current subsidies for ethanol, the market demand and supply for this alternative fuel will be estimated.

Objectives

The primary purpose of this study is to model the U.S. ethanol market and analyze the influence of state and federal incentives on ethanol production. Specific objectives are:

1. Assemble and construct a data set detailing the prices of ethanol, gasoline, MTBE, and corn, subsidies, transportation costs, and technology. This data set will contain the most current level of knowledge existing on the market for ethanol.
2. Based on this current knowledge, a model depicting the supply and demand of ethanol is developed. This model is then used to estimate the market for ethanol.
3. Utilizing this model, the effect financial incentives have on the ethanol market is determined.

Methodology

The analysis is accomplished using a panel data set collected from the Economic Research Service, the U.S. Department of Transportation, the Energy Information Administration, and the U.S. Environmental Protection Agency. Data are collected for each state as well as Washington, D.C. and encompass a 15 year period (1988-2002). A supply and demand model is then developed and estimated for the consumption of ethanol.

Outline

In the second chapter of this thesis, ethanol's competition is reviewed. The fuel characteristics, advantages and disadvantages of MTBE, biodiesel, natural gas, hydrogen, and methanol fuels are discussed. Also in this chapter, important legislation that has impacted ethanol use is reviewed.

The third chapter discusses relevant literature on alternative fuels, specifically ethanol, and their role in the market. Literature concerning demand and demand elasticities for gasoline are also covered in this chapter.

The theoretical framework for the analysis used in this paper is discussed in chapter four. Specifically, the derivation of the demand and supply models estimated in this analysis, an explanation of the variables used, and the expected signs of these variables are described in this chapter.

In the fifth chapter, the results of the model estimations are given and discussed. The conclusions and policy implications that may be drawn from this analysis are described in chapter six, as well as a discussion of possible improvements in the data analysis.

CHAPTER 2

Competition and Legislation

In this chapter, different alternative fuels are characterized and the advantages and disadvantages of each fuel are assessed. A number of policies concerning alternative fuels and gasoline are also discussed.

Ethanol Competition

Gasoline and petroleum-based diesel known as petrodiesel, as well as alternative fuels including methyl-tertiary-butyl ether (MTBE), biodiesel, natural gas, hydrogen, and methanol, each have numerous benefits and limitations. Currently, these alternative fuels, including ethanol, are competing with petroleum to alter America's fuel preference in the future.

The crude-oil-derived fuels, oxygenated gasoline, reformulated gasoline, conventional gasoline, and diesel, are the fuels against which alternative fuels are compared. The Clean Air Act Amendments (CAAA) mandated that oxygenated gasoline address the growing carbon monoxide (CO) emissions problem (EIA). According to the EIA, "CO emissions result from incomplete combustion of gasoline, and are worse during the winter months." By increasing the oxygen content of gasoline, CO emissions may be greatly reduced. This may be achieved by adding oxygenates such as ethanol or MTBE (EIA).

Gasolines are defined as complex mixtures of several hundred types of hydrocarbons. Reformulated gasoline (RFG) is considered a “clean” gasoline. The CAAA mandates that RFG must be used in nine major metropolitan areas in the U.S. with the worst air pollution problems. Other areas, however, have voluntarily switched to RFG for public health reasons. RFG has no adverse effects on vehicle performance. It may be readily used by any conventional gasoline vehicle. When RFG is combusted it releases less toxic emissions than gasoline. Even with lower emissions, however, RFG still contributes more to air pollution than any alternative fuel (EPA).

Ethanol’s primary competition in the fuel additive market is MTBE. MTBE was first synthesized in the early 1960s and commercial production began in 1979 (GeoInsight). It is a flammable, colorless liquid at room temperatures and it has an odor similar to that of turpentine (U.S. Geological Survey). MTBE is classified as a volatile organic compound (VOC) that is produced by a chemical reaction between methanol and isobutylene (Hodge). Both methanol and isobutylene may be derived from natural gas; however, isobutylene may also be produced as a byproduct of the petroleum refining process (Price).

MTBE’s strengths include its octane enhancing capabilities as well as its compatibility with all types of automotive and tank liner materials. MTBE has a high solubility in gasoline, alcohol, ether, and water as well as low emissions characteristics. Unlike ethanol, MTBE does not have a phase separation problem with water; therefore it may be shipped via pipeline. Due to increased oxygen content, MTBE in gasoline reduces carbon monoxide and hydrocarbon emissions (GeoInsight).

One of MTBE's greatest strengths, however, is also its greatest weakness. MTBE's high solubility in water has made it a serious groundwater contaminant. It dissolves quickly and is, therefore, difficult to treat once it is in a water system (Hodge). MTBE is also not readily absorbed or biodegraded in soil and is resistant to microbial decomposition (Hodge). Releases of MTBE into the environment usually occur due to leaks in underground storage tanks, pipes, and spills. Legislation banning or restricting MTBE is currently being debated by congress. Meanwhile, 18 states including Arizona, California, Colorado, Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Michigan, Minnesota, Nebraska, New Hampshire, New York, Ohio, South Dakota, and Washington have already passed legislation banning the use of MTBE by 2004 (Price). Price states that, "Much tougher regulations for underground gasoline storage tanks have now been passed, but the damage done will require nearly $20 million worth of remediation" (p.3). Exposure to MTBE may cause symptoms similar to that of the flu including headaches, nausea, dizziness, and irritation of the nose and throat (Price). According to the EPA, MTBE may soon be classified as a human carcinogen (USGS). Since MTBE is in the process of being phased out, ethanol is now playing a more significant role in the fuel additive market (Table 2.1).

Like ethanol, biodiesel is an alternative fuel derived from renewable resources. The term "biodiesel" is used to describe a large group of chemicals called "esters" which may be utilized as a diesel fuel replacement. Biodiesel is derived from renewable fats and oils, such as soybean or rapeseed through a simple refining process. Originally introduced in South Africa before World War II, biodiesel is gaining acceptance worldwide (Pacific Biodiesel).

Table 2.1. MTBE Advantages and Disadvantages

Advantages	Disadvantages
• Compatible with all types of automotive and tank liner materials • High solubility in gasoline, alcohol, and ether • Low emissions characteristics • Octane enhancer	• Highly soluble in water, therefore it is a potential groundwater contaminant • Not readily absorbed or biodegraded in soil • Resistant to microbial decomposition • Exposure may cause serious health effects • May be a carcinogen

One of the advantages of biodiesel is that pure biodiesel, or B100, is completely biodegradable; therefore, if there were ever a spill, biodiesel would not adversely affect the environment in any way. B100 is also nontoxic and essentially free of sulfur and aromatics. Pure biodiesel is an entirely renewable resource unlike petrodiesel (petroleum diesel). Biodiesel use significantly reduces targeted emissions levels. No engine modifications are required to switch from diesel to biodiesel. It also maintains the payload capacity and range of diesel (Pacific Biodiesel).

Biodiesel has many advantages, but it also has disadvantages as well. While biodiesel is compatible with standard diesel engines, replacement of non-compatible engine hoses may be necessary, but is not usually difficult or expensive (Canadian Renewable Fuels Association). Biodiesel is considered carbon dioxide neutral; meaning that the amount of carbon dioxide emitted during burning is equivalent to the amount taken up by the growing crop, thereby eliminating any contribution to the greenhouse effect. The energy required in terms of fossil fuel inputs to produce biodiesel, however, can be quite large, thereby, reducing this benefit (Culshaw and Butler). EPA regulated emissions from biodiesel are lower than those for petrodiesel, except for nitrogen oxide (NOx) emissions, which may be slightly above the baseline. However, available emissions control technologies are capable of assuaging NOx emissions. Currently, it costs more to produce biodiesel than it does to import oil. Unless foreign oil prices rise significantly or technology becomes available to produce biodiesel cheaply, imported oil is the least cost option (CRFA) (Table 2.2).

