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An analysis of government policy impacts in the ethanol and sugar markets

Hassan Marzoughi_Ardakani

Louisiana State University and Agricultural and Mechanical College

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AN ANALYSIS OF GOVERNMENT POLICY IMPACTS IN THE ETHANOL AND SUGAR MARKETS

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

In

The Department of Agricultural Economics and Agribusiness

by
Hassan Marzoughi Ardakani
B.S., Shiraz University, Iran, 1990
M.A., Shahid Beheshti University, Iran, 1994
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ABSTRACT

This study determines the impact of U.S. government policies on U.S. ethanol market and its consequences for the U.S. corn, sugar, and HFCS markets. Using corn as the primary input in ethanol and HFCS production in the United States, along with the substitutability between sugar and HFCS, has linked the U.S. ethanol market to the U.S. HFCS, sugar, and corn markets. To address the problem, two sets of data, quarterly and annual data, were collected and a simultaneous econometric model was constructed. Estimated results show that the “2007 Energy Independence and Security Act” will increase the domestic corn price and ethanol and HFCS production costs. Increases in HFCS production costs decrease the comparative advantage of HFCS over sugar and will encourage HFCS users to replace HFCS with sugar. HFCS will lose its comparative advantage over domestic raw sugar after 2009.

Without government policies that mandate consumption levels for ethanol, depending on gasoline and corn prices, maximum corn-based ethanol production would be between 1.5 and 19.6 billion gallons per year in year 2015. In the case of having “mandatory ethanol consumption,” there will be a minimum quantity of ethanol consumption and production, equal to 15 billion gallons per year in 2015. Depending on the relative levels of corn and gasoline prices, annual corn-based ethanol production will be between 15 and 19.6 billion gallons in 2015.

With regards to the profitability of sugar-based ethanol production, the U.S. sugar support program plays a critical role. Using raw sugar, at world sugar price levels, for producing ethanol, sugar can compete with corn when corn prices reach \$5.49 per bushel, when the ethanol production level approaches 9.3 billion gallons annually. With the sugar support program in force, raw and refined sugar cannot compete with corn in the near future.

Removal of the sugar import quota decreases sugar production and price while sugar imports and consumption increase. This allows sugar to be considered as a viable feedstock for the production of ethanol. Using sugar for ethanol production reduces the amount of corn needed for ethanol production, suppresses the corn price, and stabilizes the corn market.

CHAPTER I

INTRODUCTION

1.1. Introduction

Ethanol production and consumption provide many benefits to society, such as the stimulation of rural development, creation of new markets for agricultural crops, increasing farmers' income, creation of new jobs, mitigation of air pollution, and the enhancement of energy security. But sky-rocketing oil prices and mandated implementation of Clean Air Act requirements are some of the most important, current factors that are stimulating U.S. ethanol production. In 2007, the United States and Brazil together produced approximately 88% of the world's total ethanol production. The United States alone accounted for 49.6% of world production, making the United States the world's largest ethanol producer (Renewable Fuels Association (RFA), 2008).

Based on the U.S. Clean Air Act, the U.S. federal government mandated that all gasoline sold within the United States be blended with an oxygenate so that fuel would burn more cleanly thus reducing vehicle tailpipe emissions (namely carbon monoxide emissions). This law created a market for the fuel additive methyl tertiary butyl ether (MTBE) to be the oxygenation agent and has been used in the United States for some time. Recently, scientists discovered trace amounts of MTBE leaking into ground water, posing a potential threat to public health. MTBE is highly soluble in water and therefore can pollute underground and surface water supplies rendering MTBE decontamination efforts very expensive. Because of MTBE related health concerns, many states have banned using MTBE as a fuel oxygenate. Banning MTBE forces gasoline producers and distributors to use other MTBE alternatives, one of these alternatives being ethanol. This federally mandated requirement for a fuel oxygenate has created a market and as MTBE is not a viable oxygenate this opens up a possibly new market for ethanol to be

used as a substitute for MTBE. It must be noted that demand for ethanol as a gasoline oxygenate is not the ethanol's sole source of demand. The increasing number of Alternative Fuel Vehicles (AFV) on America's highways (from 172 in 1992 to 297,099 in 2006) is another potential area that will drive an increased demand for ethanol (EIA, 2008).

One interesting point in producing ethanol is the strong linkage between the ethanol industry and the sweetener industry, the sugar market in particular. Brazil is the world's largest sugar producer and the world's second largest ethanol producer. Brazil primarily uses sugarcane to produce ethanol and various factors such as oil price, ethanol price, and world sugar price determine the allocation of produced sugarcane between ethanol and sugar.

