THE ETHANOL MARKET: AN ECONOMETRIC INQUIRY INTO THE MARKET FOR E85

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THE ETHANOL MARKET: AN ECONOMETRIC INQUIRY INTO THE MARKET FOR E85

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THE ETHANOL MARKET: AN ECONOMETRIC INQUIRY INTO THE MARKET

FOR E85

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THESIS ABSTRACT

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This study analyzes the ethanol market in order to determine if E85 can replace gasoline as the United States primary fuel. After presenting the history of the ethanol market, past literature on ethanol, and legislation on ethanol, this study employs reduced form price and quantity equations along with a multiplicative heteroscedasticity approach to show that under current circumstances E85 will not replace gasoline in the United States. The main driver of E85 prices is the price of gasoline. Rising gasoline prices will significantly increase the price of E85. It was concluded that the price of E85 relative to gasoline may not change. This result coupled with increasing corn and soybean prices suggest that unless other feedstocks are discovered or there are significant advancements in technology which will greatly reduce the cost of ethanol and alleviate the strain on

already existing feedstock markets, like corn, E85 will not replace gasoline as the United States primary fuel. The future of ethanol production may rest in the newly researched ethanol feedstock switch grass but there is currently no large scale production using switch grass. The president's impact on the ethanol market was explored in this study under the variable speeches but due to data constraints it proved to be statistically insignificant. The speeches variable is recommended for future studies involving the ethanol market.

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CHAPTER I

INTRODUCTION

We heat our homes and businesses, run our factories, power our vehicles, and light our world with the help of fossil fuels. We grow our food with the help of fossil fuels and communicate over long distances with electricity derived from fossil fuels. Almost every aspect of today's existence is made from, powered with, or affected by fossil fuels. Now that resources, in particular gasoline, are increasingly being depleted; prices are sky rocketing putting the world on the brink of an oil crises. The President of the United States has acknowledged that this is a huge problem that needs to be assessed immediately. He has mentioned this issue many times in the last five years in his State of the Union Addresses and has even taken action in helping the United States become less dependent on fossil fuels by funding research programs and even giving businesses incentives through subsidies to produce alternate fuels like E85 as an alternative to gasoline.[1] There are many efforts geared toward the replacement of gasoline but can the United States actually get to the point where using gasoline as a primary fuel becomes only a part of history?

In order to switch to E85 as an alternative fuel to gasoline there must be incentives in place. Many incentives motivating a switch to E85 already exist. The main

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[1] A table of the president's State of the Union Addresses and quotes regarding energy/ethanol can be found in Appendix A.

incentive is the continuous increase in oil prices resulting in an increase in gasoline prices. These prices are rising because of a shortage in non-renewable crude oil. Experts have predicted that there is only approximately 40 years of cheap recoverable crude oil remaining but recent studies by some of the world's leading petroleum geologists suggest that global oil production could peak and begin a steep decline much sooner than that, as early as the end of this decade. Non-OPEC oil-producing countries are already nearing their peak production leaving most of the remaining reserves in the politically unstable Middle East. In desperation, the United States could turn to dirtier fossil fuels like coal, tar, sand, and heavy oil but they will only worsen global warming and endanger the earth's already-beleaguered ecosystems. (Rifkin 2003) This leads us to another incentive to switch, our continuous destruction of the world's ecosystem. Depending on how much the ecosystem is damaged, a domino effect could be triggered having effects on all of mankind for years to come. Another incentive to switch to an alternate fuel is given by the United States growing dependence on the Middle East for oil. This concern has only intensified over time because of the escalating violence between Israel and the Palestinians, the war in Iraq, and the likelihood of more terrorist attacks by the Al Qaeda network. Increasing tensions between Islam and the West are likely to further threaten our access to affordable oil. (Rifkin 2003) This will result in increased gasoline prices once again. It is obvious that something has to be done in the near future involving fuels in the United States. An alternative fuel seems to be the answer but could that fuel be E85? The United States has the incentives to switch to E85 but until buying and using E85 benefits consumers financially, gasoline will remain the primary fuel of the United States.

The main purpose of this study is to evaluate the ethanol market to assess whether the alternate fuel, E85, can eventually take the place of gasoline as the United States primary fuel. An econometric approach will be used to evaluate the ethanol market. The primary objective is to evaluate the ethanol market's reduced form equilibrium price equation to assess whether or not consumers will ever have the financial incentive to switch to E85 as a primary fuel in the United States. The ethanol market will be evaluated by observing how all markets related to the ethanol market will be effected by a significant increase in ethanol production. Some of these markets include the soybean, corn gluten feed, corn, gasoline, and flexible fuel vehicle markets. By observing the effects these related markets have on the ethanol market, we can analyze whether or not consumers will ever have the incentive to switch to E85, ultimately concluding if E85 can ever replace gasoline.

This paper will include five chapters. The current chapter (above) is an introduction. It will introduce the topic and state the problem this study is based upon. Chapter two will review the economic history, legislation, and literature on ethanol. A better understanding of the future can be obtained by evaluating past legislation, literature, and economic history of the ethanol market. Chapter three will explain the theory and methodology behind modeling the ethanol market. A general market will be discussed first in order to better understand the specific ethanol market that will follow. Chapter four will state the empirical results of the ethanol market model. This chapter will explain how all ethanol-related markets affect the equilibrium price and quantity of E85. Finally, chapter five will state conclusions and have a brief overview of the paper.

The answer to whether or not E85 can ultimately take the place of gasoline in today's society will be assessed in this final chapter.

CHAPTER II

ETHANOL: ECONOMIC HISTORY, LEGISLATION, AND LITERATURE

A: Ethanol Production in General

Ethanol is alcohol distilled from fermented grain. It can be used as a biofuel which is a fuel derived from agricultural sources. The United States and Brazil are the two largest producers of ethanol accounting for over 70% of world ethanol production in 2005.[2] Even though currently these two countries produce approximately the same amount of ethanol per year, they use a different feedstock in the production process. The United States uses mostly corn in production while Brazil uses mostly sugarcane. United States ethanol production produces roughly 2.7 gallons of ethanol, 11.4 pounds of corn gluten feed, 3 pounds of corn gluten meal, and 1.6 pounds of corn oil from only one bushel of corn. (Gallagher and Otto 2001) Ethanol production also produces the co-products distillers dried grains and carbon dioxide. Recently many research efforts have been geared toward making ethanol from renewable resources like wood chips and switch grass but they are not presently an economically feasible source of production.

Ethanol demand is growing rapidly as the possibility of using it as a fuel becomes more of a reality. As of 2006 there were 95 ethanol plants that produced almost 5 billion gallons of ethanol in the United States. When comparing it to 2002 numbers, the number

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[2] Ethanol market data received from the Biomass Energy Data Book located on the USDA's official website.

of ethanol plants had increased by 34, a 56% increase, and the total ethanol production had increased 2.725 billion gallons, a 128% increase.[2]

B. History of Ethanol Production

Contrary to popular belief, using ethanol as a fuel is not a new phenomenon. As early as 1826 Samuel Morey developed an engine that ran on ethanol and turpentine. As early as 1860, Nicholas Otto, best known for his development of a modern internal combustion engine (the Otto Cycle) in 1876, used ethanol in one of his engines. Ethanol fuel has been around for at least a hundred and fifty years.

Just before the turn of the century in 1896, Henry Ford built his first automobile, the quadricycle, which ran on pure ethanol. Twelve years after that in 1908 he created the Model T which was a flexible fuel vehicle that could run on ethanol, gasoline, or a mixture of the two. One of the main reasons he built the Model T as a flexible fuel vehicle was due to the recent lifting of the excise tax on ethanol in 1906.[3] (EIA 2006)

World War I really jump started ethanol production in the United States. Beginning in 1917 the need for fuel during World War I drove up ethanol demand to 50-60 million gallons per year. Beginning in 1920, gasoline became the motor fuel of choice but ethanol was still used as an additive. Standard Oil began adding ethanol to gasoline to increase octane and reduce engine knocking. (EIA 2006)

In the 1930's, fuel ethanol gained a huge market in the Midwest. Over 2,000 gasoline stations in the Midwest sold Gasohol, which was gasoline blended with between

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[3] Information was obtained from the Energy Information Administration (EIA).

6% and 12% ethanol as stated later in the Energy Tax Act of 1978. A few years later in 1933, tests by the United States Department of Agriculture (USDA) and Annapolis researchers found that Ethyl leaded gasoline and twenty percent ethanol blend almost exactly equal in performance but the findings were never published. In 1937, an experimental ethanol plant was created in Atchison, Kansas. The ethanol was used to boost octane levels in gasoline potentially replacing tetraethyl lead. This fuel was sold in Midwestern stations under the brand name Agrol. The idea of creating new markets for farm products was widely supported in the Midwest during the depression years despite opposition by the oil industry. In the mid to late 1930's any proposals for federal tax incentives to help ethanol compete as a motor fuel were never passed by Congress. (Kovarik 1996) Despite this government opposition, ethanol production for fuel use still increased in the early to mid 1940's due to a massive wartime increase in the demand for fuel in general.

Once World War II ended in September of 1945, ethanol use as a fuel was drastically reduced due to the decreased need for war materials and the low price of gasoline. This crash of the ethanol industry lasted until the late 1970's when virtually no commercial fuel ethanol was available anywhere in the United States.

The ethanol market began to recover in 1975 when the United States begin to phase out lead in gasoline. Ethanol then became more attractive as a possible octane booster for gasoline increasing the demand for ethanol. Demand for ethanol only slowly increased at this time because lead was not completely phased out of gasoline until 1986. (EIA 2006)

In 1979, marketing of commercial alcohol-blended fuels began. Amoco Oil

Company began marketing commercial alcohol-blended fuels, followed by Ashland, Chevron, Beacon, and Texaco. These advertising efforts were rewarded when a 1980 survey conducted by the United States government showed that 10 ethanol facilities existed, producing approximately 50 million gallons of ethanol per year. This was a major increase from the late 1950s until the late 1970s when virtually no fuel ethanol was commercially available. (EIA 2006)

After the ethanol industry began to resurrect itself in the late 1970's and early 1980's, the industry began to boom when ethanol started to be used as an oxygenate in gasoline around 1988. The next potential boost to the ethanol industry came in 1997 when major United States auto manufacturers began mass production of flexible fuel vehicles capable of operating on E85, gasoline, or both. The industry did not boom as expected since most of these vehicles used gasoline as their only fuel due to the scarcity of E85 stations.

In 2002 the United States automakers continued to produce large numbers of E85 capable vehicles to meet federal regulations that require a certain percentage of fleet vehicles to be capable of running on alternative fuels. Over 3 million of these vehicles were in use. Several states were encouraging fueling stations to sell E85 because only 169 stations in the United States were selling E85 at the time. This forced most E85 capable vehicles to operate on gasoline instead of E85. As of October 2003, a total of 18 States had passed legislation that banned MTBE but none of these 18 states were major users of MTBE.[4] Some states like California, New York, and Connecticut began switching from MTBE to ethanol even before the ban came into effect causing a

[4] States that most used MTBE were California, Connecticut, Kentucky, Missouri, and New York.

significant increase in ethanol demand. The most recent news involving ethanol fuel came in 2007 when the Indy Racing League began using 100% ethanol instead of methanol as its official race fuel. (EIA 2006) The effects of this on the ethanol market are not yet know.

C. History of Ethanol Legislation

Ethanol legislation dates back to the year 1862 when the Union Congress put a $2 per gallon excise tax on ethanol to help pay for the Civil War. This temporarily put a stop to ethanol use as a fuel because the tax made it too expensive to produce. A little more than forty years later in 1906 the excise tax was removed once again making ethanol an alternative to gasoline as a motor fuel.

The next major legislation regarding ethanol was passed in 1974 when the Environmental Protection Agency (EPA) issued the initial regulations requiring reduced levels of lead in gasoline in the Solar Energy Research, Development, and Demonstration Act. This was the first of many legislative actions to promote ethanol as a fuel. It led to research and development of the conversion of cellulose and other organic materials (including wastes) into useful energy or fuels. This turned out to be a wasted effort because even to this day there are still no commercial plants that use cellulose as a feedstock. (EIA 2006)

The next major Act that had a huge effect on ethanol was the Energy Tax Act of 1978. This was the first time the fuel Gasohol was defined as a blend of gasoline with at least 10 percent alcohol by volume, excluding alcohol made from petroleum, natural gas, or coal. This caused ethanol to be blended into gasoline since it was produced from renewable biomass feedstocks. The Energy Tax Act of 1978 also enforced a Federal excise tax on gasoline of 4 cents per gallon and ended up amounting to a 40 cent per gallon subsidy for every gallon of ethanol blended into gasoline. (EIA 2006) This incentive turned out to prove that the idea of community based ethanol plants were impractical as major grain processing companies moved in order to take advantage of the incentive. (Kovarik 1996)

In 1980, Congress enacted a series of tax benefits to ethanol producers and blenders. These benefits encouraged the growth of ethanol production. The first act was the Energy Security Act which offered insured loans for small ethanol producers (less than 1 million gallons per year) up to $1 million in loan guarantees per project that could cover up to 90 percent of construction costs on an ethanol plant, price guarantees for biomass energy projects, and purchase agreements for biomass energy used by federal agencies. Congress also placed a tariff on foreign produced ethanol. Previously, foreign producers, such as Brazil, were able to ship less expensive ethanol into the United States. A second act implemented by Congress in 1980 was the Gasohol Competition Act which banned any retaliation against ethanol resellers. The third and last act passed in 1980 was the Crude Windfall Tax Act which extended the ethanol-gasoline blend tax credit in an effort to continue to promote ethanol.

Soon after the 1980 Acts, the Surface Transportation Assistance Act of 1983 increased the ethanol subsidy from 40 cents per gallon to 50 cents per gallon. The next year saw the number of ethanol plants peak at 163 when the Tax Reform Act of 1984 increased the ethanol subsidy ten more cents to 60 cents per gallon. The ethanol market seemed to be exploding at this time but surprisingly the next year saw many of the ethanol plants go out of business even with the 60 cent subsidy. After 1985, only 74 of the 163 plants survived. (EIA 2006) One of the main reasons for producers going out of business was the very low price producers were able to receive for their ethanol due to very low crude oil and gasoline prices.