Another alternative fuel, natural gas, is a mixture of hydrocarbons, mainly methane, and is produced either from gas wells or in conjunction with crude oil

Table 2.2. Biodiesel Advantages and Disadvantages

Advantages	Disadvantages
• B100 is biodegradable • Nontoxic • Free of sulfur and aromatics • Renewable • Reduces targeted emissions levels • No engine modifications required to switch from diesel to biodiesel • Maintains payload capacity and range of diesel	• Replacement of non-compatible engine hoses may be necessary • Large amount of fossil fuel inputs required to produce • Nitrogen oxide emissions may be slightly above baseline • Costs more to produce than diesel

production (AFDC). Natural gas is gaseous in its natural state. There are two types of natural gas fuel: (1) compressed natural gas (CNG) or (2) liquefied natural gas (LNG). Currently, there is widespread consumption of natural gas in the residential, commercial, industrial, and utility markets. However, it is not commonly used by the automotive industry as a vehicle fuel source due to logistical problems except in commercial fleets such as Atlanta's free transit system Marta and U.S. Postal Office vehicles (DOT).

Natural gas is a clean-burning fuel. CNG vehicles emit 80% less ozone than gasoline vehicles, while LNG emits 60% less ozone (AFDC). Compared with gasoline, natural gas is a more complete burning fuel due to its chemical nature and relatively simple composition. Natural gas is produced domestically and has a domestic resource base. It is delivered through an extensive pipeline system and is widely accepted by consumers. Every state in the continental U.S. has access to this pipeline. Natural gas costs the same or slightly less than gasoline.

Even though natural gas has many beneficial features, it also has some drawbacks. CNG must be compressed to 140 to 220 atmospheres (atm) in order to be practically stored (EIA). And even then, it has an energy density only one fifth that of gasoline on a volumetric basis. CNG must be stored in heavy tanks that occupy a large space and reduce vehicle carrying capacity. CNG is odorless; therefore odorants must be added to detect leaks and spills. CNG and LNG generally generate less power and have a limited range (EPA). Creating LNG requires the natural gas to be cryogenically cooled to -260°F. Bodily contact with the fuel at this temperature may cause cryogenic burns, or frostbite. Odorants cannot be added to LNG so methane gas detectors must be installed in order to detect leaks. Also, due to technology constrictions, it is expensive to convert vehicles to natural gas (EIA, Alternatives) (Table 2.3).

Like natural gas, hydrogen is gaseous under the full range of ambient temperatures and pressures (AFDC). Due to its gaseous state, hydrogen presents greater transportation and storage problems than liquid fuels. Hydrogen used as fuel is not pure hydrogen gas; it also contains oxygen and other materials. There are two methods for producing hydrogen: (1) electrolysis and (2) synthesis gas production from steam reforming or partial oxidation (AFDC). Electrolysis uses electrical energy to split water molecules into hydrogen and oxygen. Hydrogen's real potential as a fuel source rests in its future role as a fuel cell. Fuel cells are created when hydrogen and oxygen are fed into a proton exchange membrane and are capable of producing enough electricity to power an electric automobile (AFDC).

When the technology becomes available to efficiently produce hydrogen, the benefits to society will be significant. Hydrogen is the cleanest burning fuel; the byproducts of hydrogen combustion are only water, hydrogen and nitrogen oxides. Unburned fuel emissions do not contribute to ozone formation. Hydrogen is an attractive fuel source because of its high-energy conversion efficiency, low emission characteristics, and the fact that it can be produced from water. With an octane rating of over 100 it is a powerful fuel and it is the fuel of choice for NASA space vehicles (EIA).

Though there are many advantages, hydrogen fuel has limitations as well. The electrolysis process is extremely expensive. Unfortunately, this high cost of production combined with the low energy density and storage problems have resulted in little

Table 2.3. Natural Gas Advantages and Disadvantages

Advantages	Disadvantages
• Clean-burning fuel • Emits considerably less ozone than gasoline vehicles • A more complete burning fuel • Produced domestically and has a domestic resource base • Is widely accepted by consumers • Every continental state has access • Costs the same or slightly less than gasoline	• CNG must be stored in heavy tanks that reduce carrying capacity • CNG has an energy density one-fifth that of gasoline • Odorants must be added to CNG to detect spills and leaks • CNG and LNG generate less power and have limited range • Bodily contact with LNG may cause cryogenic burns or frostbite • Odorants cannot be added to LNG • It is expensive to convert vehicles to natural gas

Table 2.4. Hydrogen Advantages and Disadvantages

Advantages	Disadvantages
• Cleanest burning fuel • Unburned fuel emissions do not contribute to ozone formation • High-energy conversion efficiency • Low emission characteristics • May be produced from water • Octane rating of over 100, so it is a powerful fuel	• Electrolysis process is expensive • Low energy density • Gaseous under the full range of temperatures and pressures • Transportation and storage problems • Currently no distribution system

interest in hydrogen as a replacement for conventional fuel in the foreseeable future. A distribution system for hydrogen as a transportation fuel does not currently exist. It would appear that any development in hydrogen technology from electrolysis is far in the future (EIA, Alternatives) (Table 2.4).

Like ethanol, methanol is an alcohol-based fuel, sometimes referred to as wood alcohol. Methanol is primarily produced by reforming natural gas using steam to create a synthesis gas (AFDC). The synthesis gas is then fed into a reactor in the presence of a catalyst to produce methanol and water vapor. Most synthesis gases are used to make ammonia; as a result most methanol plants are adjacent to or are a part of ammonia plants. M85 (85% methanol, 15% gasoline) is the most common methanol fuel available. It is also used to produce the oxygenate MTBE that is blended with gasoline to enhance octane.

Substituting methanol for gasoline greatly reduces many of the negative externalities associated with driving automobiles. Methanol is a high-performing liquid fuel that emits low levels of toxins and ozone-forming compounds (AFDC). It reduces ozone-forming emissions by 40% and it may be produced at prices comparable to gasoline (EIA). All major automobile manufacturers have developed cars that run on M85. Vehicles that burn pure methanol, or M100, have yet to be developed, however, most manufacturers have built a prototype (EIA). Vehicles that run on pure methanol offer greater air quality and efficiency advantages so research and development of methanol engines is worthwhile. The burning of methanol fuels does not produce soot, which is mainly advantageous in compression ignition engines (EIA). Methanol fuels have a high octane rating and low vapor pressure relative to gasoline. Methanol has long been the fuel of choice in the racing industry due to its superior performance and fire safety characteristics (EIA).

Even though methanol use would reduce emissions if substituted for gasoline, other considerations must be taken into account. Methanol is corrosive to several metals, rubberized components, gaskets, and seals (AFDC). Its low flame luminosity makes fires difficult to see in the daylight. Methanol is completely soluble in water thus underground storage tanks must be free from water contamination. Methanol-air mixtures are explosive at ambient air temperatures and are extremely toxic by either skin absorption or by ingestion. MTBE production and use has declined because it has been found to contaminate ground water. Methanol fuels only have half the energy density of gasoline making range per gallon of fuel tank capacity low. Automobile manufacturers are no longer supplying methanol-powered vehicles (EIA, Alternatives) (Table 2.5).