In the United States, there are two primary reasons for linking the U.S. ethanol industry to the U.S. sweetener industry, and ultimately the U.S. sugar program. First, the U.S. ethanol industry is linked to the U.S. sweetener market (and in turn the sugar market) through the High Fructose Corn Syrup (HFCS) industry, because both ethanol and HFCS industries use corn as their primary input. Producing more corn-based ethanol leaves less available corn (along with higher prices) with which to produce HFCS. This increases HFCS production cost and thus makes HFCS less competitive relative to sugar. This change in relative prices, in turn, increases sugar demand. Therefore, any increase in ethanol production can potentially stimulate sugar demand as prices for HFCS rise. As can be seen, HFCS is a bridge between the ethanol industry and sugar market by way of the corn market.

The second linkage between the U.S. ethanol industry and the U.S. sweetener industry is that increases in corn-based ethanol production raises corn prices, forcing ethanol producers to look at sugar (sugarcane and/or sugar beets) as a viable feedstock alternative to corn for the production of ethanol. In this regard, governmental policies that either directly or indirectly

impact U.S. ethanol production can have impacts on the U.S. corn, HFCS, and sugar markets and vice versa. Figure 1.1 illustrates the relationships among ethanol, corn, HFCS, and sugar.

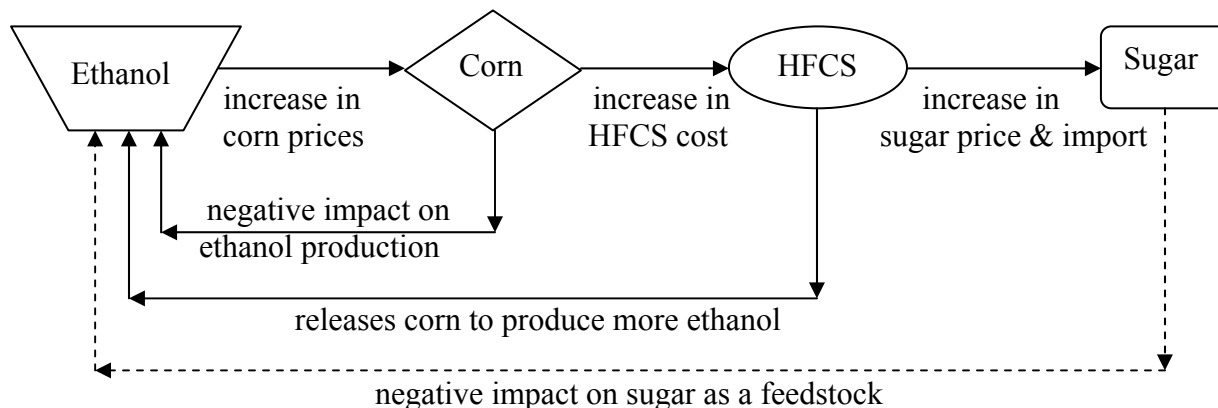


Figure 1.1. Linkages between ethanol, corn, HFCS, and sugar

1.2. Problem Statement

There is a close relationship between the ethanol market and the HFCS, corn, and sugar markets in the United States. Under the 2005 Renewable Fuel Standards Act (RFS), renewable fuel (mainly ethanol) production, in the United States, is anticipated to reach 7.5 billion gallons by 2012 (Renewable Fuel Association, 2006). But unexpectedly high oil prices along with fast development in the U.S. ethanol industry encouraged the U.S. federal government to initiate a new Energy Act in 2007. Based on the 2007 Energy Independence and Security Act, ethanol production is mandated to reach 13.2 billion gallons by 2012, 15 billion gallons by 2015, and 36 billion gallons by 2022. Meeting these requirements will have serious consequences for the U.S. corn, HFCS, and sugar markets (Renewable Fuel Association, 2008).

The objective of this dissertation is to quantify the economic effects of domestic and trade policies, including both sugar and ethanol policies, on the U.S. ethanol, HFCS, sugar, and corn markets. This will be accomplished through the development of a model to determine the

impact that the U.S. sugar program, ethanol production, and import policies (the 2007 Energy Act in particular) have had on the U.S. ethanol, corn, HFCS, and sugar markets.

1.3. Importance/Significance of the Study

There are multiple reasons that have led to recent interest in increasing domestic U.S. ethanol production:

- High crude oil prices make ethanol production more attractive and profitable for investors
- Increasing energy security by reducing U.S. dependency on imported oil
- Necessity of finding a substitute for petroleum oil - given limited world oil resources
- Banning the use of MTBE as an oxygenate leaves ethanol as a possible alternative
- More restrictive governmental regulation on clean air issue
- Global warming and environmental issues compound the necessity of reducing CO₂ emissions
- Developing new markets for agricultural products enhancing farmers' income
- Technological innovation that reduces ethanol production costs and increases feedstock variety
- Technological innovation that makes ethanol consumption more convenient and finds new uses for ethanol
- Economic development impacts, especially on rural areas
- Environmental impact through the use of urban waste, agricultural residue, and forestry waste
- Ethanol blends (up to 10%) can be used in all vehicle engines with limited or no engine modification
- Increased number of Alternative Fuel Vehicles (AFV)
- Using ethanol as an octane enhancer

- Job creation
- Providing additional revenue to the government through income and other taxes

Thus, increased ethanol production is potentially beneficial to society. However, some of these benefits, such as energy security and environmental issues, cannot be created or brought about by the private sector alone. There is an opportunity for government intervention, thus fostering the growth and development of this infant industry.