After the collapse of the ethanol market, Congress passed the Alternative Motor Fuels Act (AMFA) of 1988. Congress switched their focus from gasoline related legislation to alternative fuel vehicle related legislation. The AMFA established Corporate Average Fuel Economy (CAFE) credits for alternative fuel vehicle production. These credits put more flexible fuel vehicles on the road but many manufacturers used these credits to off set poor fuel performance of other vehicles they manufactured. The AMFA proved to have little effect on the ethanol market since manufactures did not use the credits as they were intended. (EIA 2006)

The year 1990 saw the passing of the Omnibus Budget Reconciliation Act (OBRA) and the Clean Air Act (CAA). The OBRA decreased the ethanol subsidy from 60 cents per gallon to 54 cents per gallon. Starting in 1990 most ethanol related legislation focused on the cleaning up of the environment. The first of this legislation was the Clean Air Act which mandated the use of oxygenated fuels in specific regions of the United States during the winter to reduce carbon monoxide emissions. The Clean Air Act also established the Reformulated Gasoline Program which mandated that cleaner-burning reformulated gasoline had to be sold in the nine worst ozone non-attainment areas to reduce ground level ozone and improve other elements of air quality. (EIA 2006)

The Energy Policy Act of 1992 (EPACT) provided two additional gasoline blends which were 7.7% and 5.7% ethanol. EPACT defined ethanol blends with at least 85% ethanol as "alternative transportation fuels." It also required specified car fleets to begin purchasing alternative fuel vehicles such as vehicles capable of operating on E85. EPACT provided tax deductions for purchasing or converting a vehicle that could use an alternative fuel such as E85 and for installing equipment to dispense alternative fuels. (NEVC 2007) In the same year as the EPACT, the Clean Air Act Amendments mandated the winter-time use of oxygenated fuels in thirty-nine major carbon monoxide non attainment areas (areas where EPA emissions standards for carbon monoxide had not been met) and required year-round use of oxygenates in nine severe ozone non attainment areas in 1995. Also in 1995, in another effort to clean up the environment, the EPA began requiring the use of reformulated gasoline year round in metropolitan areas with the greatest smog. By the end of that year the ethanol industry was on the verge of another collapse because of high corn prices due to a poor corn crop but many states passed subsidies in order to keep the industry alive. (EIA 2006)

In 1998 President Bill Clinton passed the Federal Highway Bill that extended the ethanol subsidy through 2007 but would be reduced gradually. The ethanol subsidy of 54 cents per gallon will be reduced to 53 cents in 2001, 52 cents in 2003, and finally to 51 cents in 2005. (Dipardo)

In 1999 some states began to pass bans on MTBE (Methyl Tertiary Butyl Ether- made from natural gas and petroleum) use in motor gasoline because traces of it were showing up in drinking water sources, presumably from leaking gasoline storage tanks.

Because ethanol and ETBE (Ethyl Tertiary Butyl Ether - made from ethanol and petroleum) are the main alternatives to MTBE as an oxygenate in gasoline, these bans increased the demand for ethanol considerably.

In 2005 the VEETC (Volumetric Ethanol Excise Tax Credit) was created. The tax credit consists of 51 cents per pure gallon of ethanol used or blended. (EIA 2006) In the same year as the VEETC, the Energy Policy Act of 2005 was passed which gave small ethanol producers an income tax credit for all facilities that produced 60 million gallons or less of ethanol per year. It also established a 30 percent credit for the cost of installing clean-fuel vehicle refueling equipment that lasts until 2010. Along with this, the Renewable Fuel Standard (RFS) was created. The RFS mandated that 4 billion gallons of renewable fuel must be produced by 2006. The RFS also helped jump start cellulosic ethanol production by requiring a minimum of 250 million gallons of cellulosic ethanol a year to be used by refineries for ethanol production starting in 2013. A summary of all ethanol subsidy legislation can be found in Appendix B. All other legislation regarding ethanol can be found in Appendix C.

D. Literature on Ethanol

One of the more important and widely discussed topics involving ethanol production regards its feedstocks. There are already many feedstocks that can be used in ethanol production. Current ethanol feedstocks used in the United States include: corn, milo, barley, wheat, waste beverage, cheese whey, and sugars. Corn is by far the most used feedstock accounting for over 92% of ethanol production in the United States in

2006.[5] The dominance of corn use in ethanol production creates a problem when looking at large scale ethanol production as would be needed if it were to replace gasoline as a fuel. There is simply not enough corn available for production. More details about this problem are presented later in this chapter. The good news is that more feedstocks are continually being discovered. As these feedstocks are discovered, the concern that ethanol production will raise the price of corn and other possible feedstocks will lessen. This will also lower the cost of E85 due to a lower input price. One main reason why there is such a push to find additional ethanol feedstocks is because producers and manufactures realize that their waste can be converted to a product with market value giving them a financial incentive to produce ethanol which leads to increased efficiency of ethanol production, increased supply of ethanol, and eventually a lower price for ethanol. For example, Coors Brewing Company is producing 1.5 million gallons per year of fuel ethanol from waste beer and is expanding that output an additional 1.5 million gallons per year in the near future.[6] (GCC 2005) Others have discussed using otherwise waste crops like freeze damaged fruit, over ripe produce like apples and even out of date bakery goods like stale bread and cakes as possible feedstock streams for ethanol plants.

A problem that may be encountered with mass production of ethanol is increased demand for the feedstocks. Large-scale production of ethanol may require substantial amounts of cultivable land with fertile soils and water. This may lead to environmental damage such as deforestation or decline of soil fertility due to reduction of organic matter. To be more specific, it has been estimated that the land area required to operate a

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[5] Ethanol feedstock data received from the Biomass Energy Data Book located on the United States Department of Energy official website. (DOE 2006)

[6] Information was obtained from the Green Car Congress (GCC) website.

motor vehicle for one year on pure ethanol, 11 acres, could feed 7 people over the same timeframe.[7] (Pimental b) The logical consequences of these competing land uses are that widespread use of ethanol would lower food production from existing agricultural land potentially inflating food prices due to less supply. Alternatively, the agricultural industry could maintain existing levels of food production and create more farmland through deforestation upon which to grow crops for energy production. The problem with this is that it could lead to the acceleration of the greenhouse effect as well as the loss of biodiversity which is against the argument for the proposition of switching to E85 that the use of E85 will reduce greenhouse gas emissions. There has also been a study in 2007 that suggests that deaths related to increased ozone would increase by 4 percent in the United States if all motor vehicles ran on E85 as opposed to petroleum products. (Jacobson 2007) Another problem associated with corn is increased soil erosion which erodes about 20-times faster than soil reformation in agriculture.[8] (Pimental b)

As ethanol production increases, it will put a strain on the feedstocks involved with production. The most talked about problem involves the corn market. Consumers are concerned that as ethanol production increases the price of corn will skyrocket and an increased amount of less efficient land will be used to grow corn for ethanol production. As the price of corn increases, ethanol production will eventually come to a halt because it will be too costly to produce ethanol. Using a model consisting of multiple commodities and multiple countries, it was estimated that ethanol expansion will stop when corn becomes $4.05 a bushel. (Elobeid and Tokgoz 2006a) Over the years 2000-

[7] Information can be obtained at http://healthandenergy.com/ethanol.htm but the date of the article is not known.
[8] Information can be obtained at http://healthandenergy.com/ethanol.htm but the date of the article is not known.

2005 corn prices peaked in April of 2004 at only $2.89 per bushel. Elobeid and Tokgoz estimate that corn based ethanol production will reach 31.5 billion gallons per year and require almost 96 million acres of corn to be planted. The estimation assumes a constant growth in corn yields which is unlikely if the United States were to turn to ethanol as an alternate fuel. Corn yields would likely increase causing the ethanol industry to expand which would have a lesser impact on the feedstocks. Another issue concerning an increased demand for the feedstock corn is the shear amount it would take to switch to ethanol as a fuel. David Pimental has concluded that it would take about 10.4 acres of corn to fuel one car with ethanol for one year. This means that nearly seven times more cropland would be required to fuel one car than is needed to feed one consumer. A total of approximately two billion acres of cropland would be required to provide the corn feedstock.[9] This amount of acreage is more than five times the amount of cropland that is actually and potentially available for all crops in the United States. If all the automobiles in the United States were fueled with 100 percent ethanol, a total of about 97 percent of United States land area would be needed to grow the corn feedstock. Corn would cover nearly the total land area of the United States.[10] (Pimentel b)

Even with the concerns mentioned above, ethanol has become one of the more popular options for an alternate energy for many reasons. One reason brought up frequently in the last few years is the sudden demand to be energy independent of other countries. A switch to ethanol would dramatically help the United States in doing so because ethanol production involves mostly domestic fuels such as natural gas and coal.

[9] Cropland acreage is calculated under the assumption that all cars in the United States run on 100% ethanol.
[10] Information can be obtained at http://healthandenergy.com/ethanol.htm but the date of the article is not known.

Only about 5% of the fossil energy required to produce ethanol from corn in the United States is obtained from non-U.S. petroleum.[11] (ACE 2005)

Another issue surrounding increased ethanol production is how it will effect the environment. To be more specific, increasing greenhouse gas emissions have become a concern for ozone protection and global warming. During ethanol production, some carbon dioxide is released but in a recent study by the University of California at Berkeley it was estimated that E85 still cuts greenhouse gas emissions by 13% over gasoline. On a per-mile-driven basis, using 1999 technology, E85 reduced petroleum usage by 74.9%, greenhouse gas emissions by 18.8%, and total fossil energy consumed by 35%. With 2005 technology, E85 reduces petroleum usage by 75.6%, greenhouse gas emissions by 25.5% and fossil energy use by 40.7%. (Acks 2007) Using 2005 technologies, the energy usage figures improve slightly with a significant decrease in greenhouse gas emissions.

How does E85 compete with gasoline on fuel efficiency? There are many variables other than fuel that effect fuel efficiency. These include the season, whether, state or tune of the vehicle, road grade, tire pressure, and the use of air conditioners. With these variables held constant some cases show that fuel efficiency actually increases but most cases show a drop in efficiency. The National Ethanol Vehicle Coalition (NEVC) states that E85 has a much higher octane than gasoline ranging from 100 to 105. Flexible Fuel Vehicles are not optimized to E85 so they experience a 10% to 15% drop in fuel efficiency.[12] (Shelton) Other studies have show even more drastic efficiency losses.

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[11] Information was obtained from the American Coalition for Ethanol (ACE).
[12] Information can be obtained at http://www.energy.gatech.edu/questions/ethanol.php but the date of the article is not known.

Some of the newest vehicles can lessen this reduction to only 5-15% but as recently as 2007 the Environmental Protection Agency (EPA) stated on its website that several of the most current flexible fuel vehicles were still losing 25-30% fuel efficiency when running on E85. (EPA 2007) In the most recent fuel economy report conducted by the United States Department of Energy (DOE), it was estimated that flexible fuel vehicles on average loss 20-30% in gasoline mileage. (DOE 2007) This problem is why the price of E85 must be significantly lower than the price of gasoline in order to have the financial incentive to switch to E85 as an alternate fuel but remember the amount of reduction in mileage is highly dependent upon the particulars of the vehicle design, composition of the ethanol-gasoline blend, and state of engine tune among other factors as stated previously.

Another way to evaluate ethanol production is to look at its net energy balance. Variations in data and assumptions used among different corn ethanol net energy balance studies have resulted in a variety of results both positive and negative. Below is a list of different net energy balance studies consisting of variations among the studies and their results. The first study evaluated is Ho's 1989 study in which a negative net energy balance of -4,000 Btu per gallon was obtained. Other negative balances were found in David Pimentel's 1991 and 2001 studies and Keeney and Deluca's 1992 study. All other studies found a positive balance with the greatest being a 30,589 Btu per gallon gain in Lorenz and Deluca's 1992 study. Working for the United States Department of Agriculture, Shapouri, Wang, and Duffield have evaluated these studies in order to come up with a more consistent estimate. They concluded a positive net energy balance of 21,105 Btu per gallon. This is equivalent to a net energy balance of 1.34 which implies that corn based ethanol has a 34% energy gain. Shapouri, Wang, and Duffield also found that the net energy balance of corn ethanol has been rising over time due to technological advances in ethanol conversion and increased efficiency in farm production. More details of this study are show in Shapouri, Wang, and Duffield's 2002 study listed below in Table 2.1. (Shapouri, et. al 2002)

Table 2.1: Results Comparison on Previous Ethanol Net Energy Balance Studies (4)

Study/year	corn yield	Nitrogen fertilizer application rate	Nitrogen fertilizer production	Corn ethanol conversion rate	Ethanol conversion process	Total energy use (2),(3)	Co-products energy credits	Net energy value
	Bu/ acre	lb/acre	Btu/lb	Gal/bu	Btu/gal	Btu/gal	Btu/ gal	Btu/gal
Ho (1989)	90	NR(1)	NR	NR	57,000	90,000 (LHV)	10,500	-4,000
Marland and Turhollow (1990)	119	127	31,135	2.5	50,105	73,934 (HHV)	8,127	18,154
Pimentel (1991)	110	136	37,551	2.5	73,687	131,017 (LHV)	21.5	-33,517
Keeney and DeLuca (1992)	119	135	37,958	2.56	48,470	91,196 (LHV)	8,078	-8,438
Lorenz and Morris (1995)	120	123	27,605	2.55	53,956	81,090 (HHV)	27,579	30,589
Shapouri et al. (1995)	122	125	21,159	2.53	53,277	82,824 (HHV)	15,056	16,193
Wang et al. (1999)	125	131	21,902	2.55	40,850	68,450 (LHV)	14,950	22,500
Agri. And Agri-Food Canada (1999)	116	125	NR	2.69	50,415	68,450 (LHV)	14,055	29,826
Pimentel (2001)	127	129	33,547	2.5	75,118	131,062 (LHV)	21,500	-33,562
Shapouri et al. (2002)	125	129	18,392	2.66	51,779	77,228 (HHV)	14,372	21,105

Notes: (1) NR: Not reported
(2)LHV: Low heat value = 76,000 Btu per gallon of ethanol. Keeney and Deluca used 74, 680 Btu per gallon of ethanol.
(3)HHV: High heat value = 83, 961 Btu per gallon of ethanol. Lorenz and Morris used 84,100 Btu per gallon of ethanol.
(4)Table was obtained from Shapouri, Wang, and Duffield's article "Corn Based Ethanol Net Energy Balance: An Update" located on the USDA's official website. (Shapouri, et. al 2002)

Another aspect of ethanol production is legislation, more specifically the ethanol subsidy. The ethanol subsidy has fluctuated mostly between 50-60 cents per gallon from 1983 to present day as shown in Appendix B. This subsidy is fixed which means it is paid regardless of how high or low the price or production cost of ethanol. The question is; how does the subsidy affect private investment and government costs? As ethanol production continues to skyrocket the government will pay an increasing amount of tax dollars. About one dollar per gallon of ethanol is from government subsidies, loans, and price supports. (Lieberman 2007) According to Quear and Tyner, the ethanol subsidy could be transformed into a variable subsidy which is defined as a subsidy that increases as the price of ethanol falls and decreases when the price of ethanol increases. This kind of subsidy could reduce private sector risk by stabilizing returns and increasing the likelihood of private investment. This could save the government many tax dollars by removing the subsidy during high ethanol prices which would fix the increasing cost to the government problem. (Tyner and Quear 2006)