Table 2.5. Methanol Advantages and Disadvantages

Advantages	Disadvantages
• High-performing liquid fuel • Emits low levels of toxins and ozone-forming compounds • Reduces ozone-forming emissions by 40% • May be produced at prices comparable to gasoline • All major automobile manufactures have developed cars that run on M85 • Burning of methanol fuels produces no soot • High octane rating • Low vapor pressure	• Corrosive to several metals, rubberized components, gaskets, and seals • Low flame luminosity • Completely soluble in water • Methanol-air mixtures are explosive at ambient temperatures • Toxic by either skin absorption or by ingestion • Fuels have half the energy density of gasoline • Low range per gallon

Alternative Fuel Legislation

The U.S. government has implemented several programs designed to provide incentives for consumers to switch to alternative fuels. By 2003, close to 70 ethanol financial incentive laws had been passed (Figure 2.1). The government agencies currently involved in alternative fuel legislation include the U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Department of Transportation, the U.S. Department of Agriculture, the Federal Transit Administration, the Federal Highway Administration, and the Internal Revenue Service. From the collective efforts of these agencies, important pieces of legislation have been passed.

The Alternative Motor Fuels Act (AMFA) of 1988 is a federal statute that "…encourages the development and widespread use of methanol, ethanol, and natural gas as transportation fuels by consumers and the production of methanol, ethanol and natural gas powered vehicles." The goal of the AMFA is to aid alternative fuels in gaining commercial application and consumer acceptability. The AMFA also created the Interagency Commission on Alternative Motor Fuels. This commission is the collaboration between the DOE, the General Services Administration (GSA), DOT, EPA, and other agencies in an effort to coordinate and develop policies (EIA).

Another important piece of legislation is the Clean Air Act Amendments (CAAA) of 1990. In 1963, the Clean Air Act was the first modern environmental law that recognized problems concerning air quality. Two important initiatives concerning transportation fuels emerged from the CAAA of 1990: (1) an oxygen content in gasoline requirement in carbon monoxide and ozone non-attainment areas and (2) a requirement for "clean cars" in California and for fleet AFVs in the worst ozone non-attainment areas.

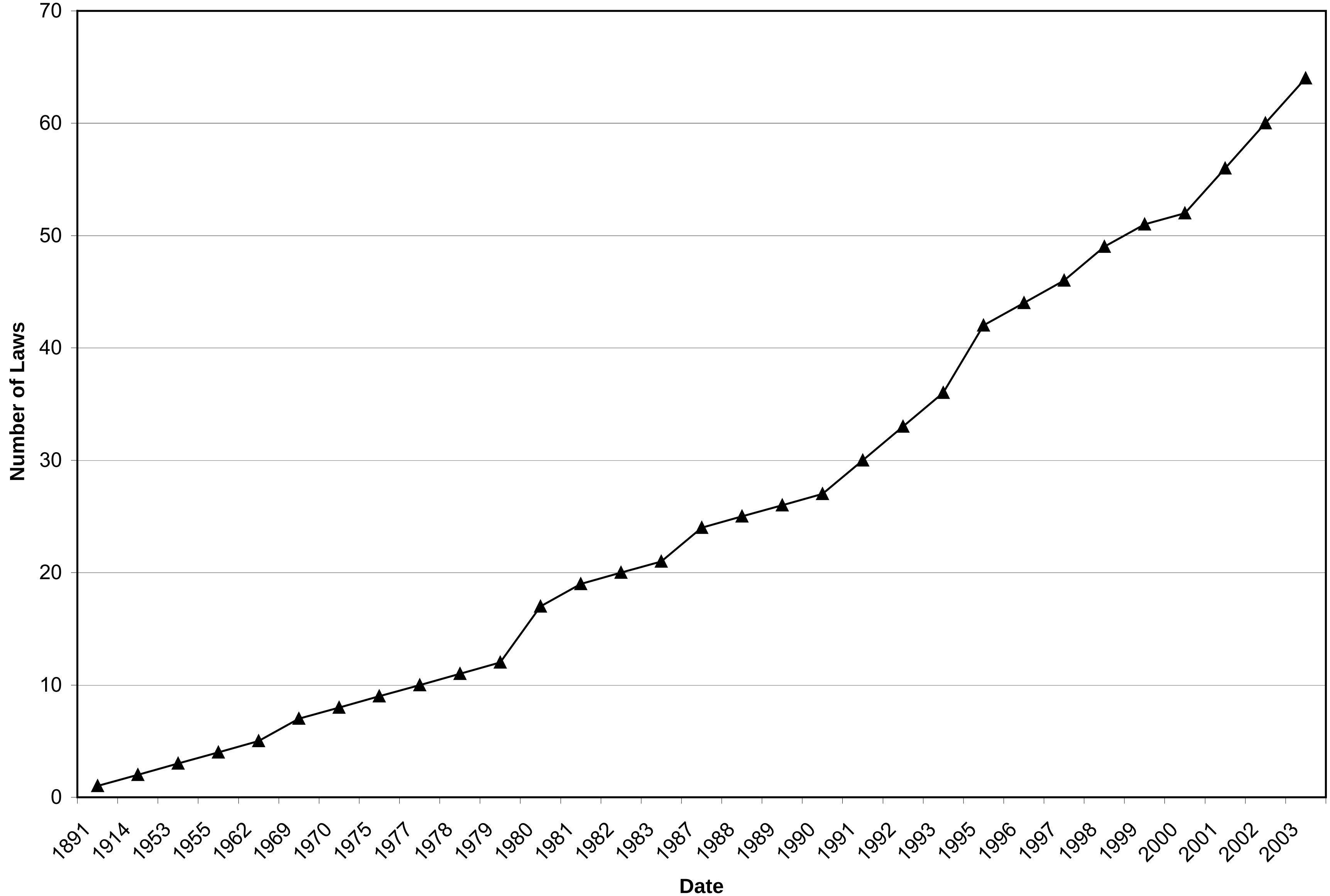

Figure 2.1 Cumulative Number of Laws by Date

According to the EIA, the “EPA designates areas as being in ‘non-attainment’ according to the degree they exceed the NAAQS”. While the CAAA does not mandate the use of alternative fuels, it does provide provisions that modify the content of gasoline and establish stricter emission standards (EIA).

One of the statutes enacted by the CAAA of 1990 was the Clean-Fuel Fleet Program intended to stimulate the development of low-polluting vehicles. This program affects 22 non-attainment areas in 19 states. Beginning in 1998, about one-third of new fleet vehicles purchased by fleet operators will be required to use clean fuels. These purchase requirements are mandated to grow to 70% by the year 2000 (EIA). The EPA estimates that this program will affect approximately 35,000 fleets and should result in about 1 million new clean-fuel vehicles by 2010.

Another program is the Energy Policy Act of 1992 (EPACT). This act was the first major legislative attempt to curb U.S. dependence on foreign oil in over a decade. Its provisions address all aspects of energy supply and demand. Included are provisions for energy efficiency, alternative fuels and renewable energy, as well as more traditional forms of energy such as coal, oil and nuclear power. The goals of this act are to decrease the nation’s dependence on foreign oil and increase energy security through the use of domestically produced alternative fuels. A tax deduction for clean fuel vehicles, whether they are for business or personal use, has also been issued (EIA).

The US government currently spends an estimated $1.4 billion in ethanol subsidies (Pimentel). There is a $0.54 subsidy issued by the federal government for each gallon of ethanol produced. States have the option of adding an additional subsidy on top of the federal subsidy. In 1891, Montana enacted the first financial incentive law for ethanol which stated that Ethanol production facilities were exempt from paying property taxes (Table 2.6). Sixty two years later in 1953, the state of New Mexico adopted an alternative fuel tax exemption. The Midwest West North Central region, which includes the states Iowa, Kansas, Minnesota, Missouri, North Dakota, and South Dakota, lead the way in ethanol incentive laws, with 18 (Figure 2.2). This is not surprising given that all of the states mentioned above are ethanol producers. South Dakota has passed the most laws regarding ethanol with five of the six occurring in 1995. The corn ethanol producing states are Wisconsin, Illinois, Tennessee, Nebraska, Minnesota, Iowa, North and South Dakota, Missouri, and Kansas. Minnesota alone has eight ethanol producing facilities. New Mexico's plant derives ethanol from grain, while New York, California, Kentucky and Florida each derive their ethanol from waste (Table 2.7).