Producing ethanol can have significant effects on U.S. agricultural crops (especially corn) and sweetener markets. For instance, increases in ethanol production can increase domestic corn prices, and therefore have a negative impact on the growth rate for ethanol production. This in turn, would force ethanol producers to look for new feedstocks. Since sugar (sugarcane and sugar beets) is a potential feedstock for producing ethanol, any changes that would include utilizing sugar as a main feedstock in ethanol production would more than likely bring up a discussion about the U.S. sugar program and its sugar support policies. Also, based on the “2008 Farm Bill’s feedstock flexibility program for bioenergy producers”, one way to prevent the forfeiture of sugar to the CCC is by buying additional sugar through the Secretary of Agriculture and, in turn, selling it to the eligible bioenergy producers (USDA, 2008).

On the other hand, sugar is a sensitive agricultural product in the United States (and many other industrial countries), and therefore the U.S. government cannot remove import barriers easily. Sugar programs support sugar prices and encourage food industries that primarily use sugar as an input to replace sugar with corn sweeteners (especially high fructose corn syrup, HFCS) to keep their costs at a minimum. This increases the demand for corn through using corn for producing HFCS and, in turn, increases ethanol production cost. Ethanol not only has to compete with the food and feed industries and export markets, it must also compete with industries that use HFCS as an input, thus serving to further push corn prices higher. Because of

these interactions, a model that coherently and cogently discusses the overall effect of ethanol production on the U.S. ethanol, corn, HFCS, and sugar markets is warranted.

1.4. Research Questions

Based on the above defined objectives, this study examines and addresses the following questions:

- What will be the effect of the 2007 Energy Act required levels of ethanol production (10.5, 13.2, and 15 billion gallons) on the U.S. corn, HFCS, and sugar markets?
- What is the maximum amount of ethanol that can be produced from corn?
- In what scenario would sugar-based ethanol production be profitable in the United States? Furthermore, what policies would make sugar a profitable feedstock for producing ethanol in the United States?
- What are the impacts of an ethanol subsidy, import tariffs, and sugar import quota on the U.S. ethanol, corn, HFCS, and sugar markets?
- What would be the effect of eliminating sugar import quotas on the U.S. sugar, HFCS, corn, and ethanol markets?

1.5. Research Hypotheses

In this study, it is hypothesized that:

- Corn-based ethanol production increases demand for corn, thereby increasing corn prices.
- Increases in the corn price force ethanol producers to look for alternative feedstocks.
- Increases in ethanol production decrease HFCS consumption and production as a result of elevated corn prices.
- Expanding or eliminating sugar import quotas would increase the possibility of using sugar as a feedstock for the production of ethanol.

A number of caveats as to the fundamental, quantitative analysis that is required in a study of this scope need to be mentioned. First, data for ethanol production, consumption, and prices are available only for a relatively short time period. This could introduce problems in conducting quantitative analyses. One way to overcome this data availability constraint is by using quarterly data instead of annual data. However, since some of the required data such as corn production are available only on an annual basis, this, in turn, introduces an additional data problem that must be addressed in the analysis. To solve this problem, two different models are used. One model uses annual data for the corn production equation while the alternative model uses a corn supply equation using quarterly data. Even though these two models are fundamentally different, the estimation results are surprisingly similar.

1.6. Literature

Ethanol can be produced from many different materials including grains and wastes which contain starch. The most typical feedstocks used for producing ethanol are sugarcane and corn. The United States and Brazil are the first and second largest world ethanol producers, respectively. The United States primarily uses corn and Brazil primarily uses sugarcane for producing ethanol. Even though cellulosic feedstocks such as wood, bagasse, straw, and switchgrass have been mentioned as the potential source of producing ethanol in the future, producing ethanol from cellulose is not yet economically practical nor will it likely be in the near future. With grains (especially corn) as the main feedstock for producing ethanol in the United States, it is critical to understand the dynamic relationship between the ethanol and corn markets and its impact on the U.S. sweetener market.

Environmental concerns related to using MTBE as a fuel oxygenate in gasoline and its subsequent banning by the U.S. Environmental Protection Agency (EPA), federal and state governments' ethanol related policies including both 2005 and 2007 Energy Acts, and record high

gasoline prices , are all factors that have helped stimulate ethanol production in the United States. Since the demand for ethanol plays a critical role in ethanol markets, without government policies, support, and incentives, the ethanol industry could not develop the necessary capacity to exist in the presence of high oil prices.