Yet another way to evaluate increased ethanol production is to look at how new ethanol plants affect local economies. Since many ethanol plants are built in small communities an addition of an ethanol plant can have a huge effect on the local economy. The most obvious and most talked about benefit to the local community is the creation of jobs. The Renewable Fuels Association (RFA) estimated in 2006 that the ethanol industry supported the creation of more than 160,231 jobs in the United States economy boosting United States household income by $6.7 billion. (RFA 2006) In addition to creating jobs, ethanol plants can provide a local community with a steady cash flow. In an analysis conducted in 2000, it was suggested that gains for consumers, producers, and local economies would more than offset any possible lost federal tax revenues in those communities who decide to build an ethanol plant. (Gallagher et. al 2000)

Another way to analyze increased ethanol production is to evaluate the foreign effects. As stated previously, Brazil and the United States are the world's largest producers of ethanol but since the production costs of ethanol using sugarcane are lower than that of corn, Brazil's ethanol is more competitively priced on the world market. Congress addressed this issue by granting protection to the United States domestic ethanol industry. This protection ultimately made Brazil's ethanol uncompetitive with United States' ethanol. Recently in 2006 Elobeid and Tokgoz stated that the removal of the United States trade barriers would decrease the worldwide price of ethanol by 13.6 percent resulting in a 7.2 percent decline in United States production and a 3.6 percent increase in consumption. They also stated that United States net ethanol imports would increase by almost 200 percent and Brazil would increase its ethanol production by 9.1 percent. (Elobeid and Tokgoz 2006b) How will the United States trade balance be affected by ethanol? Petroleum imports account for approximately 35 percent of the United States current trade deficit. Some projections suggest that petroleum imports will rise to over 60 to 70 percent of the United States trade deficit in the next 10 to 20 years. In 2002 the United States spent just under $110 billion on foreign oil and with the recent increase in oil prices that total is certain to increase in upcoming years. If ethanol can replace gasoline the United States trade balance will be helped significantly. According to a 1997 study by the Kellogg School of Management, ethanol production improved the trade balance of the United States by approximately $2 billion that year alone.[13]

(NCGAc)

[13] Information can be obtained at http://www.ncga.com/ethanol/main/economics.htm but the date of the article is not known.

CHAPTER III

MODELING THE ETHANOL MARKET: THEORY AND METHODOLOGY

A. Modeling a Market

The main goal of this study is to analyze the ethanol market in order to gain some insight into its potential impact on United States fuel usage. In order to analyze the ethanol market a demand curve and supply curve will be estimated. Since a market involves the interaction between supply and demand in order to reach equilibrium, reduced form price and quantity models will be formulated by solving the demand and supply equations simultaneously using ordinary least squares (OLS) regression. This chapter will show and explain the theory and methodology behind formulating the reduced form price and quantity equations for the ethanol market. The concept of supply and demand will be explained first in order to understand the specific modeling of the ethanol market to follow.

Before the ethanol market can be evaluated, the general concepts of the demand and supply equations need to be introduced. The market demand function for good X can be expressed as a function of the price of that good (Px), the price of all other goods associated with that good i.e. complements (Pc) and substitutes (Ps) for good X, the tastes and preferences of the buyers (p), the number of consumers (nc), the income of the buyers (m), and any other factors (o) that may affect demand for that particular good.

The demand function for good X is:

$$X_D = f\,(Px \,|\, Ps, Pc, p, nc, m, o)$$

All factors do not affect the demand function the same, therefore, behavior assumptions will be addressed and explained with the use of partial derivatives. $\partial X_D/\partial Px$ is less than zero implying that the price of good X is negatively related to the demand of good X. $\partial X_D/\partial Pc$ is also less than zero implying a negative relationship between the price of a complement and the demand of good X. $\partial X_D/\partial Ps$, $\partial X_D/\partial p$, $\partial X_D/\partial nc$, and $\partial X_D/\partial m$ are all greater than zero implying a positive relationship between the price of a substitute, taste and preferences, number of consumers, income, and the demand of good X assuming good X is a normal good. Table 3.1 below summarizes the demand functions behavioral assumptions.

Table 3.1: Demand Function Behavioral Assumptions

Variable	Mathematical representation	Relationship	Explanation
Price good X (Px)	$\partial X_D/\partial Px < 0$	Negative	If Px increases demand for X decreases.
Price Substitute (Ps)	$\partial X_D/\partial Ps > 0$	Positive	If Ps increases demand for X increases.
Price Complement (Pc)	$\partial X_D/\partial Pc < 0$	Negative	If Pc increases demand for X decreases.
Taste and preferences (p)	$\partial X_D/\partial p > 0$	Positive	If p increases demand for X increases.
Number of consumers (nc)	$\partial X_D/\partial nc > 0$	Positive	If n increases demand for X increases.
Income (m)	$\partial X_D/\partial m > 0$	Positive	If m increases demand for X increases.

The producer's supply function for the same good X can be expressed as a function of the price of X (P_x), the cost of production including input prices (COP), the price of rival goods (P_r), the price of joint goods (P_j), technology (t), number of producers (np) and any other factors (o) that could affect supply for that particular good. Rival goods are goods that can be produced instead of good X. A joint good is a good that is produced along with good X. The supply function for good X is:

$$X_S = f\,(Px \mid COP, Pr, Pj, t, np, o)$$

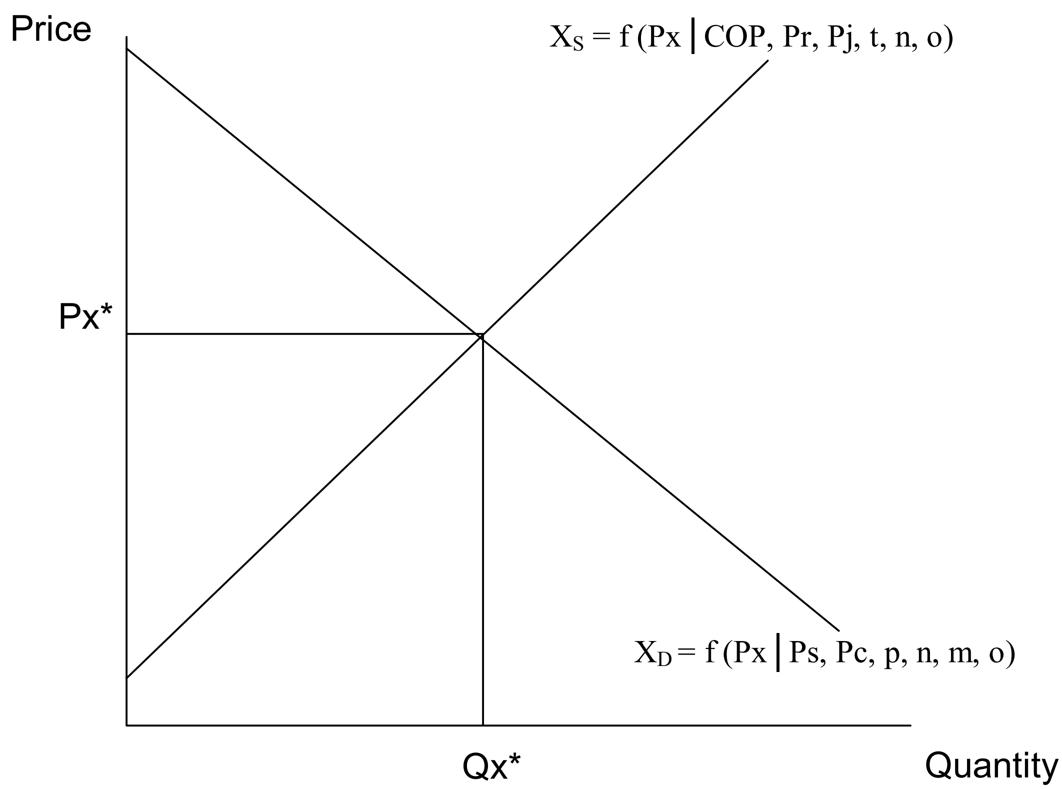
As is the case with the demand function, not all factors have the same affect on the supply function. $\partial Xs/\partial Px$ is greater than zero implying that the price of good X is positively related to the supply of good X. $\partial Xs/\partial COP$ and $\partial Xs/\partial Pr$ are less than zero implying a negative relationship between the price of an input or rival good and the supply of good X. $\partial Xs/\partial Pj$, $\partial Xs/\partial t$, and $\partial Xs/\partial np$ are greater than zero implying a positive relationship between the price of a joint good or technology and the quantity supply of good X. Table 3.2 below summarizes the supply functions behavioral assumptions.

Table 3.2: Supply Function Behavioral Assumptions

Variable	Mathematical representation	Relationship	Explanation
Price good X (Px)	$\partial Xs/\partial Px > 0$	Positive	If Px increases, supply for X increases.
Cost of production (COP)	$\partial Xs/\partial COP < 0$	Negative	If COP increases, supply for X decreases.
Price rival (Pr)	$\partial Xs/\partial Pr < 0$	Negative	If Pr increases, supply for X decreases.
Price joint (Pj)	$\partial Xs/\partial Pj > 0$	Positive	If Pj increases, supply for X increases.
Technology (t)	$\partial Xs/\partial t > 0$	Positive	If t increases, supply for X increases.
Number of producers (np)	$\partial X_S/\partial np > 0$	Positive	If n increases, supply for X increases.

Now that general supply and demand functions and their behavioral assumptions have been explained, market concepts can be discussed. On the graph below the X_S equation represents the supply curve and the all the factors that could affect it as explained in the supply function. The X_D equation represents the demand curve and all the factors that could affect it explained previously in the demand function. The equilibrium price and quantity are Px* and Qx* respectively.

Figure 3.1: Market Equilibrium for Good X



These demand and supply functions are simply functional representations of the demand and supply curves. The market demand curve can be defined as the graph depicting the relationship between the price of a certain commodity and the amount of it that consumers are willing and able to purchase at that given price holding all other arguments of the demand function constant. The market demand curve represents the (horizontal) sum of the individual's demand curves within the marketplace. By summing the individual demand curves, the market demand curve represents generic consumer attitudes towards good X. The law of demand states that when the price of a good rises the quantity demanded falls or when the price falls the quantity demanded rises, ceteris paribus. (Henderson 2002) This explains why the slope of the demand curve is downward sloping. The supply curve shows how much of a given commodity producers are willing to produce at a given price in the marketplace holding all other arguments of the supply curve constant. The market supply curve is the (horizontal) sum all producer supply curves within the marketplace. It tells the amount of good X that will be produced at various prices and represents all producers' attitudes in producing good X. The law of supply states that the supply curve is upward sloping implying that as the price of good X increases producers are willing to produce more of good X, ceteris paribus.

The point at which the supply and demand curves intersect is the equilibrium point**.** The equilibrium point establishes equilibrium quantity exchanged and equilibrium (market-clearing) price. Any price above the equilibrium price will leave surpluses since quantity supplied will exceed quantity demanded for the good. Any price below the equilibrium price will leave shortages since quantity demanded will exceed quantity supplied of the good. Market equilibrium is a condition where a market price is established through competition such that the amount of goods or services sought by buyers is equal to the amount of goods or services produced by sellers. The equilibrium price will remain constant unless there is a change in demand or supply.

The demand and supply curves will shift depending on the direction and magnitude of a change in any of the factors, other than product price, affecting the supply and demand functions above. For example, as long as good X is a normal good, the demand curve should shift outward (right) if there is an increase in income. This is because there is more money available to spend within the marketplace. If consumer preferences or expectations change in favor of good X the demand curve will shift outward. If the price increases for a complement good of good X or the price decreases for a substitute good the demand curve will shift inward (left). Shifts outward in the supply curve can arise if the price of inputs decreases, technology improves, producer expectations become positive, the price of a rival good decreases, or the price of a joint good increases.

There can also be movements along the demand and supply curves. This occurs when there is a change in the price of the good in question; the price of X in the functions above. The law of demand states that with all other factors held constant, if the price of good X increases quantity demanded for good X will decrease, i.e. a movement along the demand curve. The only way this could not be true for market demand is if the good was a “giffen good”. In order to be a “giffen good” the good in question must be an inferior good, there must be a lack of close substitute goods, and the good must constitute a substantial percentage of the consumer's income. E85 is not expected to be a giffen good since it is perceived to be a normal good and has a close substitute in gasoline. Before the structural and reduced form equations for the ethanol market are analyzed, there must be an explanation of how they were derived. Structural equations are simply a form of the supply and demand equations that describe the structure of the market for good X. Structural equations can be used to derive reduced form price and quantity equations. Since price and quantity are often jointly determined a substitution method is one method that can be used to create the reduced form equations. To better explain how reduced form price and quantity equations are derived a general example is listed below.[14] The general supply and demand structural equations are below.

(a) **Demand Equation:** Quantity = $a_0 + a_1Px + a_2Ps + a_3m + a_4Pc + a_5nc + a_6p + a_7o + e_1$

Where: $a_1<0$, $a_2>0$, $a_3>0$, $a_4<0$, $a_5>0$, $a_6>0$ and $a_7=?$

(b) **Supply Equation:** Quantity = $b_0 + b_1Px + b_2COP + b_3Pj + b_4Pr + b_5t + b_6np + b_7o + e_2$

Where: $b_1>0$, $b_2<0$, $b_3>0$, $b_4<0$, $b_5>0$, $b_6>0$ and $b_7=?$

(c) **Quantity Demanded = Quantity Supplied**

Since quantity and price are endogenous, they are jointly determined (in both the supply and demand equation). The variables price of a substitute (Ps), price of a complement (Pc), income (m), number of producers (np), consumers taste and preferences (p), cost of production (COP), price of a joint good (Pj), price of a rival good (Pr), technology (t), number of producers (np), and any other factor that affects either demand or supply (o) are exogenous, meaning they are determined outside the model. To get from the structural equations to the reduced form equations the demand and supply equations must be solved so as to express the endogenous variables (Px and X) in terms of the exogenous variables and parameters alone. Solving simultaneously first the price, we find the reduced form equations. Below is the reduced form price equation (d).