Table 2.6. Ethanol Financial Incentive Laws Timeline

Date	State	Law
unknown	Maine	Agriculturally derived fuel fund
unknown	Maine	Special Fuel Tax Act
1891	Montana	Tax exempt property: ethanol production facility
1914	Federal	Restrictions on the purchase of gasohol and synthetic motor fuel
1953	New Mexico	Alternative fuel tax exemption
1955	Federal	Special fuels tax rate: ethanol
1962	Federal	Exemption of farmers' cooperatives from tax: gasohol
1969	Montana	Refund or credit: gasohol
1969	Montana	Gasoline license reduced tax rate: gasohol
1970	Federal	Fuels not used for taxable purposes: ethanol
1975	Federal	Alternative fuel use by light duty Federal vehicles
1977	Federal	Grants for research on the production and marketing of alcohols and industrial hydrocarbons from agricultural commodities and forest products
1978	New Mexico	Alternative Fuels Tax Act
1979	Maryland	Gasohol testing program
1980	Hawaii	Exemption of sale of alcohol fuels
1980	Kentucky	Alcohol production exemption certificate
1980	Federal	Use of gasohol in Federal motor vehicles
1980	Federal	Credit for producing fuel from a non-conventional source
1980	Federal	Alcohol used as fuel
1981	California	Tax rate on ethanol and methanol
1981	Ohio	Qualified fuel credit: ethanol
1982	Federal	Procurement of gasohol as motor vehicle fuel
1983	Idaho	Fuels tax deduction for ethanol contained in gasohol
1987	Arkansas	Tax credit for advanced biofuels facility
1987	Kansas	Kansas qualified agricultural ethyl alcohol producer incentive fund
1987	Kansas	Ethyl alcohol production incentives
1988	Missouri	Missouri qualified producer incentive fund
1989	Federal	National goals and multi-year funding for Federal wind photovoltaics, and solar thermal programs
1990	Nebraska	Ethanol tax credits
1991	Louisiana	Purchase or lease of fleet vehicles; use of alt. fuels; exceptions
1991	Missouri	Fuel conservation for state vehicles program
1991	Oregon	Use of alternative fuels for certain district vehicles
1992	Colorado	Colorado clean vehicle fleet program
1992	Colorado	Tax credit for purchases of vehicles using alt. fuels
1992	Federal	Deduction for clean-fuel vehicles and certain refueling property

Table 2.6. Continued

Date	State	Law
1993	Minnesota	Ethanol development program
1993	Montana	Credit for alternative fuel motor vehicle conversion
1993	South Dakota	Transfer of funds to ethanol fuel fund
1995	Kansas	Tax credit for alternative fueled motor vehicle property expenditures
1995	South Dakota	Fuel excise tax rates: ethanol blends
1995	South Dakota	Tax refund for gasoline used to denature alcohol
1995	South Dakota	Tax report credit allowed to blender for creation of ethanol blend E85 or M85
1995	South Dakota	Production incentive payment available to ethanol producers to ethyl alcohol fully produced in South Dakota
1995	South Dakota	Denature and blending of ethyl alcohol with gasoline required for production incentive payment
1996	New York	State clean-fueled vehicle program
1996	West Virginia	Alternative fuel motor vehicle tax credit
1997	Alaska	Motor fuel tax reduction for gasohol
1997	New York	Alternative fuels tax credit (corporate)
1998	Georgia	Income tax credits for low-emission vehicles
1998	Illinois	Use Tax Act: ethanol and biodiesel sales tax exemption
1998	Wyoming	Fuel tax remedies: ethanol
1999	Arizona	Clean burning alternative fuel requirements for new buses
1999	Wisconsin	Payments to ethanol producers
2000	Hawaii	Ethanol investment credit
2001	Iowa	Ethanol blended gasoline tax credit
2001	Iowa	Retail sales tax exemption: ethanol
2001	Nebraska	Ethanol production incentive cash fund
2001	Texas	Diesel fuel tax exemptions
2002	Florida	Refunds to ethanol dealers
2002	Louisiana	Tax credit for conversion of vehicles to alternative fuel usage
2002	Mississippi	Cash payments to producers of ethanol, anhydrous alcohol, bio-diesel and wet alcohol
2002	Ohio	Credit for investment in certified ethanol plant
2003	North Dakota	Ethanol production incentive
2003	North Dakota	Ethanol production incentive fund
2003	Texas	Vehicles using alt. fuels
2003	Texas	Alternative fuels conversion fund