The increase in ethanol production and the accompanying increase in corn prices bring different consequences to the world and U.S. agricultural and sweetener markets, especially the corn, sugar, and HFCS markets. Since the United States accounts for more than 66 percent (2.4 billion bushels) of world corn exports in 2007, an increase in U.S. corn prices impacts the world corn market (NCGA World of Corn, 2008a). Furthermore, based on the 2007 Energy Independence and Security Act, 15 billion gallons of corn-based ethanol is mandated to be produced by 2015. If we suppose that each bushel of corn produces 2.75 gallons of ethanol, then 5.4 billion bushels of corn, more than 40 percent of the total U.S. corn production in 2007, are needed to meet the 15 billion gallon ethanol target slated for 2015. This means that there will be less corn available for export, intensifying the impact on the world corn market.

In the domestic corn market, an increase in the corn used for producing ethanol reduces the amount of corn available for feed, serving to increase livestock production costs. Also, an increase in corn prices increases the HFCS production costs and makes HFCS less competitive with sugar, which in turn, may dramatically increase sugar demand.

An increase in corn prices impacts not only sugar and HFCS markets, it also affects other crops' prices as well. Boosts in corn prices increase the expected net returns per acre for corn from around \$125 in 2006 to more than \$325 in 2007. This amounts to a more than 150 percent increase in just one year alone. The expected increase in net returns per acre for soybeans and wheat were less than 100% for the same period (Collins, 2007). Higher net returns for corn, relative to other agricultural crops, encourages farmers to shift land away from producing

alternative crops to produce corn. This decreases the production of other crops, thus increasing their prices (by virtue of reduced supply).

Feedstock costs contribute to more than half of ethanol's production cost and therefore the availability and cost of feedstock plays a critical role in the ethanol production chain. Currently, more than 95 percent of the ethanol produced in the United States uses corn as a feedstock because of its relative low cost as compared to other U.S. crops (NCGA, 2008a). Since the U.S. sugar program results in elevated domestic sugar prices, domestically produced sugar cannot compete with corn for producing ethanol. Even though high corn prices make sugar molasses competitive with corn in producing ethanol, molasses still does not play a major role in ethanol production. One factor that prevents ethanol producers from using molasses as an ethanol feedstock is that, in order to use molasses for ethanol, molasses must be collected from different sugar refinery plants and taken to the ethanol plant. Its bulky physical consistency limits its ability to be transported in an efficient manner.

Corn is the main feed for livestock in the United States. Therefore, any change in the U.S. corn market impacts the U.S. livestock industry as well. One argument against corn-based ethanol production is that producing ethanol from corn reduces the amount of corn available for livestock feed. A study conducted by the USDA concludes that although using corn for ethanol production may have a negative impact on the livestock industry through increase in corn prices, this impact is small. This study illustrates that dry distillers' grains (DDGs), an ethanol byproduct in dry mill plants, is equivalent to 0.8 bushels of corn for use in the livestock industry. Therefore, each additional bushel of corn used for producing ethanol decreases the amount of corn available for feed by only 0.2 bushel. DDGs not only can displace corn, it can also be used instead of soybean meal in the feed rations so that the DDGs produced from each bushel of corn used for ethanol production would displace 1.2 pounds of soybean meal (ERS, 2007).

Note that there is a wide variation of nutrient content in DDGs. This variation results from variations in nutrient concentrations and physical characteristics, including crude protein, crude fat, lysine, color, and smell which results in the production of DDGs with different quality and protein contents (Thaler, 2002).

1.7. Data

The model framework specified herein has two models, one based on annual data, the other based on quarterly data. Given this, both annual and quarterly data were collected. Annual data is typically more accessible than quarterly data. Some data variables, such as agricultural crops for production, are only available as annual data. Therefore, some of the data collected for the annual model was different from the data collected for the quarterly model.

The quarterly model begins with the first quarter of 1982 and ends with the last quarter of 2007. It includes more than 67 variables. The annual model covers the period from 1975 to 2007 and has more than 75 variables. Most of the data collected are from USDA data bases and reports. Energy, fuel, and ethanol information are collected from the Energy Information Administration (EIA), Renewable Fuels Association (RFA), and Nebraska Ethanol Board. Demographic and economic data are collected from International Financial Statistics (IFS) and the Economic Time Series Page ([www. economagic.com](http://www.economagic.com)).

1.8. Model and Research Approach

As mentioned before, two econometric models are applied in this study: one based on quarterly data and the other one based on annual data. Each model consists of 14 behavioral equations and 4 identity equations. The behavioral equations consist of 2 equations for the ethanol market, 5 equations for the sugar market, 5 equations for the corn market, and 2 equations for the HFCS market. Each market is closed with an identity equation which allows for market clearing.

Since we have a simultaneous equation system the Ordinary Least Squares (OLS) approach is not efficient. Thus, Two Stage Least Squares (2SLS) or Three Stages Least Squares (3SLS) methods must be used. Considering the interrelationship (correlation) among different equations, the 3SLS is preferred over the 2SLS and, therefore, the 3SLS approach is applied to both models.