[14] This particular method of derivation is discussed in Damodar N. Gujarati's *Basic Econometrics* fourth edition on pages 737-738. (Gujarati 2003)

(d) Equilibrium Price = $(b_0-a_0)/(a_1-b_1) + b_2/(a_1-b_1)COP + b_3/(a_1-b_1)Pj + b_4/(a_1-b_1)Pr + b_5/(a_1-b_1)t + b_6/(a_1-b_1)np - a_2/(a_1-b_1)Ps - a_3/(a_1-b_1)m - a_4/(a_1-b_1)Pc - a_5/(a_1-b_1)nc - a_6/(a_1-b_1)p + (b_7-a_7)/(a_1-b_1)o$[15] $+ (e_2-e_1)/(a_1-b_1)$

By substituting the reduced form price equation (d) in either the structural equations (a or b) the reduced form quantity equation is obtained. The reduced form quantity equation (e) is below.

(e) Equilibrium Quantity = $(a_1b_0-a_0b_1)/(a_1-b_1) + a_1b_2/(a_1-b_1)COP + a_1b_3/(a_1-b_1)Pj$ $a_1b_4/(a_1-b_1)Pr + a_1b_5/(a_1-b_1)t + a_1b_6/(a_1-b_1)np - b_1a_2/(a_1-b_1)Ps - b_1a_3/(a_1-b_1)m - b_1a_4/(a_1-b_1)Pc - b_1a_5/(a_1-b_1)nc - b_1a_6/(a_1-b_1)p + (a_1b_7-a_7b_1)/(a_1-b_1)o$[16] $+ (a_1e_2-b_1e_1)/(a_1-b_1)$

The coefficients derived in the reduced form equations are important to the study because once they are combined with economic theory expected signs can be hypothesized. By using the signs that were derived from economic theory from the structural equations (a) and (b) above, the signs of the variables in the reduced form equation's coefficients can be hypothesized. Tables 3.3 and 3.4 below show the sign hypothesis of the general reduced form price and quantity equations.

[15] In this general case it is assumed that the variable other (o) affects both supply and demand.
[16] In this general case it is assumed that the variable other (o) affects both supply and demand.

Table 3.3: Sign Hypothesis for the General Reduced Form Price Equation

Variables	a and b price equation	price equation expected sign
Cost of production (COP)	$(b_2 /a_1 \text{-} b_1)$	(neg/neg)=pos
Price joint good (Pj)	$(b_3/a_1 \text{-} b_1)$	(pos/neg)=neg
Price rival good (Pr)	$(b_4/a_1 \text{-} b_1)$	(neg/neg)=pos
Technology (t)	$(b_5 /a_1\text{-}b_1)$	(pos/neg)=neg
Number of producers (np)	$(b_6/a_1\text{-}b_1)$	(pos/neg)=neg
Price substitute (Ps)	$\text{-}(a_2 /a_1\text{-}b_1)$	neg(pos/neg)=pos
Income (m)	$\text{-}(a_3/a_1\text{-}b_1)$	neg(pos/neg)= pos for normal
Price complement (Pc)	$\text{-}(a_4/a_1\text{-}b_1)$	neg(neg/neg)=neg
Number of consumers (nc)	$\text{-}(a_5/a_1\text{-}b_1)$	neg(pos/neg)=pos
Consumer tastes and preferences (p)	$\text{-}(a_6/a_1\text{-}b_1)$	neg(pos/neg)=pos
Other (o)	$(b_7\text{-}a_7/a_1\text{-}b_1)$	(?-?/neg)=?

Table 3.4: Sign Hypothesis for the General Reduced Form Quantity Equation

Variables	a and b price equation	price equation expected sign
Cost of production (COP)	$(a_1b_2 /a_1 \text{-} b_1)$	(neg*neg/neg)=neg
Price joint good (Pj)	$(a_1b_3/a_1 \text{-} b_1)$	(neg*pos/neg)=pos
Price rival good (Pr)	$(a_1b_4/a_1 \text{-} b_1)$	(neg*neg/neg)=neg
Technology (t)	$(a_1b_5 /a_1\text{-}b_1)$	(neg*pos/neg)=pos
Number of producers (np)	$(a_1b_6/a_1\text{-}b_1)$	(neg*pos/neg)=pos
Price substitute (Ps)	$\text{-}(b_1a_2 /a_1\text{-}b_1)$	neg(pos*pos/neg)=pos
Income (m)	$\text{-}(b_1a_3/a_1\text{-}b_1)$	neg(pos*pos/neg)= pos for a normal good
Price complement (Pc)	$\text{-}(b_1a_4/a_1\text{-}b_1)$	neg(pos*neg/neg)=neg
Number of consumers (nc)	$\text{-}(b_1a_5/a_1\text{-}b_1)$	neg(pos*pos/neg)=pos
Consumer tastes and preferences (p)	$\text{-}(b_1a_6/a_1\text{-}b_1)$	neg(pos*pos/neg)=pos
Other (o)	$(a_1b_7\text{-}a_7b_1)/(a_1\text{-}b_1)$	(neg*?-?*pos)/neg)=?

The sign hypothesis for the reduced form equations for this general market are derived using the positive or negative relationship status of each individual variable obtained from the structural equations (a) and (b) explained previously in this chapter.

Economic theory can be used to confirm that the mathematics explained above make sense.[17] The variable cost of production (COP) is positive in the reduced form price equation and negative in the reduced form quantity equation. Economic theory suggests that if the cost of production increases the price of good X should also increase because it becomes more expensive to produce good X confirming a positive coefficient of the cost of production variable in the reduced form price equation. The negative coefficient on the cost of production variable is also consistent with economic theory because if it becomes more expensive to produce good X producers will have to cut production in order to compensate for increased cost. The variable price of a joint good (Pj) is negative in the reduced form price equation and positive in the reduced form quantity equation. If the price of a good that is produced along with good X increases producers will increase production in order to gain from the higher market price of the joint good but the price of good X is expected to fall due to this increase in supply. The reduced form price equation suggests a positive coefficient on the variable price of a rival good (Pr) while the reduced form quantity equation suggests a negative coefficient. In this case it is expected that producers will reduce supply of good X because more producers will shift their production from good X to its rival good in order to gain from its higher market price. This decrease in supply will cause the price of good X to increase implying that an increase in the price of a rival good should in fact cause a negative coefficient in the reduced form quantity equation and a positive coefficient in the reduced form price equation. The Technology (t) variable is negative in the reduced form price equation and positive in the reduced form quantity equation. An improvement in technology is

[17] All individual variables theory and expect signs assume all other variables are held constant.

expected to increase supply because producers are able to produce either at a lower cost or produce more for the same cost. This increase in the supply of good X will lower the price of good X implying a negative coefficient for technology on the reduced form price equation and a positive coefficient on the reduced form quantity equation. The number of producers (np) variable is negative in the reduced form price equation and positive in the reduced form quantity equation. If the number of producers increases supply will increase because there are simply more producers producing good X. Since the market supply curve is a horizontal summation of all individual supply curves, more individual producer supply equal increased market supply. This increased supply will cause quantity to increase and price to decrease for good X implying a negative relationship between the number of producers and the price of good X and a positive relationship between the number of producers and the quantity of good X. The price of substitute (Ps) variable is expected to be positive in both reduced form equations. If the price of a substitute of good X increases more consumers will demand good X because it has become relatively less expensive. This increase in demand will cause both the quantity and price of good X to increase implying a positive coefficient on the price of a substitute variable in both reduced form equations. There is a positive relationship between income (m) and both the price and quantity of good X assuming good X is a normal good. If a consumers income increases, demand for all normal goods including good X will increase causing both the quantity and price of good X to increase confirming a positive relationship between income and both the price and quantity of good X. The coefficient on the price of a complement (Pc) variable is negative in both reduced form equations. If the price of a complement to good X increases consumers will demand less of good X because it becomes relatively more expensive. This decrease in demand will cause both the quantity and price of good X to decrease. This is why the coefficients in both reduced form equations for the price of a complement variable are negative. The variable number of consumers (nc) is positive in both reduced form equations. Economic theory simply suggests that more consumers cause increased demand. Since the market demand curve is a horizontal summation of all individual demand curves, more individual demand equal increased market demand. This increased demand will cause both quantity and price of good X to increase. The coefficient on the variable consumer taste and preferences (p) is positive in both reduced form equations. If consumer's attitude toward good X becomes positive either through advertising or any other reason, demand for good X is expected to increase. This will cause both the price and quantity to increase implying a positive coefficient for consumer taste and preferences in both reduced form equations. The other (o) variable varies depending on the conditions of the factor affecting the market for good X.

B. Modeling the Ethanol Market

The ethanol market has erupted over the last ten years due to the "oil crises". Because of this, the main component of the ethanol market is based around gasoline. Gasoline prices have two effects on the ethanol market. Current gasoline prices act as a substitute to E85. Lagged gasoline prices act as a cost of production or input price. Other components of the ethanol market include corn prices, soybean prices, corn gluten feed prices, average income, flexible fuel vehicles, and speeches. Corn prices act as a cost of production or input price since corn is the main feedstock used in United States ethanol production. Soybean prices act as a rival good to ethanol since soybeans are a farmers best alternative to corn, the main component of ethanol production. Corn gluten feed prices act as a joint good in ethanol production because it is made along with ethanol in the production process. A change in average income will affect the ethanol market in that, if ethanol is a normal good, an increase in income will cause the demand for ethanol to increase. The quantity of flexible fuel vehicles act as a representation of consumer taste and preferences in the demand equation since they consist of the number of flexible fuel vehicles being driven and not flexible fuel vehicle prices. The quantity of flexible fuel vehicles act as a measure of producer expectations in the supply equation. Finally, another factor that affects both the supply and demand of ethanol is presidential speeches. The speeches variable is specified as a dummy variable and measures the affect the presidents' mentioning of ethanol in his state of the union addresses has on the ethanol market. It represents a consumer's tastes or preference change in the demand function and producers expectations in the supply function which fall under the category "other" in the general case mentioned previously in this chapter. `

The ethanol market will be modeled using the general method discussed previously in this chapter. The structural equations used to evaluate the ethanol market are stated in equations one and two below. The structural equations are followed by Table 3.5 representing the sign hypothesis of each coefficient.

(1) Demand (E85): Quantity of E85 = a_0 + a_1 Price of E85 + a_2 Price of Gasoline + a_3 Income + a_4 Flexible Fuel Vehicles + a_5 Speeches +μ_1

(2) Supply (E85): Quantity of E85= $b_0 + b_1$ Price of E85 + b_2 Price of Corn Gluten Feed + b_3 Price of Soybeans+ b_4 Price of Corn + b_5 Lagged Price of Gasoline + b_6 Speeches + b_7 Flexible Fuel Vehicles + μ_2

Table 3.5: Sign Hypothesis for the Ethanol Market's Structural Equations

Variable	Coefficient	Sign hypothesis
Price $E85_D$	a_1	Negative
Price Gasoline	a_2	Positive
Income	a_3	Positive
Flexible Fuel $Vehicles_D$	a_4	Positive
Speeches	a_5	Positive
Price $E85_S$	b_1	Positive
Price Corn Gluten Feed	b_2	Positive
Price Soybeans	b_3	Negative
Price Corn	b_4	Negative
Lagged Price Gasoline	b_5	Negative
Speeches	b_6	Positive
Flexible Fuel $Vehicles_S$	b_7	Positive

The coefficient on the price of E85 in the demand equation (a_1) is expected to be negative because consumers will demand less E85 if it becomes more expensive. The coefficient on the price of E85 in the supply equation (b_1) is expected to be positive because producers will increase production to capitalize on rising E85 prices. The coefficient on the price of gasoline (a_2) is expected to be positive because consumers will demand more E85 since an increase in gasoline prices will cause E85 to become relatively cheaper as a fuel. The average income coefficient (a_3) is expected to be positive since consumer demand will increase with an increase in spending power. The coefficient on the price of corn gluten feed (b_2) is expected to be positive since a rise in the price of ethanol's joint good should give producers the incentive to increase production to gain from the higher market price. The coefficient on the price of soybeans (b_3) is expected to be negative because a rise in soybean prices should give farmers the incentive to plant more soybeans and less corn for ethanol production in order to gain from the higher market price. The coefficient on the price of corn (b_4) and lagged gasoline prices (b_5) are costs of production and are expected to be negative since a rise in cost will cause a decrease in production. The coefficients on the flexible fuel vehicles variable (a_4 in the demand equation, b_7 in the supply equation) are expected to be positive. A rise in the quantity of flexible fuel vehicles being driven should cause consumers to increase demand since it represents a positive trend in consumer taste and preferences. It should also cause producers to increase production due to greater expectations. The coefficient on the speeches variable (a_5 in the demand equation, b_6 in the supply equation) should be positive because the president is expected to have a positive impact on ethanol demand and production.

Data used in this study includes monthly data for the years 2000 to 2005 for the entire United States, a total of 72 observations. More detailed information on all data and variables are explained in the following paragraphs.

The dependant variable in both supply and demand equations is ethanol quantity. Monthly United States data on ethanol quantities does not currently exist but annual data can be obtained.[18] The state of Minnesota is currently the only state that tracks monthly ethanol quantities.[19] In order to transform yearly United States quantities to monthly

[18] United States yearly E85 quantities were obtained from the Biomass Energy Data Book located on the United States government's Center for Transportation Analysis website.
[19] Minnesota monthly E85 quantities were obtained from Minnesota's Department of Commerce website.

quantities a simple OLS (ordinary least squares) regression was used. United States yearly quantities were regressed against the state of Minnesota's monthly quantities in order to get a constant term and coefficient to best predict United States monthly quantities. This will represent United States data well since Minnesota is one of the largest providers of E85 and its trends in quantity should mirror United States trends. Price data on E85 consists of Minnesota E85 prices, not United States prices.[20]

This data was used as a proxy variable because the state of Minnesota is the only state that tracks the price of E85. Prices are calculated by averaging all prices reported by E85 stations every month. Most but not all stations report prices. Since Minnesota is one of the largest suppliers of E85 in the United States, Minnesota price data should accurately represent United States prices. The price of E85 is in both the supply and demand equation because the price of the good in question affects both quantity supplied and quantity demanded. The signs of the coefficients on the price of E85 are the most important to this study. The coefficients are a_1 in the demand equation and b_1 in the supply equation. Assuming E85 is not a "giffen good", when the price of E85 increases the quantity demanded of ethanol will decrease according to the law of demand. This means a_1 should be negative. For b_1, as the price of E85 increases the quantity supplied of ethanol should also increase according to the law of supply. This implies that b_1 should be positive. Thus, the overall sign of the difference $(a_1 - b_1)$ should be negative.