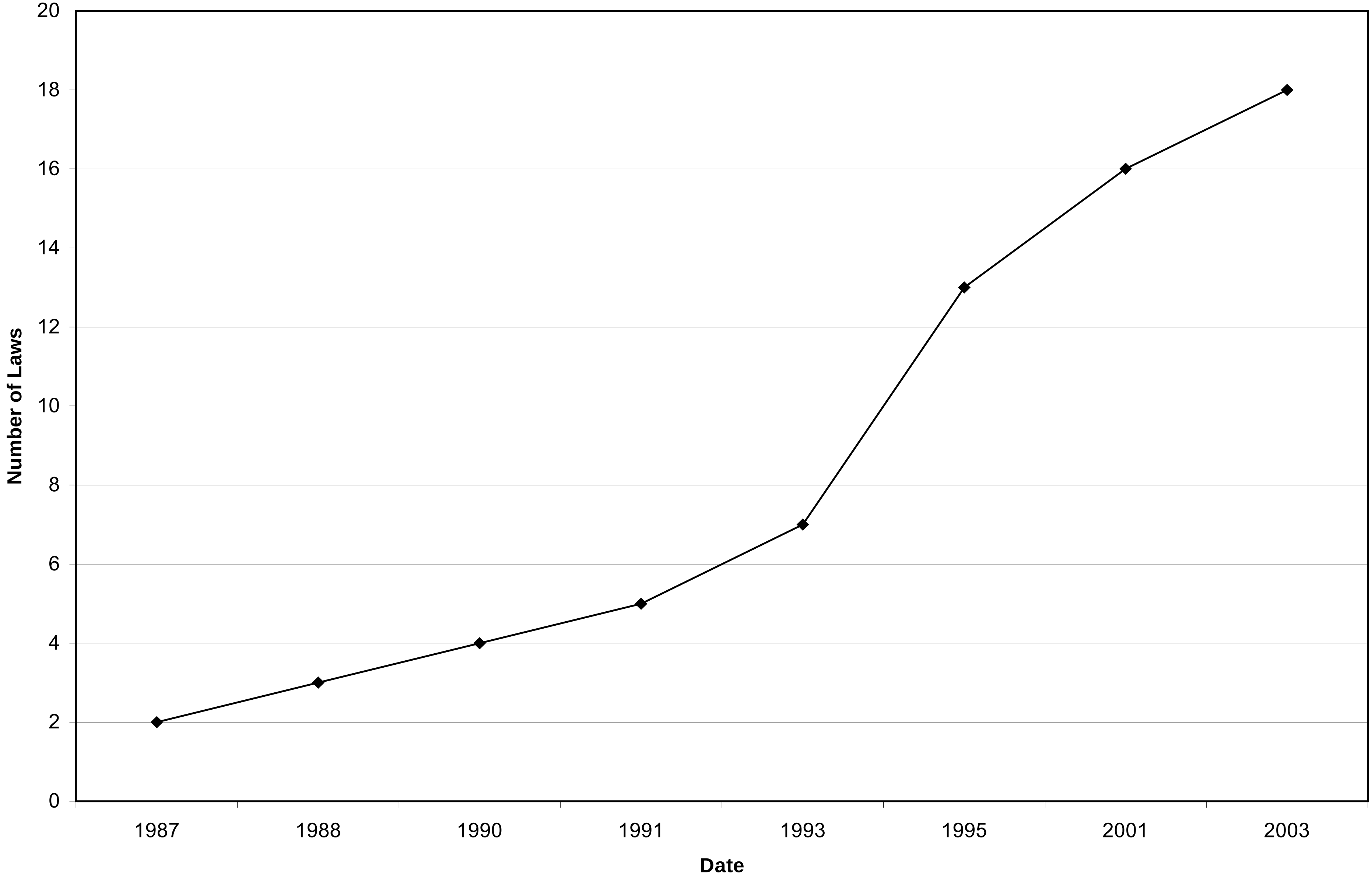

Figure 2.2 Midwest West North Central Region (IA, KS, MN, MS, ND, SD) Cumulative Number of Laws by Date

Table 2.7. Ethanol Producing States

	Derived From	Number of Plants
California	Solid waste	1
Florida	Solid waste	1
Illinois	Corn	4
Iowa	Corn	4
Kansas	Corn	2
Kentucky	Solid waste	1
Minnesota	Corn	8
Missouri	Corn	2
Nebraska	Corn	5
New Mexico	Grain	1
New York	Solid waste	1
North Dakota	Corn	1
South Dakota	Corn	2
Tennessee	Corn	1
Wisconsin	Corn	2

Source: Dr. Jeffery Price, Virginia Department of Transportation

CHAPTER 3

Literature Review

In this chapter, two different topics are covered. The first concerns previous analyses on alternative fuels, specifically ethanol, and their role in the market. The second concerns demand and demand elasticities for gasoline.

Kevin N. Rask's paper entitled *Clean Air and Renewable Fuels: The Market for Fuel Ethanol in the U.S. from 1984 to 1993* provides insight into the ethanol market. Ethanol use in fuel is changing from an octane enhancer to a gasoline substitute. Rask developed a supply and demand model that depicted the important economic features of the ethanol market. His supply model included the price of ethanol, input costs (corn price), technology and market revenues of the corn co product corn gluten feed. Since all of the prices of corn co products tend to move together, the price of corn gluten feed is used as a proxy to represent all co product prices. According to Rask, the important characteristics included in the demand model are the price of ethanol, the price of gasoline, the price of MTBE, transport costs, and the number of registered vehicles in the market.

Rask used a Tobit two-stage least squares approach to estimate the supply and demand of ethanol. Results of these estimations indicated that, "The Clean Air Act mandates, especially in areas in the Midwest with additional state subsidies, did lead to extremely large increases is the ethanol market over its usual level" (p.340). The results also suggest that, "…significant savings could be achieved if the subsidies were adjusted during mandated months" (p.341). Rask also used a Probit model to predict ethanol use at the state level. The results of this estimation yielded that the probability of a state having an ethanol market is higher if there is production in the state, a positive state subsidy, or the state is not in the north-east.

In David Pimentel's article entitled *Ethanol Fuels: Energy Balance, Economics, and Environmental Impacts are Negative*, a dissenting view of the ethanol market is given. Pimentel expands the list of inputs into the production of ethanol to include "…direct costs in terms of energy and dollars for producing the corn feedstock as well as for the fermentation/distillation process" (p.128). He also includes "…federal and state subsidies, plus costs associated with environmental pollution and/or degradation that occur during the entire production system" (p.128).

Pimentel states that there is a negative energy balance in the ethanol production system. He found that, "The total energy input to produce a gallon of ethanol is 99,119 BTU. However, a gallon of ethanol has an energy value of only 77,000 BTU. Thus, there is a net energy loss of 22,119 BTU per gallon of ethanol produced" (p.128). He also suggests that U.S. ethanol production would be significantly reduced or would cease altogether without government subsidies. For this reason, ethanol production is uneconomical.

Ethanol production increases the price of its primary input, corn, for consumers as well as the beef industry that uses corn products for its feed, thus increasing beef prices. Pimentel adds, "Therefore, in addition to paying tax dollars for ethanol subsidies, consumers are expected to pay significantly higher food prices in the market place" (p.129).

Pimentel also believes that ethanol production yields negative environmental impacts. He lists his reason as, "U.S. corn production causes more total soil erosion than any other crop. In addition corn production uses more herbicides and insecticides than any other crop produced in the U.S. thereby causing more water pollution than any other crop. Further, corn production uses more nitrogen fertilizer than any crop produced and therefore is a major contributor to ground water and river water pollution" (p.130).

Dr. Michael S. Graboski of the Colorado School of Mines and Dr. John McClelland of the National Corn Growers Association recently wrote a response entitled *A Rebuttal to "Ethanol Fuels: Energy, Economics, and Environmental Impacts" by Dr. David Pimentel*. According to Graboski and McClelland, four separate research groups have reported that corn-based ethanol exhibits a positive energy balance. As previously noted, Pimentel states that this energy balance is negative. Graboski and McClelland claim that this discrepancy is a result of Pimentel's use of out-of-date information. They state that, "By using old data and questionable assumptions, Pimentel draws the wrong conclusion about corn agriculture, and the use of ethanol as it relates to sustainability and domestic energy policy" (p.1). Using the most recent data available, Graboski and McClelland estimate that there is a positive energy balance by approximately 30%.

In the case study *Fuel-cycle greenhouse gas emissions from alternative fuels in Australian heavy vehicles* by Tom Beer et al, vehicles including trucks and buses, as well as farming vehicles such as tractors were tested using alternative fuels. Greenhouse gas emissions were monitored for seven different alternative fuels: compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gas (LPG), E95 (95% ethanol, 5% gasoline), BD35 (35% biodiesel, 5% diesel), BD100 (100% biodiesel or pure biodiesel), low sulfur diesel (LSD), and ultra-low sulfur diesel (ULS). This study used a life-cycle assessment (LCA) that was applied to the emissions from each alternative fuel. The greenhouse gases monitored were carbon dioxide, nitrous oxide and methane. “A full LCA of fuel emissions takes into account not only the direct emissions from vehicles, but also those associated with the fuel’s extraction, production, transport, processing, conversion, and distribution” (p.754).

The fuel-cycle emissions were divided into two parts: 1) the tailpipe emissions due to combustion and 2) the pre-combustion (or up-stream) emissions that arise from fuel production. Emissions related to vehicle manufacture, maintenance and disposal, and to road building and infrastructure were not included in this study due to the fact that they were not likely to differ significantly with the use of each fuel. The authors of this study used the term “exbodied” greenhouse gases to refer to the greenhouse gas emissions during the whole life cycle. Using a commercial LCA software package called SimaPro, the life-cycle assessments were determined. The mass of emissions per kilometer of distance traveled was used to compare different fuels.

The results of this case study were that both ethanol and biodiesel emitted the lowest exbodied greenhouse gas emissions. Ethanol reduced emissions by 49-55%. Even though ethanol combustion produced higher quantities of carbon dioxide than conventional fuels, that fraction was not counted towards the greenhouse gas emissions from the fuel because most of the carbon dioxide was from renewable carbon stocks. This study confirms that ethanol is a climate friendly fuel, even when considered on a life-cycle basis.