1.9. Outline of Dissertation

This dissertation contains five chapters. Chapter two reviews previous studies related to the U.S. ethanol, corn, sugar, and HFCS markets and provides an overview of related variable trends for the time period under consideration. Chapter three specifies and develops the econometric equations and model framework utilized herein based on the economic theories behind producer and consumer behavior in related markets. Chapter four is dedicated to the estimation of the econometric models. First, it analyzes the estimation results equation by equation. It then discusses the research questions using the estimated models. Chapter five summarizes the study and concludes the work.

CHAPTER II

LITERATURE REVIEW

2.1. Introduction

Ethanol has attracted much attention in the United States in recent years because of different factors serving to stimulate ethanol demand. Among these are governmental policies requiring mandatory usage of specific minimum levels of ethanol, high gas prices, and environmental issues such as the phasing out of MTBE. These factors have had a significant impact on ethanol production and this trend will continue for the next decade.

A boost in ethanol production would have significant impacts on and consequences for other industries, such as the HFCS industry and sweetener users, in addition to the cultivation of agricultural crops especially corn and sugar crops. Therefore any governmental policy regarding biofuels has a direct impact on related industries and on agricultural crops production and prices. On the other hand, since biofuels are produced from agricultural crops, every governmental policy directed towards agricultural crops, especially crops which are used or can be used to produce ethanol, impacts the ethanol industry either directly or indirectly.

Corn is the main ethanol feedstock in the United States. There is naturally a strong relationship between the corn and ethanol markets. An increase in ethanol production raises demand for corn and therefore helps to increase corn prices. An increase in corn prices impacts the High Fructose Corn Syrup (HFCS) industry which also uses corn as its main input factor, by increasing HFCS production cost, therefore influencing the sugar market (Figure 2.1). Furthermore, any increase in corn prices raises sugar's competitiveness with corn as the primary input factor for ethanol production. Therefore through virtue of sugar's ability to be an ethanol feedstock, the U.S. sugar's market's impact on ethanol production is enlarged.

In this chapter the U.S. ethanol, corn, sugar, and HFCS markets are investigated and explored through an overview of both related data and previous studies. An overview of each market is presented in the following sections.

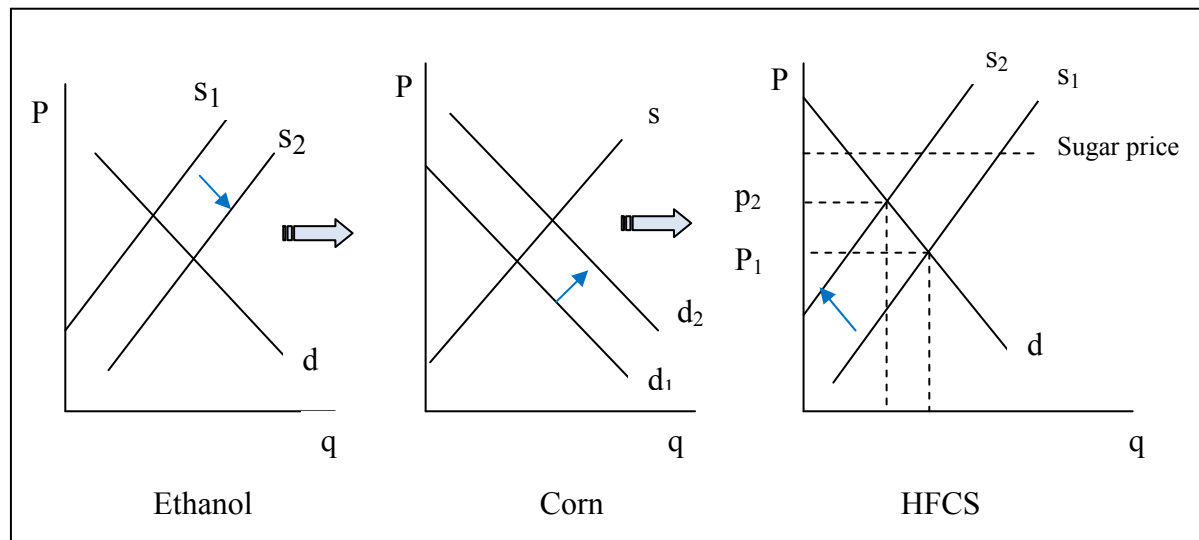


Figure 2.1. Relationship between ethanol and sweetener markets

2.2. The U.S. Ethanol Market

In the United States, ethanol is blended with gasoline as an oxygenate and octane enhancer, replacing lead which had previously performed this function. If fuel burns too quickly it causes engine knock. Raising fuel's octane value by the addition of ethanol makes fuel to burn slower, thus preventing engine knock. Adding ethanol to gasoline increases the fuel's octane value by 3 full points. In fact, blending gasoline with ethanol oxygenates the fuel and amplifies the fuel's oxygen content, causing a cleaner burn, and lessening harmful pollutants being emitted into the atmosphere. Ethanol also has more recently been used to expand the supply of gasoline and to help reduce U.S. dependence on imported oil. Ethanol is commonly blended with gasoline at a rate of up to ten percent by volume.