Gasoline price data consists of the average monthly price of regular conventional grade gasoline.[21] Gasoline prices are represented by cents per gallon. The main issue with gasoline is to find out the relationship between gasoline and E85. Since E85 is

[20] Minnesota monthly E85 prices were obtained from Minnesota's Department of Commerce website.
[21] Gasoline prices were obtained from the United States Department of Energy Website.

made up of 85% ethanol and 15% gasoline, gasoline is an input cost, and hence a supply variable. On the other hand, since gasoline is currently the main fuel used in the United States it also acts as a substitute to E85 and hence a demand variable. This is why current and lagged gasoline prices are used in this study. Lagged gasoline prices are used as an input cost in the supply equation under the assumption that the gasoline input into E85 comes from an inventory purchased in the previous month. Since it is expected that current gasoline consumption is a substitute for current E85 consumption, current gasoline prices are in the model to act as a substitute in the demand equation. The coefficient of current gasoline prices is represented by a_2. The sign should be positive representing increased demand for E85 as the price of gasoline increases. The argument is that if the price of gasoline increases, consumers will shift consumption from gasoline toward E85 in order to avoid paying a higher price for gasoline. The coefficient of lagged gasoline prices is represented by b_5. It should be negative representing a decrease in supply with an increase in last month's gasoline prices. This is because lagged gasoline is expected to act as an input cost and if an input price increases, producers will not be able to produce as much E85.

The coefficient of the income variable is represented by a_3. It consists of the total private average earnings of workers in the United States.[22] This data consisted of weekly data but was converted to monthly data to be consistent with the other variables.[23] It is placed into the demand equation because as income increases an individual is willing and able to purchase more E85, since E85 is expected to be a normal good. If E85 is a

[22] Income data was obtained from the Bureau of Labor Statistics (BLS) website.

[23] In order to scale the weekly income data to monthly data every week in each month was averaged together then multiplied by 4 1/3 weeks (average weeks in a month). Then the Bureau of Labor Statistics inflation calculator was used to convert these averages from 1982 dollars to 2005 dollars.

normal good then higher income will lead to greater demand making a_3 positive.

The coefficients on the flexible fuel vehicles variable are represented by a_4 in the demand equation and b_7 in the supply equation. The flexible fuel vehicle variable represents the number of flexible fuel vehicles on the road in the United States.[24] Monthly data does not exist so yearly data was converted to monthly data in order to be consistent with all other variables.[25] Flexible fuel vehicles are in the demand equation because they represent consumer's tastes and preferences towards E85. Flexible fuel vehicles are in the supply equation to represent producer expectations. Flexible fuel vehicles can run on gasoline, ethanol, or a mixture of the two (E85). The sign of the coefficient on flexible fuel vehicles in the demand equation, a_4, is positive and the sign of the coefficient on flexible fuel vehicles in the supply equation, b_7, is also positive. Demand is a function of prices, and since there is no price data available on flexible fuel vehicles, quantity sold (exchanged) is used in the model. Because of this, flexible fuel vehicles do not act as a complement to ethanol production; instead they represent future expectations for producers and taste and preferences for consumers. If more flexible fuel vehicles are being driven producers expectations will increase causing more ethanol to be produced. If more flexible fuel vehicles are being bought and driven, it represents a positive trend in consumer taste causing the demand for ethanol to increase.

The speeches variable is represented by a_5 in the demand equation and b_6 in the supply equation. It is used as a dummy variable in which a one is used for any year President George W. Bush mentions ethanol by name in his State of the Union Address

[24] Data on flexible fuel vehicles was obtained from the United States Department of Energy Website.
[25] Using OLS, all yearly flexible fuel quantities were regressed on an exponential time trend. The time trend consisted of 72 months. The resulting monthly values from the OLS regression were used in this study.

and a zero for every year he does not.[26] It is put into the demand and supply equation because both consumers and producers see the speeches. If ethanol is mentioned, supply and demand are both expected to increase making a_5 and b_6 positive.

The effect of the price of soybeans is represented by b_3. Soybean prices are in the supply equation because soybeans act as a rival good in corn production, which is the main feedstock and input for ethanol production in the United States.[27] Farmers have the option of planting soybean on land where corn could be planted. Below are land usage maps of the four major crops in the United States; corn, soybeans, wheat, and hay. The maps below suggest that soybeans are the best choice for a rival good of ethanol production rather than hay or wheat because they are planted in the same areas as corn in high quantities. Since soybean is a rival good, b_3 is expected to be negative because an increase in the price of soybean will give farmers an incentive to move production away from corn and towards soybeans. The price of soybeans variable enters the models with a five month lag. This is because it takes four months to grow a crop of corn and effects of the soybean market on the corn market should not take effect until after the current crop is harvested.

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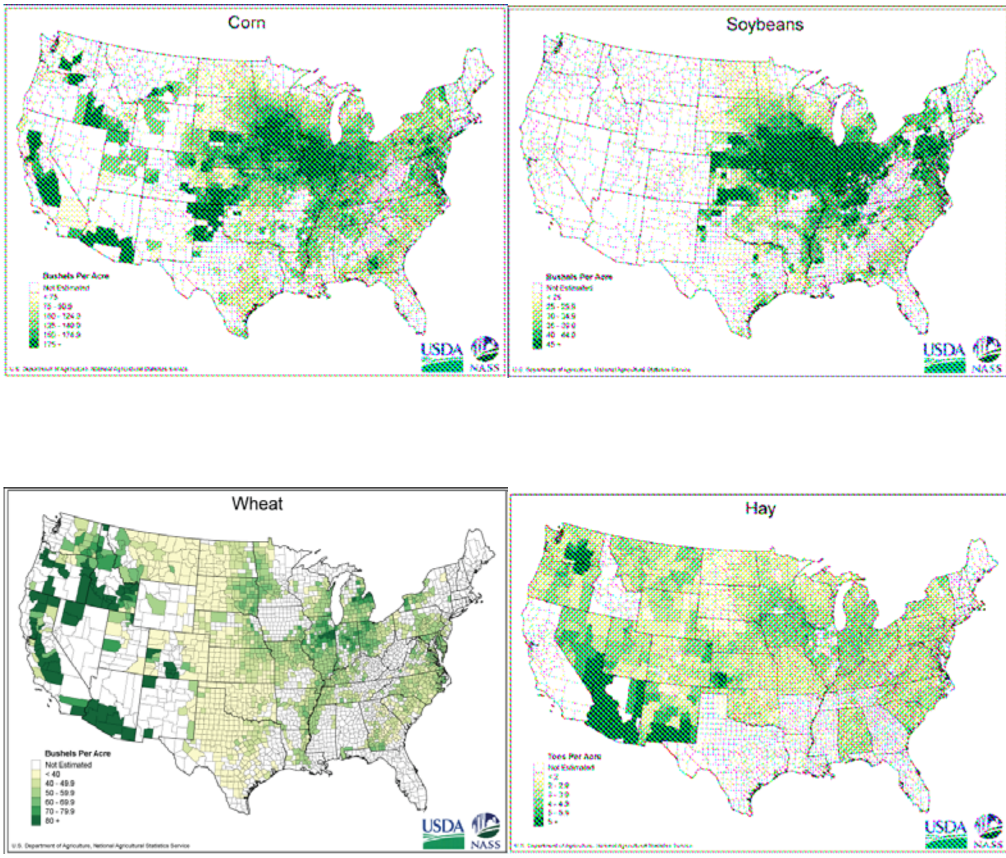
[26] A table of State of the Union Address energy quotes, year, and president can be found in Appendix A.
[27] Price data on soybean was obtained from the United States Department of Agriculture (USDA) website under the national agriculture statistics service (NASS) section. Prices came from the monthly prices received table and units consist of dollars per bushel.



[28]

The price of corn gluten feed is put into the supply equation because corn gluten feed is a joint good of ethanol since it is a by-product of ethanol production.[29] As mentioned in chapter two, 2.7 gallons of ethanol and 11.4 pounds of corn gluten feed can be produced from one bushel of corn. Corn gluten feed is the number one co-product of ethanol production. The effect of the price of corn gluten feed variable is represented by b_3. The sign of the coefficient is expected to be positive representing an increase in the supply for ethanol with an increase in the price of corn gluten feed. The rationale behind this is that ethanol producers will have an incentive to produce more ethanol, and hence

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[28] All maps are located in the Biomass Energy Data Book located on the United States Government's Center for Transportation Analysis website and are based on 2004 land use data.

[29] Corn gluten feed prices were obtained from the United States Department of Agriculture (USDA) website in table four of the Feed Outlook documents from January 2000 to July 2006. Prices are represented in dollars per ton.

more corn gluten feed if they can receive a higher market price for corn gluten feed. The price of corn gluten feed variable enters the models with a five month lag for the same reason as the price of soybeans. Corn farmers cannot respond instantaneously to a price increase in corn gluten feed because they already have a crop in the field. They are forced to wait until that crop is harvested to take advantage of the corn gluten feed price increase. Since corn gluten feed is made from corn this applies.

The price of corn is in the supply equation to represent a cost of production, or an input price, of ethanol production.[30] The coefficient for the price of corn is represented by b_4. The expected sign should be negative showing that as the price of corn increases quantity supplied of ethanol should decrease because production becomes more expensive. Corn prices are not lagged since corn harvested is immediately put into ethanol production or sold as feed at the going price.

With the variables introduced and economic theory explained, the ethanol market's reduced form equations and sign hypothesis can be discussed. The price of E85 affects both the demand and the supply side of the ethanol market as shown in the structural equations. Because of this, a substitution method can be used to transform the quantity demanded and quantity supplied structural equations into a reduced form price equation for E85. This procedure is explained in detail previously in this chapter. The price equation (3) represents the reduced form equation derived from the structural equations (1) and (2). The price equation is estimated to determine whether or not there

[30] Price data on corn was obtained from the United States Department of Agriculture (USDA) website under the national agriculture statistics service (NASS) section. Prices came from the monthly prices received table and units consist of dollars per bushel.

will ever be a financial incentive given to consumers to switch from gasoline to E85 as a primary motor fuel. The price equation is as follows:

(3) Equilibrium Price (E85) = (b_0-a_0/a_1-b_1) + (b_2 /a_1-b_1) Price of Corn Gluten Feed + (b_3 /a_1-b_1) Price of Soybeans + (b_4 /a_1-b_1) Price of Corn + (b_5 /a_1-b_1) Lagged Price of Gasoline + (b_6-a_5/a_1-b_1) Speeches - (a_2 /a_1-b_1)Price of Gasoline - (a_3/a_1-b_1) Income - (b_7-a_4/a_1-b_1) Flexible Fuel Vehicles + (μ_2-μ_1/a_1-b_1)

In order to get there reduced form quantity equation the reduced form price equation (3) is substituted into either structural equation (1) or (2) in this case it is substituted into the demand structural equation (1). After terms are multiplied, the reduced form quantity equation simplifies to equation (4) below.

(4) Equilibrium Quantity (E85) = (a_1b_0-a_0b_1/a_1-b_1) + (a_1b_2 /a_1-b_1) Price of Corn Gluten Feed + (a_1b_3 /a_1-b_1) Price of Soybeans + (a_1b_4 /a_1-b_1) Price of Corn + (a_1b_5 /a_1-b_1) Lagged Price of Gasoline + (a_1b_6-a_5b_1/a_1-b_1) Speeches – (b_1a_2/a_1-b_1) Price of Gasoline – (b_1a_3/a_1-b_1) Income + (a_1b_7-b_1a_4/a_1-b_1) Flexible Fuel Vehicles + ($a_1\mu_2$ – $b_1\mu_1$/a_1-b_1)

With the reduced form equations specified, the next step is to explain the sign hypothesis. Determining the expected signs of the coefficients is important because that is what conclusions are based on. The hypothesized signs of the coefficients are concluded from economic theory explained in the variable descriptions earlier in this chapter and will act as a guide to help interpret the empirical results. Tables 3.6 and 3.7 below show the expected signs of the reduced form equations for the ethanol market.

Table 3.6: Expected Signs for the Equilibrium Price Equation

Variables	a and b price equation	price equation expected sign
Price of Corn Gluten Feed	$(b_2 /a_1\text{-}b_1)$	(pos/neg)=neg
Price of Soybean	$(b_3/a_1\text{-}b_1)$	(neg/neg)=pos
Price of Corn	$(b_4/a_1\text{-}b_1)$	(neg/neg)=pos
Lagged Price of Gasoline	$(b_5 /a_1\text{-}b_1)$	(neg/neg)=pos
Price of Gasoline	$-(a_2 /a_1\text{-}b_1)$	Neg(pos/neg)=pos
Income	$-(a_3/a_1\text{-}b_1)$	Neg(pos/neg)= pos for normal
Flexible Fuel Vehicles	$(b_7\text{-}a_4/a_1\text{-}b_1)$	(pos-pos/neg)=?
Speeches	$(b_6\text{-}a_5/a_1\text{-}b_1)$	(pos-pos/neg)=?

Table 3.7: Expected Signs for the Equilibrium Quantity Equation

Variables	a and b quantity equation	quantity equation expected sign
Price of Corn Gluten Feed	$(a_1b_2 /a_1\text{-}b_1)$	neg*pos/neg=pos
Price of Soybean	$(a_1b_3 /a_1\text{-}b_1)$	neg*neg/neg=neg
Price of Corn	$(a_1b_4 /a_1\text{-}b_1)$	neg*neg/neg=neg
Lagged Price of Gasoline	$(a_1b_5 /a_1\text{-}b_1)$	neg*neg/neg=neg
Price of Gasoline	$-(b_1a_2/a_1\text{-}b_1)$	neg*pos*pos/neg=pos
Income	$-(b_1a_3/a_1\text{-}b_1)$	neg*pos*pos/neg=pos
Flexible Fuel Vehicles	$(a_1b_7\text{-}b_1a_4/a_1\text{-}b_1)$	(neg*pos)-(pos*pos)/neg=pos
Speeches	$(a_1b_6\text{-}a_5b_1/a_1\text{-}b_1)$	(neg*pos)-(pos*pos)/neg=pos

C. Methodology

Ordinary least squares (OLS) regression analysis was the initial method used in estimating the reduced form price and quantity equations for the ethanol market. OLS is defined as a method for linear regression that determines the values of unknown quantities in a statistical model by minimizing the sum of the residuals (the difference between the predicted and observed values) squared. (Gujarati 2003) The OLS approach was used in this regression analysis because it has been shown to be optimal. It is optimal because it satisfies the Gauss-Markov theorem. The Gauss-Markov theorem states that least squares estimators are BLUE (Best Linear Unbiased Estimators) in nature. "It (estimator) is linear, that is, a linear function of a random variable, such as the dependent variable in the regression model. It is unbiased, that is, its average or expected value is equal to the true value. It has minimum variance in the class of all such linear unbiased estimators; an unbiased estimators." (Gujarati 2003) This is true under the assumptions that the error terms are expected to be zero, have a constant variance, and are uncorrelated with one another. Reduced form equations were used in this study instead of using a traditional structural equation system because using reduced form equations eliminates the simultaneity bias that would occur when estimating the market supply and demand equations, and, more importantly, because we are interested in the market equilibrium prices and quantities exchanged of E85. With the simultaneity bias removed, estimating the reduced form equation with OLS is optimal. The reduced form price equation makes it easy to conclude whether or not E85 can ever replace gasoline as the United States primary motor fuel by evaluating the direction and magnitude of the coefficients on each variable.