While there is limited research available on the demand for ethanol, there is considerable research available on demand and demand elasticities for gasoline. Three articles written by, C.J. Nicol, Carol Dahl and Thomas Sterner, and Yu Hsing are a good representation of the type of research that is currently available. The first article, *Elasticities of Demand for Gasoline in Canada and the United States* written by C.J. Nicol, estimates a complete system of demand equations including the demand for gasoline. For this study, survey data from the Canadian family expenditure (FAMEX) and the U.S. consumer expenditure (CEX) were used. Elasticities for various household groups were estimated using household-level data. The author found that, as expected, gasoline demand is both own-price and income inelastic. In Canada, gasoline demand was more responsive to price and income changes than in the U.S. Also, family size and housing tenure had a larger impact on differences in elasticities than differences in regions. Though the elasticities found by this study are consistent with previous results, the ability to compare elasticities by household group is a valuable one.

The next article, entitled *Analysing Gasoline Demand Elasticities: a Survey* by Carol Dahl and Thomas Sterner, attempts to find consistency in a field where different studies appear to arrive at contradictory results. They found that with proper stratification of studies by model and data type, conflicting results reach agreement. In this survey, studies were classified by data type, time series, cross-section, or cross-section-time series, and by ten different categories of model. With the exception of seasonal data which tend to be unstable, Dahl and Sterner determined that there is, in fact, a consensus regarding average short-run and long-run income and price elasticities. The authors believe that since average long-run price elasticities are high, gasoline demand could be curtailed by gasoline taxes.

The final article, *On the Variable Elasticity of the Demand for Gasoline: The Case of the USA* by Yu Hsing, tests the demand for gasoline by applying the Savin and White Box-Cox extended autoregressive (BCEA) model. Hsing believes that the BCEA model is superior to the log-linear model because both functional form and autocorrelation may be considered simultaneously. The primary conclusions that are drawn from this analysis include log-linear and linear functional forms may be rejected in favor of the BCEA model and that the price and income elasticities of gasoline demand change over time. Based on this study, demand for other energy items such as electricity and alternative fuels may be estimated using the BCEA model.

CHAPTER 4

Theoretical Framework

In this chapter, the demand and supply for ethanol is derived. This underlying theory is applied for my analysis of the demand and supply for ethanol. Expectations of results are then hypothesized.

Demand Theory

Economists model individual's preferences using the concept of utility. In my model, the blenders of ethanol and gasoline will maximize utility where one of their commodities is vehicle transportation. A utility function representing vehicle transportation is

$$U\ (\ x, V\ )\ \ \text{s.t.}\ \ px + p_v V = I.$$

Where p is the price vector of all other commodities, x is all other commoditities, p_v is the composite price of vehicle transportation, and I is income. The derived demand for vehicle transportation from the first order conditions is

$$V^* = f\ (\ p, p_v, I\ ).$$

Given this optimal level of vehicle transportation, V*, consumers will attempt to minimize transportation costs subject to this level. In addition, there are environmental constraints on this cost minimization.

$$\min\ \ v\,y\ \ \ \text{s.t.}\ \ V = f\ (\ y\ ) \text{ and } R = f\ (\ y\ ).$$

Where y is a vector containing the quantities of ethanol, conventional gasoline and MTBE. And where R is the environmental constraint imposed by the CAAA and the phase-out of MTBE. The price vector is composed of the price of ethanol, P_E, price of conventional gasoline, P_G, and price of MTBE, P_{MTBE}. From the first order conditions, the blenders' demand function for ethanol may be derived as a function of the model's parameters

$$q_E^D = f\ (P_E, P_G, P_{MTBE}, V, R).$$

Horizontal summation over all blenders yields the market demand for ethanol, Q_E^D.

Supply Theory

Given a standard profit function where

$$\pi\ (P_E, P_{MTBE}, S, r)$$

Where S is a subsidy and r is the input price vector. The supply function for ethanol manufacturers is then derived from the first order conditions as a function of the model's parameters

$$q_E^S = f\ (P_E, P_{MTBE}, r, S).$$

Horizontal summation over all individuals yields the market supply of ethanol

$$\Sigma\ q_E^S = Q_E^S.$$

Empirical Model Estimation

The interaction of supply and demand determines the prices and quantities transacted in the ethanol market. For this analysis, the following equations represent the demand and supply functions for ethanol. Both are state (i) and time dependent (t).

$$Q_{it}^{D} = \alpha_0 + \alpha_1 PePm_{t-1} + \alpha_2 Pgas_{t-1} + \alpha_3 Cars_{it} + \alpha_4 CAAA_{it} + \alpha_5 Rwp_i + \alpha_6 Rwm_i + \alpha_7 Rmwc_i + \alpha_8 Rne_i + \alpha_9 Rsc_i + \varepsilon_{it}^{D} \quad (1)$$

$$Q_{it}^{S} = \beta_0 + \beta_1 PePm_t + \beta_2 Pcorn_{i(t-1)} + \beta_3 Subsidy_i + \beta_4 Rwp_i + \beta_5 Rwm_i + \beta_6 Rmwc_i + \beta_7 Rne_i + \beta_8 Rsc_i + \varepsilon_{it}^{S} \quad (2)$$

Q = annual ethanol quantity sold in the state

PePm = annual price wedge between the price of ethanol and the price of MTBE

Pgas = annual grade-weighted wholesale price of gasoline (weighted by sales volume)

Cars = annual number of registered automobiles in the state

CAAA = Clean Air Act non-attainment dummy variable

Rwp = Western Pacific region dummy variable

Rwm = Western Mountain region dummy variable

Rmw = Midwest Central region dummy variable

Rne = North East region dummy variable

Rsc = South Central region dummy variable

Pcorn = state-level annual corn price

Subsidy = state-level subsidy

The prices for ethanol, gasoline, MTBE, and corn are lagged one year due to the possibility that the market may not immediately respond to price effects. Since state-level data for the prices of ethanol, gasoline and MTBE were not available, possible collinearity among prices may exist. Therefore, the data set is not rich enough to investigate separately the price effects. Thus, the price differences between the two close substitute commodities (ethanol and MTBE), or the price wedge (PePm), for each year are calculated. Five regional dummy variables are included to capture any effects certain regions may have on the demand and supply of ethanol. The Western Pacific region consists of Alaska, California, Hawaii, Oregon, and Washington. Included in the Western Mountain region are Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin comprise the Midwest Central region. The states in the North East region are Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. Lastly, the states in the South Central region are Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas. The region that was excluded was the South East including Florida, Georgia, North and South Carolina, Virginia, and West Virginia.

Expected Signs

In the demand equation, the impact of the price wedge between ethanol and MTBE should be negative, meaning as the price wedge increases the demand for ethanol should decrease. For the ethanol substitute gasoline there should be a positive relationship. The number of registered vehicles is included in the model to allow for market size. There should be a positive relationship between ethanol demand and market size. CAAA non-attainment states should have higher demand for ethanol.

In the supply equation, the expected own-price effect should theoretically be positive. Corn is the major input cost to ethanol production; therefore the price of corn should have a negative relationship. Lastly, a subsidy variable is included to account for government production incentives. A positive relationship is expected between subsidies and the supply of ethanol. Table 4.1 lists the expected signs that were previously discussed.

Table 4.1 Expected Signs

Variable	Expected Sign
Demand	
Price Wedge	-
Price of Gasoline	+
Number of Vehicles	+
CAAA	+
Supply	
Price Wedge	+
Price of Corn	-
Subsidy	+

A change in the own price is expected to move demand along the demand curve (D), while a change in the price of gasoline, number of vehicles, or CAAA is expected to shift demand outward (D`) (Figure 4.1). For the supply, a change in the own price is expected to move supply along the supply curve (S). An increase in the price of corn shifts the supply curve to the left (S`), while a change in the subsidy shifts the supply curve to the right (S``) (Figure 4.2).