In many countries, ethanol has been examined as a viable alternative to motor fuel. High petroleum prices, resulting from a high demand for oil along with limited supply, have forced many countries to search for an oil alternative. Environmental concerns, especially issues related to greenhouse gasses, global warming, and the need for finding non-traditional markets for agricultural products as a way of enhancing farmers' incomes are important factors to be considered in the analysis of the dynamics of the ethanol market.

Although the idea of using ethanol as a motor fuel in the United States dates back many years, (Henry Ford experimented with alcohol fuel-based cars in the early twentieth century, the Model T (ca. 1906) could run on either gasoline or ethanol), the 1970s oil crisis was the catalyst that spurred the examination of ethanol as an alternative to petroleum-based gasoline.

Ethanol has attracted much attention because of its many potential benefits to society. It decreases U.S. dependence on imported oil, decreases air pollution (especially CO₂ emissions), has a positive impact on the reduction of greenhouse gases (GHG), and expands the market for farm products (therefore increasing landowner income, and serves to stimulate rural development).

Ethanol can be used as fuel for automobiles either alone (E100) in a special engine or as an additive to gasoline for petroleum engines. In fact, ethanol can be blended up to 10% by volume with gasoline for use in any current vehicle without requiring any subsequent changes be made to those cars. For gasoline blends containing more than 10% ethanol, engine modifications are needed to prevent engine damage.

Ethanol can be blended with gasoline in different quantities to reduce the consumption of gasoline, in addition to the positive benefits of a reduction in air pollution. The resulting fuel mixture, known as gasohol, has two ordinary mixtures are designated as E10 and

E85. Gasohol E10 contains 90% gasoline and 10% ethanol and gasohol E85 contains 15% gasoline and 85% ethanol.

In addition to E85, almost half of the U.S. gasoline used today in the United States is blended with ethanol at levels up to 10 percent (Environment News Service, 2008). E85 can only be used in so called flexible-fuel vehicles that have special engine modifications that allow usage of E85. Since selling E85 requires additional equipment for its storage and dispensing in gas stations, it is only available in some limited areas in the United States. As Figure 2.2 shows, E85 is mostly available in the northeastern of United States. Minnesota, Wisconsin, and Illinois have the largest number of E85 refueling locations.

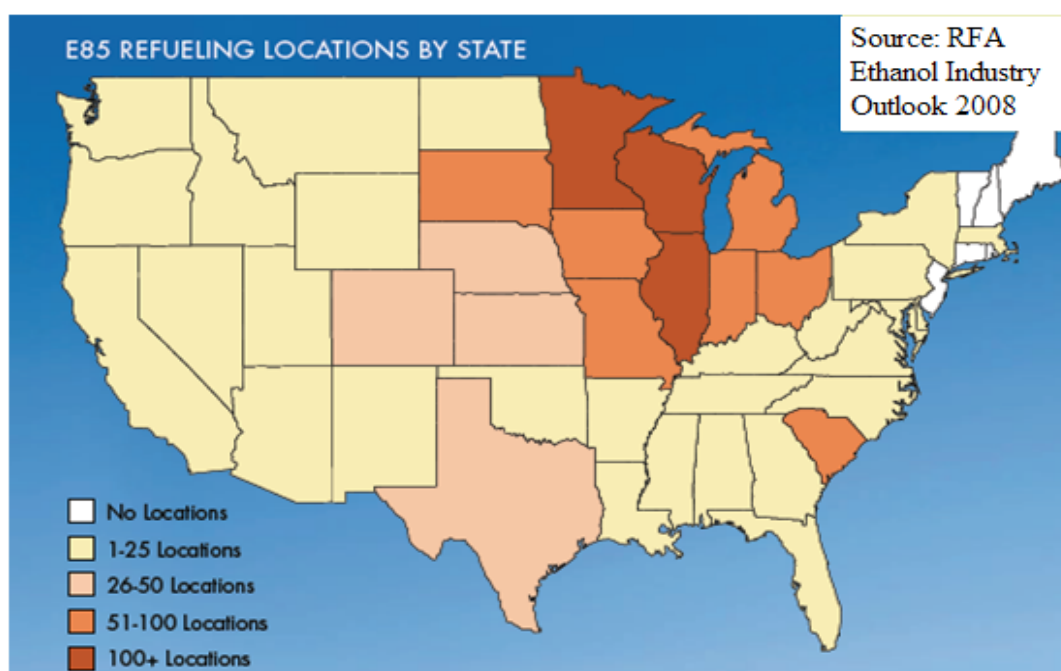


Figure 2.2. E85 refueling locations by states
Source: RFA, Ethanol Industry Outlook, 2008.