CHAPTER IV

EMPIRICAL ESTIMATES OF THE ETHANOL MARKET MODEL

Initial results obtained from standard OLS regression estimation using contemporaneous prices and quantities saw a problem with heteroscedasticity and autocorrelation. A positive Breusch-Pagan test suggested that heteroscedasticity did exist in the model.[31] Depending on its nature, heteroscedasticity can result in t-statistics being either over or underestimated, ultimately causing a variable to appear to be either statistically significant when it may not be or not statistically significant when it actually is significant. In an attempt to correct this problem, all data was put into logarithmic form. This helped but did not correct for heteroscedasticity indicating that the model still does not satisfy the OLS requirement that the error terms must have a constant variance.[32] In a third attempt to correct for heteroscedasticity, Newey- West Standard Errors will be used. This is explained below.

Along with heteroscedasticity, autocorrelation had existed in the model. The Durbin-Watson statistic showed that there was a problem with autocorrelation, a common

[31] The Breusch-Pagan Statistic was 13.55 in the reduced form price equation and 18.68 in the reduced form quantity equation proving heteroscedasticity did exist in both initial models. For more information on the Breusch-Pagan test for heterscedasticity see (Gujarati 2003) p.411-412.
[32] The Breusch-Pagan Statistic after the models were logged was still 11.68 for the price equation and 8. 44 in the quantity equation proving that heterscedasticity still exists in both models.

problem with time-series data.[33] Autocorrelation occurs when the error terms are correlated with one another, a violation of OLS assumptions. Autocorrelation will often lead to OLS standard errors being underestimated and t-statistics being overestimated. This will cause type one error in which the null hypothesis of a coefficient being statistically different from zero is rejected when it is actually true making a coefficient appear statistically significant when it is not significant. Newey-West Standard Errors (also known as heteroscedasticity- and autocorrelation-consistent standard errors) provide consistent estimates of the true OLS standard errors; the traditional formulas yield inconsistent estimates in the presents of heteroscedasticity or autocorrelation. Newey-West Standard Errors with a two period lag were used in order to correct for both heteroscedasticity and autocorrelation.[34] Newey-West Standard Errors are valid in relatively large samples and are valid in this study.

After autocorrelation and heteroscedasticity were accounted for, a Ramsey RESET test proved that there was a problem with specification error.[35] If a model has specification error the coefficients become biased, inconsistent, and inefficient because of the violation of OLS assumptions. These problems will cause unreliable results. Specification error could mean a few different problems may be wrong with the model. The first possibility is that the model could not be in correct functional form. After changing functional forms and still failing the RESET test in both reduced form equations, incorrect functional form proved not to be the problem with this particular

[33] A Durbin-Watson statistic of 2 indicates no autocorrelation. If the Durbin-Watson statistic is substantially less than 2, there is evidence of a positive correlation. If the Durbin-Watson statistic is substantially more than 2, there is evidence of a negative correlation. The Durbin-Watson Statistic in the reduced form price equation was 1.25 and .76 in the reduced form quantity equation showing positive correlation. For more details concerning the Durbin-Watson Statistic see (Gujarati 2003) p.467-470.
[34] The Newey-West standard error method is discussed in Greene, op. cit, Fourth edition, p. 462-463.
[35] The Ramsey RESET is discussed in (Gujarati 2003) p.521-523.

model. A second possibility is error in measurement. After analyzing the data for possible errors it proved that there were no avoidable errors in measurement. A third possibility is that there are omitted variables in the model. A good possibility of omitted variables lies in seasonality. Gasoline, E85, and agricultural prices may be affected by the season but all season dummy variables proved to be insignificant and still failed the RESET test. Many other variables were found and placed into the model but all proved to be statistically insignificant and none resulted in a pass of the RESET test. After all these results, perhaps a non-constant variance in the model was the problem.

To remedy this differently, a multiplicative heteroscedasticity regression estimation approach was used to obtain the reduced form equation's maximum likelihood estimates.[36] The variance function estimated will include the time trend variable (1-72) as well as the subsidy variable. The subsidy variable accounts for all changes in the ethanol subsidy between the years of this study (2000-2005). Using this multiplicative heteroscedasticity regression estimation approach, both the reduced form price equation and the reduced form quantity exchanged equation pass the Ramsey RESET test signaling correct model specification. Once the model was specified correctly, another problem often associated with time-series data, stability, was addressed. A Dicky-Fuller

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[36] The multiplicative heteroscedasticity approach gives parameter estimates that are maximum-likelihood estimates. A regression and variance function is estimated in the model. The logarithm of the variance is assumed to be a function of a different set of explanatory variables which may or may not appear in the regression function. The first step of this method is estimating the regression function by using ordinary least-squares (OLS) and then saving the residuals. These residuals are then squared and logged. These adjusted residuals become the dependent variable for the variance function and are estimated by OLS. The predicted values from this variance function are then used as weights in a generalized least-squares (GLS) estimation of the regression function. The residuals are once again kept, squared, logged, and act as the dependent variable for a new estimation of the variance function. Iteration between estimates of the regression function and variance function continue until the coefficients of the two models stabilize and converge. When this stabilization and convergence occurs, the parameter estimates are the maximum-likelihood estimates presented later in this chapter. This method is mathematically explained in (Greene 2003) p. 232-235.

test was run on both price and quantity models and showed that both models were stable.[37] Table 4.1 shows the maximum likelihood estimates of the reduced form price equation as well as the variance function for the reduced form price equation and Table 4.2 reports the maximum likelihood estimates of the reduced form quantity exchanged equation as well as the variance function for the reduced form quantity exchanged equation.

Table 4.1: Maximum Likelihood Estimators for Reduced Form Price Equation

Variable	Coefficient	Standard Error	T-statistic[38]
Constant	-2.806	6.079	-0.462
Price of Corn Gluten Feed	-0.054	0.023	-2.318**
Price of Soybean	0.163	0.066	2.469**
Price of Corn	0.129	0.069	1.872*
Price of Gasoline	0.947	0.115	8.266***
Lagged Price of Gasoline	-0.07	0.108	-0.652
Income	0.05	0.769	0.065
Flexible Fuel Vehicles	-0.195	0.063	-3.11***
Speeches	0.043	0.044	0.988

Variance Function

Variable	Coefficient	Standard Error	T-statistic
Sigma	0.228	0.193	0.118
Time	-0.053	0.013	-3.913***
Subsidy	-106.544	31.24	-3.41***

R2: .897
Adj. R2: .884
F-Statistic: 68.69
Observations: 72

[37] The t-statistics of 2.83 in the price model and 3.21 in the quantity model suggest that both models are stable.
[38] The significance levels of ten, five, and one percent are represented by one, two, and three asterisks respectively.

All variables in the reduced form price equation were statistically significant except for lagged gasoline prices, income, and speeches. The price of gasoline and the quantity sold of flexible fuel vehicles were the only two variables significant at the one percent level but the price of corn gluten and the price of soybean were significant at the five percent level. The price of corn just missed being significant to the five percent level but is significant at the ten percent level. All variables signs match the sign hypothesis in Table 3.6 and are consistent with economic theory except for lagged gasoline prices which proved to be statistically insignificant. More details on the results of each variable will be explained after the reduced form quantity equation results are stated on the next page.

Table 4.2: Maximum Likelihood Estimators for Reduced Form Quantity Equation

Variable	Coefficient	Standard Error	T-statistic[39]
Constant	-9.603	5.575	-1.722*
Price of Corn Gluten Feed	0.155	0.027	5.745***
Price of Soybean	-0.381	0.07	-5.444***
Price of Corn	-0.251	0.09	-2.795***
Price of Gasoline	0.616	0.098	6.303***
Lagged Price of Gasoline	-0.268	0.098	-2.738***
Income	2.338	0.724	3.228***
Flexible Fuel Vehicles	0.96	0.064	15.04***
Speeches	-0.11	0.058	-1.885*

Variance Function

Variable	Coefficient	Standard Error	T-statistic
Sigma	0.171	0.144	0.118
Time	0.087	0.013	6.485***
Subsidy	86.084	31.24	2.756***

R2: .939
Adj. R2: .931
F-Statistic: 121.74
Observations: 72

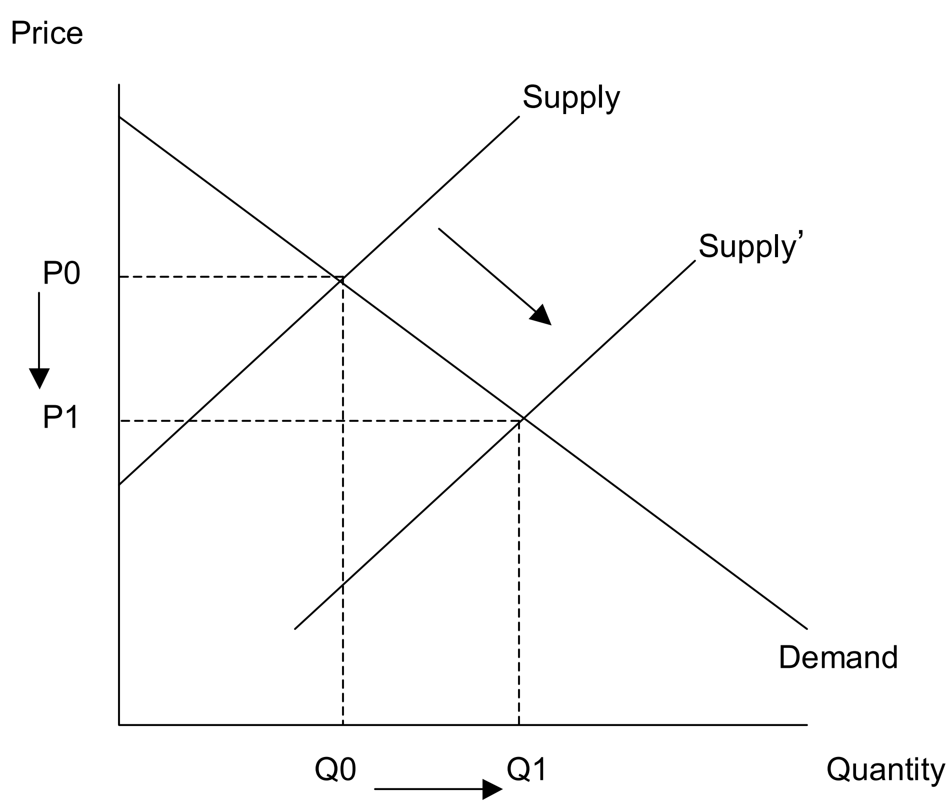
All variables in the reduced form quantity equation were statistically significant at the one percent level of significance except for speeches, which was significant at the ten percent level. All variables signs match the sign hypothesis in Table 3.7 and are consistent with economic theory except for the dummy variable speeches. More details on the results of each variable in both reduced form equations will be discussed below.

The price of corn gluten feed is expected to be negative in the price equation and positive in the quantity equation. The derivations of the expected signs for all variables

[39] The significance levels of ten, five, and one percent are represented by one, two, and three asterisks respectively.

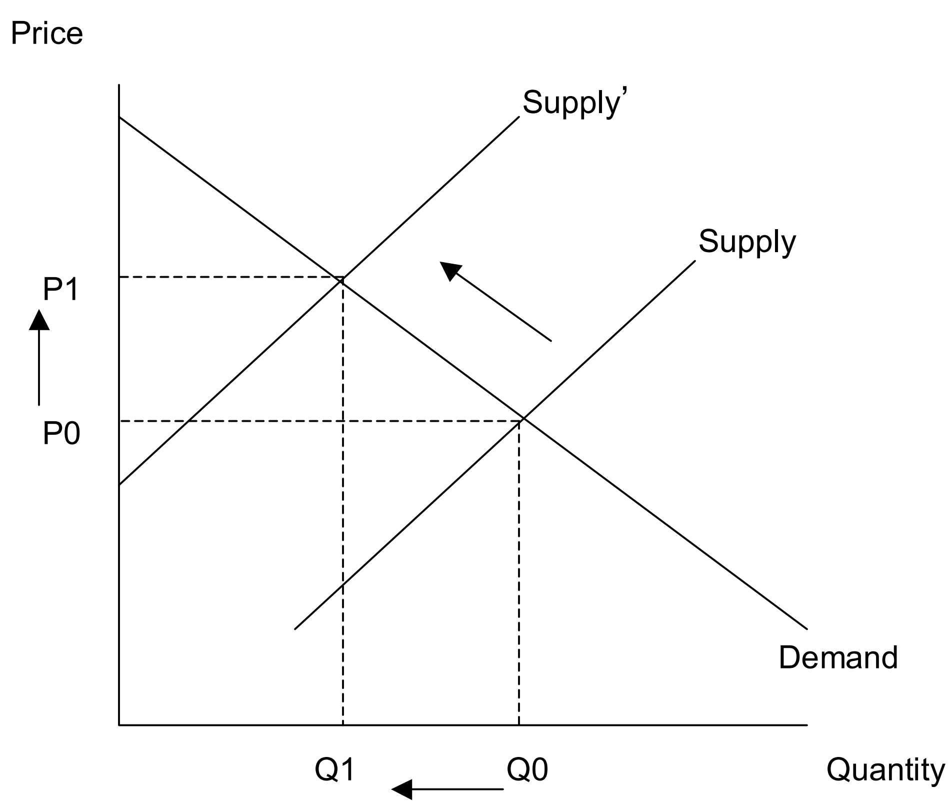
are shown mathematically in chapter three. The equations for the expected signs are shown in Tables 3.6 and 3.7. The idea for corn gluten feed is that ethanol producers will produce more ethanol if they can receive a higher market price for its co-product, corn gluten feed. This will increase the supply of ethanol causing equilibrium price to decrease and equilibrium quantity to increase with an increase in the price of corn gluten feed. A graphical representation of this is shown below. This is exactly what happens in both the equilibrium price and quantity models. A ten percent increase in the price of corn gluten will decrease the equilibrium price of ethanol by .54 percent and increase the equilibrium quantity of ethanol by 1.55 percent.