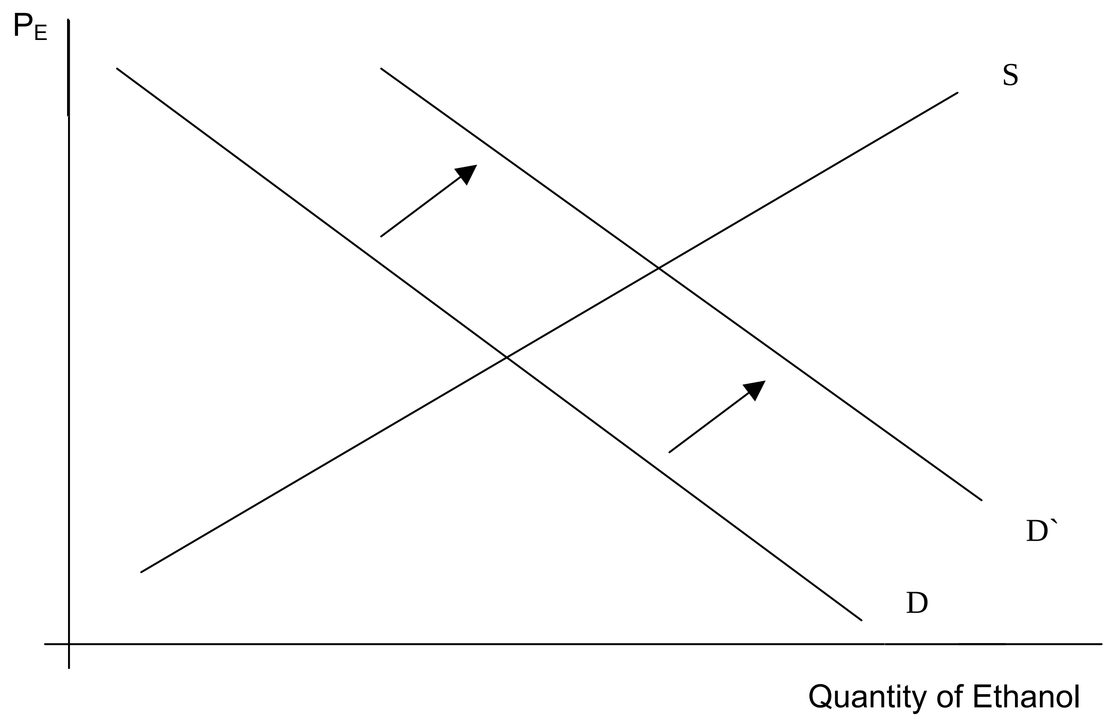

Figure 4.1. Demand Shift

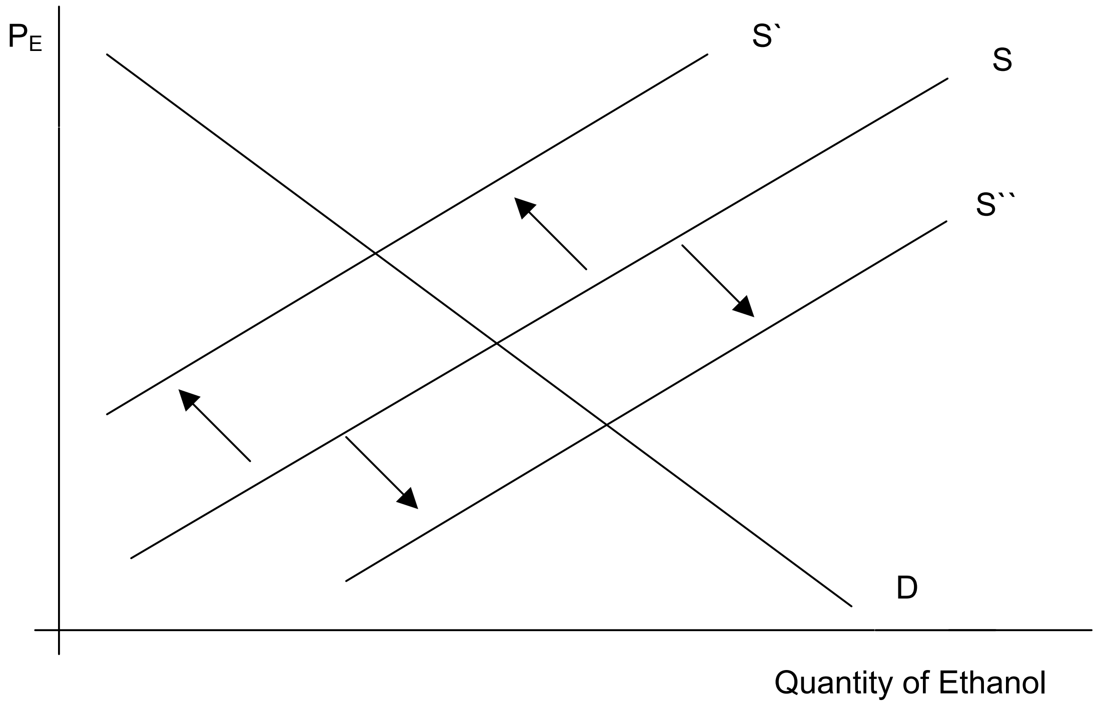

Figure 4.2. Supply Shift

Data for this analysis were collected from a number of sources. The data set consists of 714 observations that are cross-section by state over 15 years (1988-2002). The price variables, ethanol, gasoline, MTBE, and corn, were lagged one year. Data include the prices of ethanol, conventional gasoline, MTBE, and corn, the number of registered vehicles in each state, and the amount of subsidy by state. Also included in the data is a dummy variable illustrating the NAAQS attainment status of each state and five regional dummy variables. Data on the corn industry were provided by the Economic Research Service. Highway statistics were provided by the U.S. Department of Transportation. The Energy Information Administration supplied ethanol data. Gasoline and MTBE information were made available by the Environmental Protection Agency.

The type of data used in this analysis is panel data. According to Gujarati, “In panel data the same cross-sectional unit… is surveyed over time. In short, panel data have space as well as time dimensions” (p.636). Both models used in this analysis are fixed effects models (FEM). “This is appropriate if we strongly believe that the individual, or cross-sectional, units in our sample are not random drawings from a larger sample” (Gujarati, p.650). Equations. (1) and (2) are simultaneous equations with an endogenous price wedge (Pethanol - Pmtbe) variable in the market. Therefore, these models were estimated using instrumental variable techniques, specifically two-stage least squares. When I employed 2SLS to the models, the reported standard errors were not the “true” standard errors. To correct for this, I made a simple modification following the procedure outlined by Gujarati.

Out of a total number of 714 observations on quantity of ethanol, 32% of the observations are zero, therefore, an OLS procedure that only included those observations with positive ethanol consumption would lead to biased results. To counteract this problem a censored Tobit procedure is performed. Specifically, an OLS regression of the price wedge in terms of all other independent variables is estimated. This regression yields a new estimation of the price wedge ($Pe\hat{P}m$). Then, the supply and demand equations are estimated using a Tobit procedure in which the price wedge is replaced by ($Pe\hat{P}m$). Table 4.2 lists the summary statistics for this analysis.