Ethanol can be produced from a vast variety of feedstocks, such as sugar cane, miscanthus, sugar beet, sorghum, switchgrass, barley, hemp, kenaf, potatoes, sweet potatoes, cassava, sunflower, fruit, molasses, whey or skim milk, corn, corn cobs, grain, wheat,

wood, paper, straw, cotton, grain sorghum, other biomass, as well as many types of cellulosic waste. Feedstock cost has a critical impact on ethanol plants' profitability and capacity.

Therefore, underlying cost concerns dictate the type of feedstock that ethanol producers in each country can use to produce ethanol.

2.2.1. Ethanol Production

Even though ethanol has been produced in the United States for many years, it has not been considered a significant fuel source until recently. Efforts to reduce air pollution, concerns over global warming, the elimination of Methyl Tertiary Butyl Ether (MTBE) as a fuel oxygenate (due to underground water pollution concerns), the existence of a cheap and abundant source of grain (especially corn), high oil prices, and finally energy security concerns are some of the most important factors that have served to stimulate the U.S. ethanol market in recent years.

As Figure 2.3 demonstrates, U.S. ethanol production has increased from 175 million gallons in 1980 to 6,485 million gallons in 2007. The rate of rise in ethanol production has been especially high after 2000.

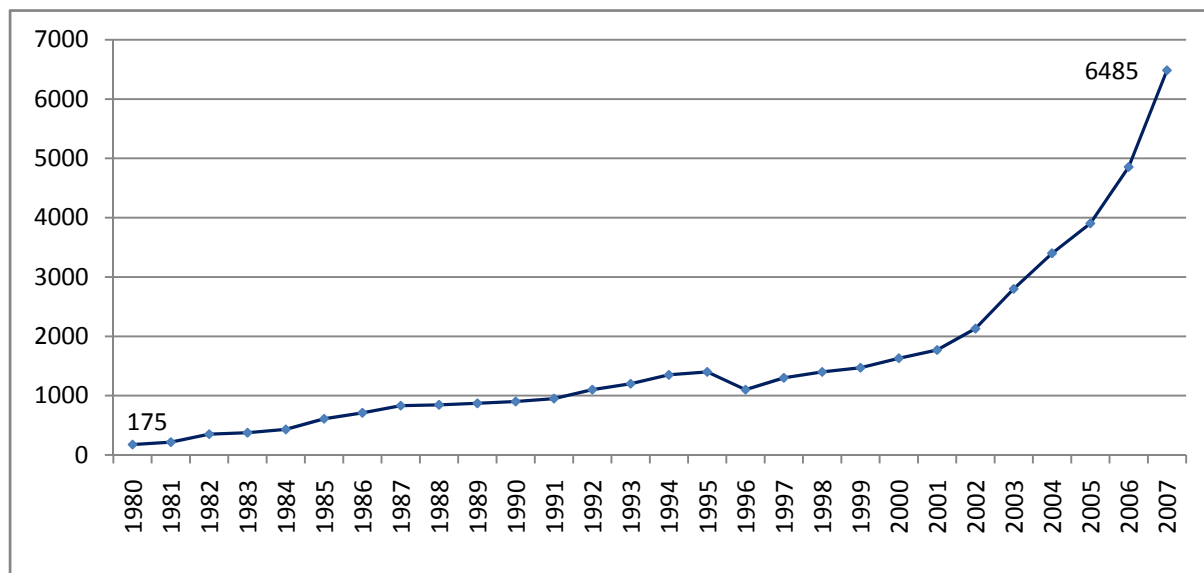


Figure 2.3. Ethanol production trend (million gallons)

Source: Renewable Fuel Standards (RFA), 2008.

As can be seen in Table 2.1, the number of Bio-refineries increased from 54 in January of 2000 to 139 in January of 2008. Ethanol's production capacity increased from 1,748.7 million gallons per year to 7,888.4 million gallons per year for the same period (2000-2008). Enhancement in the U.S. ethanol production was so high that the United States surpassed Brazil, which was for years the leading world ethanol producer. Now the United States is the world's largest ethanol producer. The number of ethanol plants has had a volatile trend before its recent surge in the past few years. Governmental policies related to ethanol, such as tax credits, import tariffs, loan programs, and subsidies have increased the number of ethanol plants from less than 10 plants in 1980 to more than 150 plants in 1984. But low ethanol prices have been detrimental to ethanol producers, so much so that only 74 plants had ethanol production in 1985. This downward trend continues so that only 50 plants were producing ethanol in 1999 (Todd Neeley, 2006).