Figure 5.1: The Effects of Corn Gluten Feed Prices on The Ethanol Market



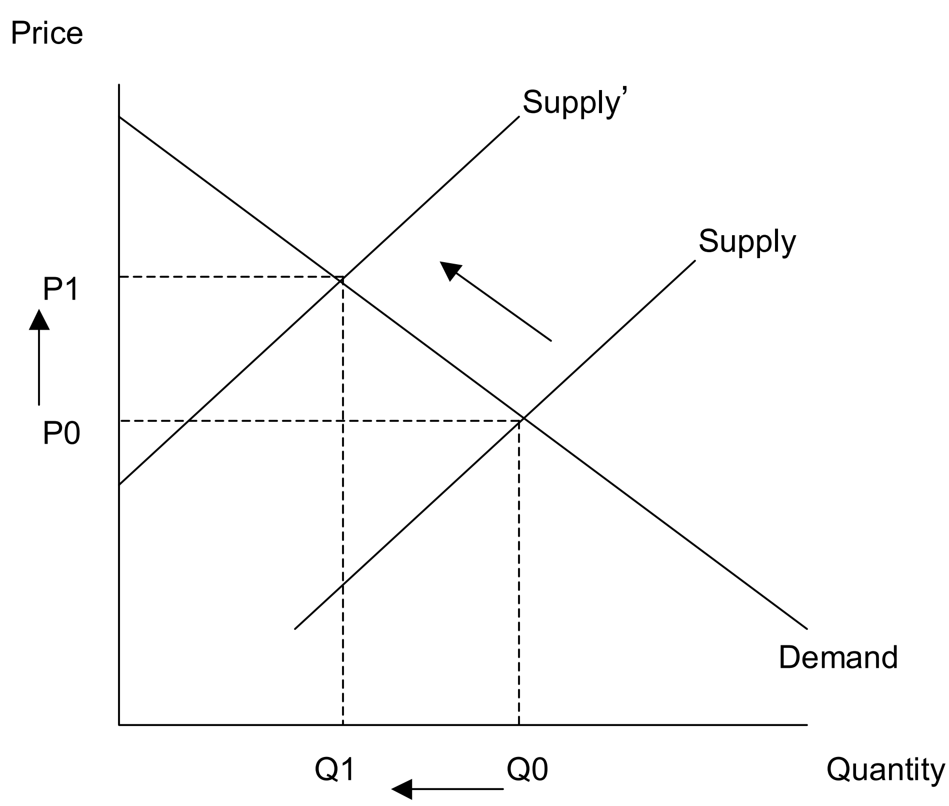
The coefficient on the price of soybean is expected to be positive in the price equation and negative in the quantity equation. Since soybeans act as a rival good to ethanol production, if soybean prices increase, farmers will plant more soybeans and less corn in order to gain from a higher market price for soybeans. This in turn will decrease the supply of corn which will ultimately decrease the supply of ethanol causing the equilibrium price of ethanol to increase and the equilibrium quantity of ethanol to decrease. A graphical representation of this is shown below. Tables 3.6 and 3.7 show that the results are in agreement with economic theory. A ten percent increase in the price of soybean causes a 1.63 percent increase in the equilibrium price of ethanol and a 3.81 percent decrease in the equilibrium quantity of ethanol.

Figure 5.2: The Effects of Soybean Prices on The Ethanol Market



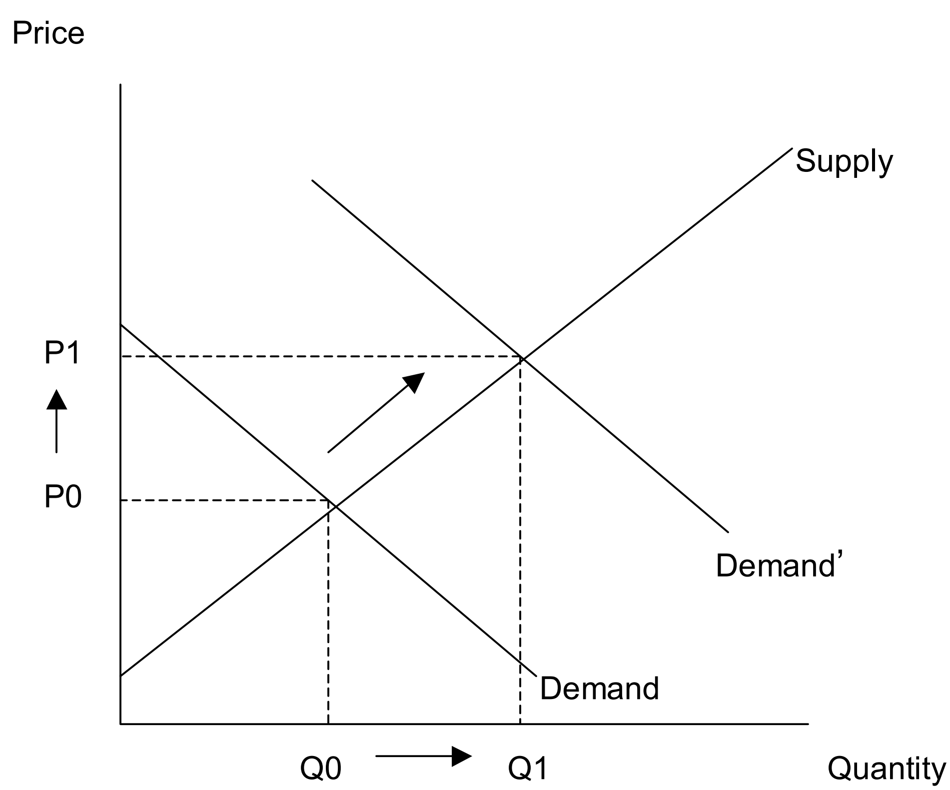
The coefficient on the price of corn is expected to be positive in the price equation and negative in the quantity equation. The results are consistent with economic theory. Since corn is the main input of ethanol production in the United States, an increase in its price should cause a decrease in the supply of ethanol because it is more expensive to produce. This would cause the equilibrium price of ethanol to increase and the equilibrium quantity of ethanol to decrease. Once again results agree with economic theory. A ten percent increase in the price of corn would cause a 1.29 percent increase in the equilibrium price of ethanol and a 2.51 percent decrease in the equilibrium quantity of ethanol.

Figure 5.3: The Effects of Corn Prices on The Ethanol Market



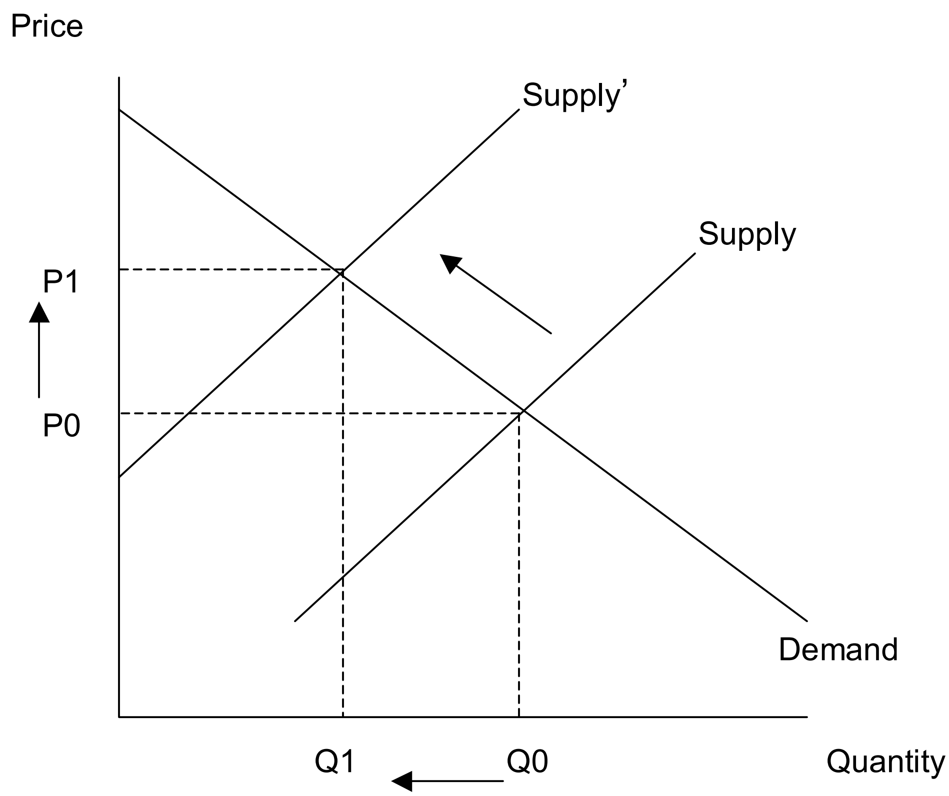
The coefficient on the price of gasoline is expected to be positive in both equilibrium price and quantity equations. The results turn out to be consistent with economic theory. Current period gasoline prices act as a substitute to E85 so it is expected that an increase in the price of gasoline should increase the demand for E85 because more consumers will consume E85 instead of gasoline. This will cause equilibrium ethanol prices to increase as well as equilibrium quantity. A graphical representation of this is shown below. The results show that a ten percent increase in the price of gasoline will result in a 9.47 percent increase in the equilibrium price of E85 and a 6.16 percent increase in the equilibrium quantity.

Figure 5.4: The Effects of Gasoline Prices on The Ethanol Market



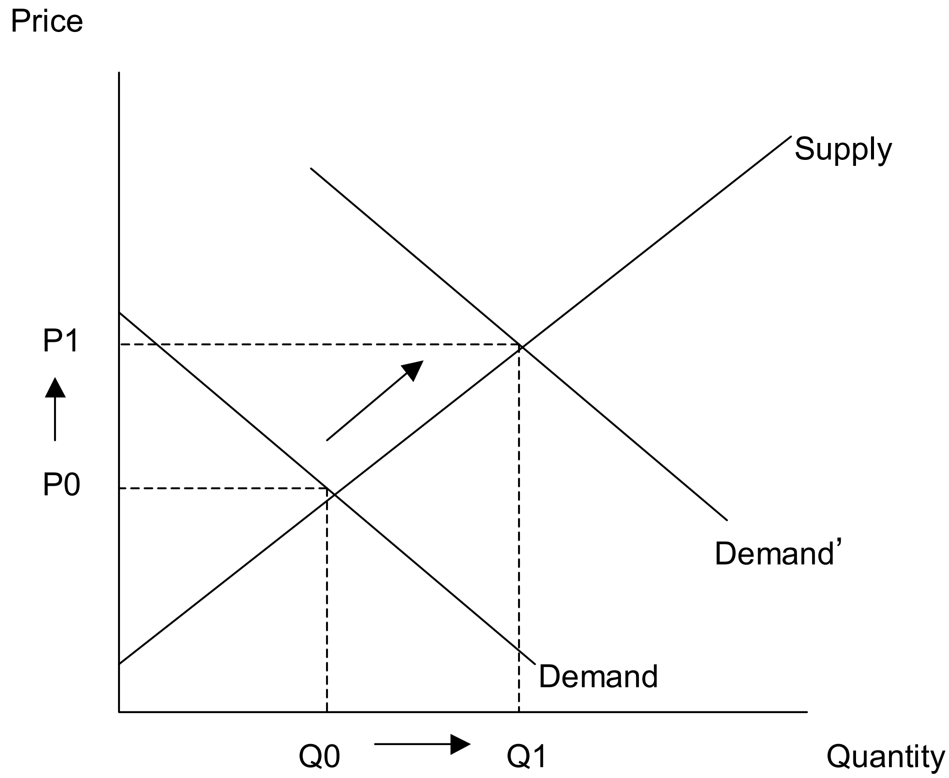
Lagged gasoline prices are expected to be positive in the equilibrium price equation and negative in the equilibrium quantity equation. Lagged gasoline prices are put into the supply side structural equation as an input good since it is fifteen percent of the good. Lagged gasoline prices are used instead of current gasoline prices in the supply side because gasoline used in E85 production is assumed to come from an inventory purchased in the previous month. A rise in the price of last month's gasoline prices should decrease the supply of E85 as long as it acts as an input good. This should cause equilibrium price for E85 to increase and equilibrium quantity to decrease. A graphical representation of this is shown below. The equilibrium quantity results are consistent with economic theory. The equilibrium quantity results show a decrease of 2.68 percent with an increase of last month's gasoline prices of ten percent. The equilibrium price results show a negative relationship between last month's gasoline prices and current E85 prices which is contrary to economic theory but the results prove to be statistically insignificant. A significant negative relationship between last month's gasoline prices and current E85 prices combined with an insignificant result in the equilibrium price equation could suggest that producers adjust input production by decreasing quantity rather than increasing price in order to keep E85 prices competitive with gasoline prices. Another explanation to why lagged gasoline prices are insignificant in the reduced form price equation could be explained by the price behavior of the gasoline market. If last month's gasoline prices rise, this month's gasoline price may fall if gasoline price behavior is cyclical.

Figure 5.5: The Effects of Lagged Gasoline Prices on the Ethanol Market



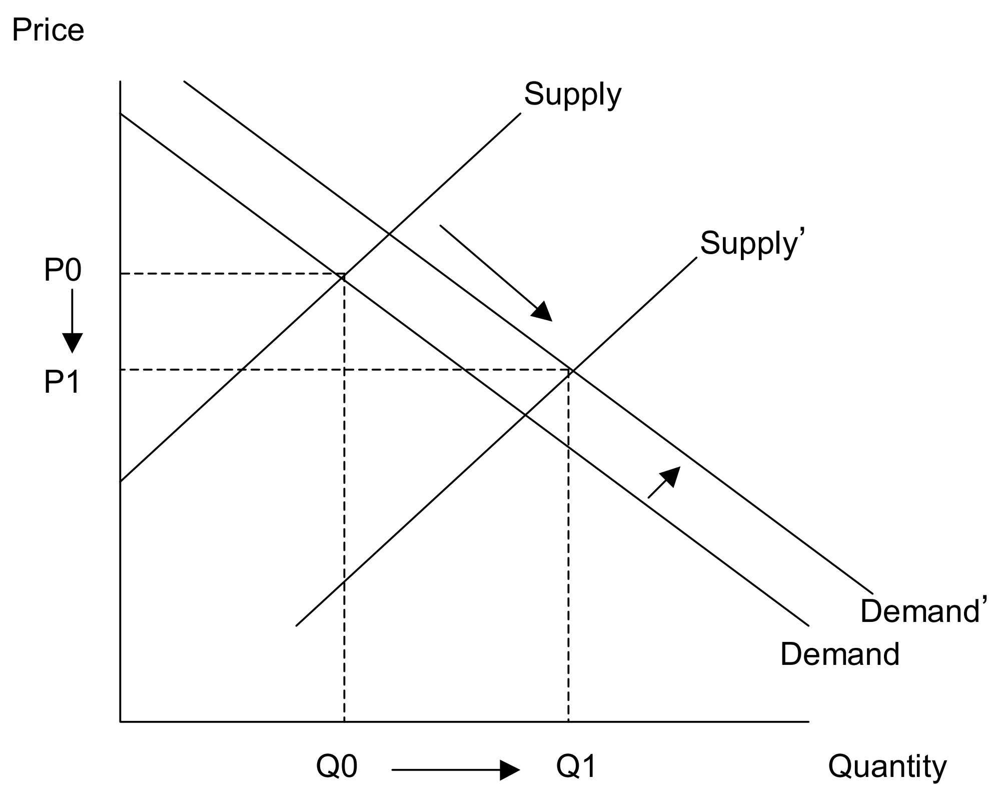
Income is expected to be positive in both the equilibrium price and quantity equations. Since E85 is expected to act as a normal good an increase in average income should increase the demand for E85 which would increase the equilibrium price and quantity for E85. A graphical representation of this is shown below. The expected signs of the results prove to be consistent with economic theory except average income is insignificant in the equilibrium price equation. The equilibrium quantity equation shows that E85 equilibrium quantity rises by 23.38 percent for an increase in average income by ten percent. Average income is positive but insignificant in the equilibrium price equation implying that income has little effect on E85 prices.