Table 4.2. Summary Statistics

	Mean	Standard Deviation	Minimum	Maximum
Ethanol Consumed (1000 gal)	21,259	41,402	0	220,000
Price Wedge ($/gal) [a] (Pethanol – Pmtbe)	-0.21	0.11	-0.42	-0.01
Price of Gasoline ($/gal)	1.22	0.15	0.96	1.55
Price of Corn ($/bu)	2.32	0.43	1.55	3.91
Number of Vehicles (millions)	4.02	4.26	0.229	30
Subsidy	0.06	0.02	0.05	0.14
CAAA (dummy) [b]	0.77	0.42	0	1
Region [c]				
1	0.10	0.30	0	1
2	0.16	0.36	0	1
3	0.24	0.42	0	1
4	0.24	0.42	0	1
5	0.16	0.36	0	1

[a] Price wedge between the price of ethanol and the price of MTBE
[b] Clean Air Act Amendments state attainment status
1 if in non-attainment, 0 if in attainment
[c] Region 1: Western Pacific (Alaska, California, Hawaii, Oregon, Washington)
1 if in region 1, 0 if otherwise
Region 2: Western Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming)
1 if in region 2, 0 if otherwise
Region 3: Midwest Central (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin)
1 if in region 3, 0 if otherwise
Region 4: North East: (Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)
1 if in region 4, 0 if otherwise
Region 5: South Central (Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas)
1 if in region 5, 0 if otherwise

CHAPTER 5

Empirical Results

Table 5.1 lists the estimated coefficients and standard errors from the fixed effects Tobit two-stage least squares model as well as elasticities calculated at the mean values. For the demand equation, coefficients associated with the Price Wedge, Price of Gasoline, Number of Vehicles, and CAAA are all significantly different from zero at the 5% level. These results indicate demand for ethanol is most responsive to the price of gasoline. A 1% increase in the price of gasoline yields a 1.34% increase in ethanol demand. Thus, demand is primarily driven as a function of the increase in gasoline prices.

The significance of the price wedge between ethanol and MTBE indicates that consumers, i.e. ethanol-gasoline blenders, are responsive to the difference in price of these two oxygenates. Demand for ethanol is also responsive to the number of vehicles. Therefore, a 1% increase in the number of vehicles yields a 0.87% increase in ethanol demanded.

Governmental regulation of the environment in the form of the Clean Air Act Amendments (CAAA) also has a positive effect on the demand for ethanol. If a state is designated as a non-attainment state for not meeting NAAQS, ethanol demand increases by nearly 30 million gallons. These results indicate that the stricter emissions standards and gasoline oxygen requirements mandated by the CAAA is having a direct effect on the use of alternative fuels such as ethanol.

Turning now to the supply equation, the coefficients associated with the price wedge, the price of corn, and the subsidy are all significant at the 5% level. The significance of the coefficient associated with the price of corn, the major input in ethanol production, indicates an influence on supply. This is consistent with the idea of capacity constraints where firms will operate at near full capacity unless a marked persistent increase in variable costs dictates incurring the costs of shutting down. Such persistent increases in corn prices did not occur in the study's time period, and the subsidies on ethanol production provide incentives to continue to operate at near full capacity regardless of short-run fluctuations in corn prices.

States providing additional subsidies as an incentive for firms to establish ethanol plants within their state, at least in the short-run, have not elicited the desired response. The negative coefficient associated with the Subsidy variable indicates states with higher subsidies, designed to induce plant locations, are not achieving their desired effect. The economic rents associated with ethanol plant locations have already been exhausted by those states that first attached such subsidies. Over the last decade, the increases in state ethanol subsidies have not resulted in inducing a positive supply response. In the long run, as the demand for ethanol expands due in part to the MTBE phase out, such incentives may play a role in plant locations. This result supports the theoretical implication of market-based incentives generally needing a longer gestation period to achieve the desired response compared with command and control policies.

Table 5.1. Tobit Two-Stage Least Squares Results

	Coefficients [a]	Standard Errors	Elasticities [b]
Demand			
Intercept	-90,646*	16,573	
Price Wedge [c]	-89,911*	22,113	-0.88
Price of Gasoline	23,270*	10,214	1.34
Number of Vehicles (x 10^{-4})	46*	4	0.87
CAAA [d]	29,646*	4,203	
Region [e]			
1	-8,199	6,432	
2	11,146*	5,415	
3	66,344*	4,740	
4	-27,995*	5,655	
5	-859*	5,095	
Supply			
Intercept	469,641*	63,870	
Price Wedge (x 10^{+6})	1.23*	0.17	12.05
Price of Corn	-55,259*	8,143	-6.03
Subsidy (x 10^{+6}) [f]	-1.12*	0.14	-3.18
Region			
1	-9,693	7,928	
2	-25,969*	7,404	
3	39,517*	6,863	
4	-48,950*	7,141	
5	-11,747*	6,217	

[a] *Significantly different from zero at the 5% significance level
[b] Elasticities calculated at the mean values
[c] Price wedge between the price of ethanol and the price of MTBE
[d] Clean Air Act Amendments state attainment status
1 if in non-attainment, 0 if in attainment
[e] Region 1: Western Pacific (Alaska, California, Hawaii, Oregon, Washington)
1 if in region 1, 0 if otherwise
Region 2: Western Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming)
1 if in region 2, 0 if otherwise
Region 3: Midwest Central (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin)
1 if in region 3, 0 if otherwise
Region 4: North East: (Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)
1 if in region 4, 0 if otherwise
Region 5: South Central (Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas)
1 if in region 5, 0 if otherwise
[f] Federal and state subsidy given to ethanol producers per gallon of ethanol

CHAPTER 6

Conclusion and Results

Due to rising gasoline prices, air quality issues and security concerns, many Americans are looking to alternative fuels. Alternative fuels, specifically ethanol, provide an opportunity for the U.S. to not only decrease its dependence on foreign oil, but to benefit the environment as well. Ethanol is a renewable fuel source that contributes no net carbon dioxide into the atmosphere. Ethanol is clean-burning and, when blended with gasoline, increases octane and improves emissions quality.

Ethanol's primary competition as a fuel additive is MTBE. Recently, however, MTBE was found to be a serious groundwater contaminant. MTBE is now in the process of being phased out. This may lead to a more significant role in the fuel market for ethanol.

In recent decades, the U.S. government has implemented several programs and incentives designed to increase the attractiveness of alternative fuels to consumers. Programs such as the Alternative Fuels Act of 1988, the Clean Air Act Amendments of 1990, the Energy Policy Act of 1992, and subsidies have all contributed to an increase in alternative fuel use.

In an effort to determine the effectiveness of ethanol subsidies, demand and supply models were estimated for ethanol. The results indicate that the price of corn significantly affects the supply of ethanol. If the demand for ethanol continues to increase, the expansion of existing plants and the establishment of new plants will increase the demand for corn and possibly positively influence the market price of corn. In 2000, there were 55 ethanol plants in production, 46 of which use corn as their primary input. By 2002, the number of ethanol plants increased by 10 with 10 more under construction (Price).

The results of the demand estimation revealed that the prices of ethanol, gasoline, and MTBE have an effect on the demand of ethanol. With the Clean Air Act Amendments resulting in the establishment of a demand for ethanol in non-attainment states, the continued federal and state subsidies for ethanol may have outlived their usefulness. States may, however, wish to continue their subsidies for ethanol in the hope of attracting new ethanol plants. The policy implication of this study is that a gradual reduction in the federal subsidy for ethanol is warranted. With the impending phase out of MTBE, the ethanol industry should increase its market share. Therefore, due to the CAAA mandates, the supply and demand of ethanol would not be significantly altered if there were a phase out of the federal subsidy.

Limitations

The prices of ethanol, MTBE and gasoline were not available at the state level. Including state-level prices would greatly enrich the data set. The CAAA attainment status' significance in this analysis reveals an area in which my data set may be improved in the future. Areas of the country are assessed by the NAAQS on a monthly basis. Air quality attainment is a seasonal variable. Areas that are in attainment in the summer may not achieve attainment in the winter. This data set could benefit from an expansion of the yearly data to monthly data.

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