Figure 5.6: The Effects of Average Income on the Ethanol Market



Flexible fuel vehicles are expected to be positive in the quantity equation and the sign is unknown in the price equation. Since demand is a function of prices and only quantity exchanged data exists for flexible fuel vehicles, the expected sign of the equilibrium price equation is unknown because it is unknown if flexible fuel vehicles have a bigger affect on consumers or producers. If an increase in the quantity of flexible fuel vehicles affects consumers more than producers the sign of the coefficient in the reduced form price equation will be positive. If an increase in the quantity of flexible fuel vehicles affects producers more than consumers the sign of the coefficient in the reduced form price equation will be negative. A ten percent increase in the quantity of flexible fuel vehicles exchanged results in a 9.6 percent increase in the equilibrium quantity of E85. A ten percent increase in the quantity of flexible fuel vehicles exchanged will decrease the price of E85 by 1.95 percent. In this study it appears as though producers are affected more by an increase in the quantity exchanged of flexible fuel vehicles than consumers, hence a negative coefficient in the reduced form price equation. A graphical representation of the affects the quantity exchanged of flexible fuel vehicles on the ethanol market are shown below.

Figure 5.7: The Effects of Flexible Fuel Vehicles on the Ethanol Market



The coefficient on the speeches dummy variable is expected to be positive in the quantity equation and could be positive or negative in the price equation depending on how much the President's speeches affect the supply versus the demand of E85. Equilibrium price equation results are insignificant and equilibrium quantity results are only significant at the ten percent level and go against the economic theory that the

President's speeches positively affect the quantity of E85. Equilibrium quantity results show a 1.1 percent decrease in E85 in years where ethanol was mentioned by name in the President's speeches. The negative relationship between speeches and the quantity of E85 could be because of a number of factors. The first explanation could be because it may take time to for the effects of the speech to take place. Data in this study only expands to 2005 and because of this it may be too soon to see the effects. Future studies may want to use this variable since ethanol was mentioned by name in 2006 and 2007. Another explanation could be because starting in January of 2005 the ethanol subsidy dropped from 52-51 cents per gallon. This would decrease production because it becomes more expensive to the producer.

Overall, the results were consistent with economic theory. The main driver of E85 prices were gasoline prices as expected. Since E85 and gasoline prices are so competitive, the affects of all ethanol-related markets (corn gluten feed, corn, soybeans, flexible fuel vehicles, and gasoline) were more prominent and larger in ethanol quantity changes rather than price changes. A rise in gasoline prices, corn prices, and soybean prices all increase the price of E85. A rise is corn gluten feed prices will lower the price of E85 along with a rise in the number of flexible fuel vehicles. Average income, speeches, and lagged gasoline prices all proved to be statistically insignificant in regards to the price of E85. In the next chapter conclusions will be made from interpreting the results of the ethanol market.

CHAPTER V

SUMMARY AND CONCLUSIONS

Over the past ten years there has been much speculation involving ethanol fuel. The main issues commonly discussed are the effects increased ethanol production will have on the environment, the corn market, and the gasoline market. Experts on the subject suggest that increased ethanol production will alleviate most economic, social, and environmental pressures that exist today. The biggest concern is that increased ethanol production will cause a huge strain on the corn market. The concern of not having enough cropland to grow enough corn to produce enough ethanol could lead to environmental damages and the concern of using more corn for fuel promotes the food versus fuel debate. The answer to this problem could lie in technological advances involving corn ethanol production or in the discovery of different ethanol feedstocks.

The results of this study suggest evidence that agree with most experts that under certain conditions, E85 will not replace gasoline as the United States primary fuel. Unlike many previous studies involving the ethanol market, this study uses a reduced form equilibrium price equation in order to judge whether or not consumers will ever have the financial incentive to switch from gasoline to E85. Some previous studies analyze the ethanol market by calculating corn-based ethanol's net energy balance. Others analyze the ethanol market by evaluating how the environment will be affected or by evaluating resource constraints like corn. Even though these approaches to evaluating the ethanol market need to be addressed, using the reduced form equilibrium price equation's results to conclude whether or not consumers will have a financial incentive to switch to E85 is the best way to evaluate the ethanol market since without a financial incentive, most consumers will not switch.

As stated in the literature review, the price of E85 has to be less than the price of gasoline for consumers to have a financial incentive to switch to E85 due to worse fuel efficiency. The actual amount E85 must be cheaper varies across studies and between vehicles. The price of E85 can be lowered by an increase in corn gluten feed prices, a decreased in soybean, corn, and gasoline prices, or an increase in the number of flexible fuel vehicles being driven. Below are conclusions drawn from the empirical results of the reduced form price equation for E85 (Table 4.1).

At first glance, looking only at gasoline prices, consumers will eventually have the financial incentive to switch to E85 as the United States primary fuel since the coefficient on the price of gasoline is less than one. This implies that increasing gasoline prices would cause the price gap between E85 and gasoline to widen to the point where the loss in fuel efficiency obtained with E85 use would be outweighed by a low enough price of E85 relative to the price of gasoline. Since the coefficient on the price of gasoline is close to one, a test was run to determine if the coefficient could actually be one. After the test was run to conclude if the price of gasoline is statistically different from one it was concluded that the coefficient on the price of gasoline could actually be one.[40] This implies that any percent change in the price of gasoline could an equal percent change in the price of E85 causing the relative price not to change. This implies that consumers will not have the financial incentive to switch from gasoline to E85 unless technological advances cause E85 fuel efficiency to become equal to or more efficient than gasoline. Of course, the price of gasoline is not the only factor affecting the price of E85. Elobied and Tokgoz suggest that with increased ethanol production corn prices will rise causing soybean prices to rise.[41] This will only raise the price of E85 giving consumers an incentive not to switch to E85. A rise in corn gluten feed prices, which are expected since corn prices are expected to increase along with ethanol production, will cause the price of E85 to decrease but by a very small percentage. A rise in the number of flexible fuel vehicles being driven will also lower the price of E85 but the number of flexible fuel vehicles being driven is not expected to significantly increase unless E85 does become as readily available as gasoline and relatively cheaper than gasoline. With this being the situation, any rise in the price of corn gluten feed or quantity exchanged of flexible fuel vehicles should be more than offset by any rise in corn and soybean prices. Therefore, unless other feedstocks are discovered or great technological advances take place greatly reducing the cost of ethanol and alleviating the strain on already existing feedstock markets like corn, E85 will not replace gasoline as the United States primary fuel. Recently there have been efforts in finding other less costly and more efficient

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[40] A t-statistic was calculated by taking the coefficient on the price of gasoline (.947) subtracting one and dividing that number by the standard error on the price of gasoline variable (.115). The resulting t-statistic was .46 concluding that the coefficient on the price of gasoline was not statistically significant from one.

[41] Amani Elobied and Simla Tokgoz suggest that a rise in ethanol production will cause a rise in corn prices in their paper "An Analysis of the Link Between Ethanol, Energy, and Crop Markets". (Elobied and Tokgoz 2006a)

feedstocks like switch grass but currently there is no large scale ethanol production from switch grass.

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APPENDIX A

STATE OF THE UNION ADDRESSES AND ENERGY QUOTES

The President of the United States uses the State of the Union Address to introduce new ideas for legislation to both Congress and the public. From 1978 to 2007 the topic of energy has been addressed 18 times into these speeches. The speeches variable used in this study was a dummy variable that's purpose was to see whether or not the presidents speeches have any effect on ethanol production. A one was assigned to those years in which ethanol were used by name and a zero in years where it was not mentioned. These were the years 2005-2007 but only the year 2005 was represented in this study. The following table offers selected quotations from the 18 speeches in which the topic of energy was addressed.

President and Year	Selected Quotation
Carter (1978)	"Every day we spend more than $120 million for foreign oil. This slows our economic growth, it lowers the value of the dollar overseas, and it aggravates unemployment and inflation here at home…Almost 5 years after the oil embargo dramatized the problem for us all, we still do not have a national energy program. Not much longer can we tolerate this stalemate. It undermines our national interest both at home and abroad."

Carter (1980)	"The crises in Iran and Afghanistan have dramatized a very important lesson: Our excessive dependence on foreign oil is a clear and present danger to our Nation's security."
Reagan (1981)	"We will continue support of research leading to development of new technologies and more independence from foreign oil..."
Reagan (1982)	"By deregulating oil we've come closer to achieving energy independence…"
Reagan (1985)	"We seek to fully deregulate natural gas to bring on new supplies and bring us closer to energy independence."
H.W. Bush (1991)	"…a comprehensive national energy strategy that calls for energy conservation and efficiency, increased development, and greater use of alternative fuels…"
H.W. Bush (1992)	"…Step eight, Congress should enact the bold reform proposals that are still awaiting congressional action…my national energy strategy."
Clinton (1993)	"Our plan includes a broad-based tax on energy…promotes energy efficiency, promotes the independence, economically, of this country…"
Clinton (1998)	"…I propose $6 billion in tax cuts and research and development to encourage innovation, renewable energy, fuel-efficient cars…"
Clinton (1999)	"Tonight I propose a new clean air fund to help communities reduce greenhouse and other pollution, and tax incentives and investments to spur clean energy technology."

Clinton (2000)	"The greatest environmental challenge of the new century is global warming…If we fail to reduce the emission of greenhouse gases, deadly heat waves and droughts will become more frequent, coastal areas will flood, and economies will be disrupted. That is going to happen, unless we act…efficient production of bio-fuels will give us the equivalent of hundreds of miles from a gallon of gasoline…I think we should give a major tax incentive to business for the production of clean energy and to families for buying…the next generation of super efficient cars…"
G.W. Bush (2001)	" We have a serious energy problem that demands a national energy policy."
G.W. Bush (2002)	"Good jobs also depend on reliable and affordable energy. This Congress must act to encourage conservation, promote technology, build infrastructure, and it must act to increase energy production at home so America is less dependent on foreign oil."
G.W. Bush (2003)	"Our third goal is to promote energy independence for our country, while dramatically improving the environment."
G.W. Bush (2004)	" Consumers and businesses need reliable supplies of energy to make our economy run—so I urge you to pass legislation to…make American less dependent of foreign sources of energy."
G.W. Bush (2005)	"To keep our economy growing, we also need reliable supplies of affordable, environmentally responsible energy…And my budget provides strong funding for leading-edge technology…to renewable sources such as ethanol…I urge Congress to pass legislation that makes America more secure and less dependent on foreign energy."

G.W. Bush (2006)	“So tonight, I announce the Advanced Energy Initiative—a 22 percent increase in clean-energy research…We'll also fund additional research in cutting-edge methods of producing ethanol, not just from corn, but from wood chips and stalks, or switch grass.”
G.W. Bush (2007)	“It's in our vital interest to diversify America's energy supply -- the way forward is through technology. We must continue investing in new methods of producing ethanol, using everything from wood chips to grasses, to agricultural wastes.”

APPENDIX B

SUBSIDY LEGISLATION

Year	Legislation	Subsidy $/gal
1978	Energy Tax Act of 1978	$0.40
1983	Surface Transportation Assistance Act of 1983	$0.50
1984	Tax Reform Act of 1984	$0.60
1990	Omnibus Budget Reconciliation Act of 1990	$0.54
1998	Federal Highway Bill of 1998	$0.54
2001	Federal Highway Bill of 1998	$0.53
2003	Federal Highway Bill of 1998	$0.52
2005	Federal Highway Bill of 1998	$0.51

APPENDIX C

OTHER ETHANOL LEGISLATION

Year	Legislation	Brief Explanation
1974	Solar Energy Research, Development, and Demonstration Act	Created research programs for cellulosic energy
1978	Energy Tax Act	Gasohol defined, $0.04 excise tax on gasoline, $0.40 subsidy on ethanol
1980	Energy Security Act	Loans given to small ethanol producers, Tariff placed on foreign ethanol
1980	Gasohol Competition Act	Banned retaliation against ethanol resellers
1980	Crude Windfall Tax Act	Extended ethanol-gasoline blend tax credit
1988	Alternative Motor Fuels Act	Created corporate average fuel economy (CAFE) credits
1990	Clean Air Act	Created regulation in order to increase air quality with cleaner burning fuels
1992	Energy Policy Act	Created regulations to help promote flexible fuel vehicles, E85 defined as an alternative transportation fuel
2005	Energy Policy Act	Income tax credit given to small ethanol producers, Renewable Fuel Standard created to promote cellulosic ethanol

APPENDIX D

DESCRIPTIVE STATISTICS OF VARIABLES

(NOT LOGARITHMIC FORM)

Variable	Mean	Standard Deviation	Minimum	Maximum	Cases
Price E85 ($/gal)	1.459	0.258	0.958	2.327	72
Quantity E85 (gal)	233,284,462	73,487,298	124,815,467	418,625,902	72
Price Corn ($/Bushel)	2.097	0.281	1.52	2.89	72
Price Soybeans ($/Bushel)	5.614	1.312	4.09	9.62	72
Price Corn Gluten Feed ($/ton)	61.614	13.309	43.2	105.9	72
Price Gasoline (¢/gal)	165.463	35.845	108.6	290.3	72
Lagged Price Gasoline (¢/gal)	164.25	35.502	108.6	290.3	72
Income ($)	2,430.51	23.802	2,388.15	2,497.60	72
Flexible Fuel Vehicles (quantity)	12,752.70	4,193.20	6,876	21,234	72