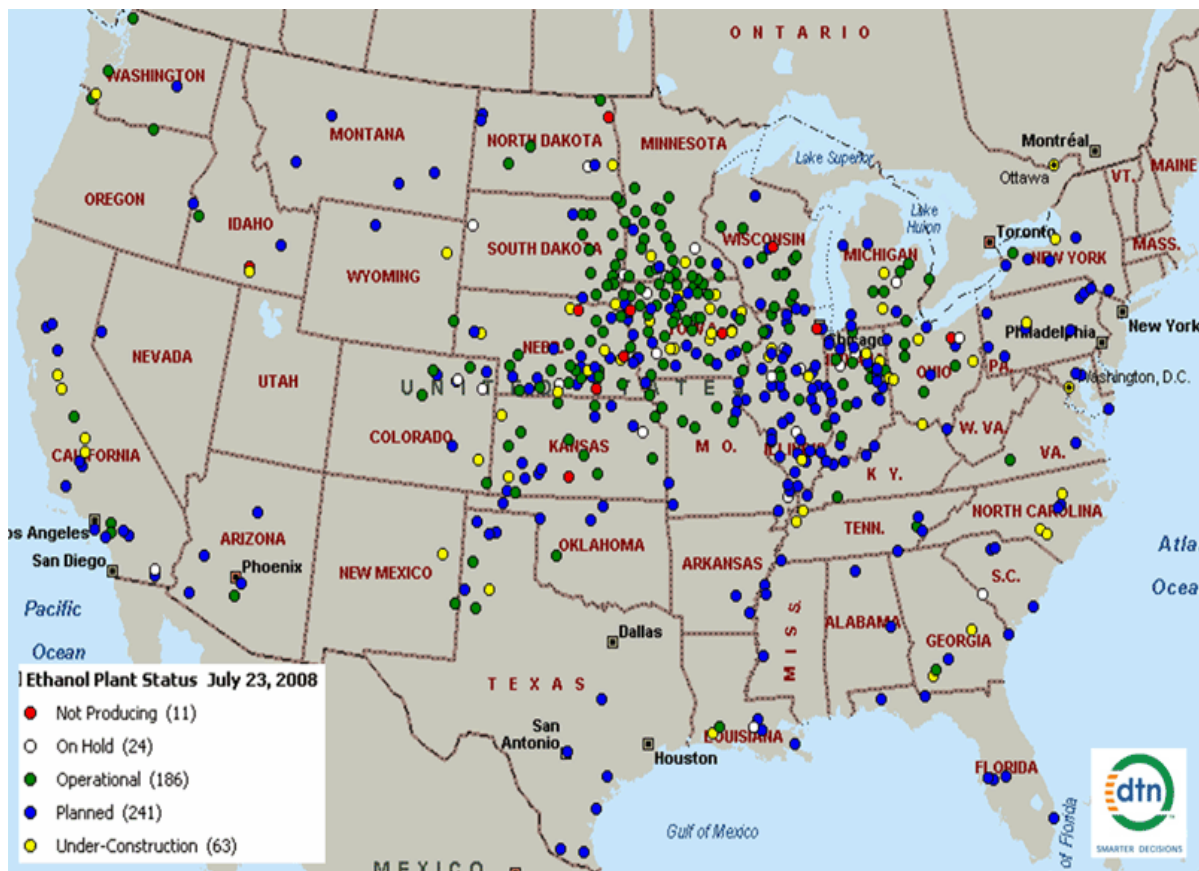
Banning the use of MTBE in gasoline (which was implemented in 1999), and by the adoption of Ethanol as an MTBE substitute, has served to stimulate the demand for ethanol, helping to increase the number of ethanol plants to 81 in 2005 (Table 2.1). The 2005 Energy Act, along with a boost in gasoline prices has also pushed the demand for ethanol and therefore the number of ethanol plants so high that as of July 2008, 186 plants were producing ethanol, 63 ethanol plants were under construction and 241 plants were in the planning stages (Figure 2.4).

U.S. ethanol production capacity reached 10.25 billion gallons per year in September 2008 with an additional 3.50 billion gallons per year of projected capacity under construction (33 plants) and expansion (5 plants) (RFA, 2008). Based on Table 2.2, Iowa, Nebraska, Illinois, Minnesota, and South Dakota are the largest producers of ethanol in the United States. These five states have a total of 5392.1 million gallons (MGY) of annual online ethanol production capacity, which amounts to 68 percent of total U.S. online ethanol production capacity. In July

Table 2.1. Recent ethanol industry expansions

Year	Bio-refineries Online	Capacity (mgy)
Jan 2000	54	1748.7
Jan 2001	56	1921.9
Jan 2002	61	2347.3
Jan 2003	68	2706.8
Jan 2004	72	3100.8
Jan 2005	81	3643.7
Jan 2006	95	4336.4
Jan 2007	110	5493.4
Jan 2008	139	7888.4

Source: Renewable Fuels Association (RFA),
January 2008.



*Alaska has one ethanol plant in the planning stage
*Hawaii has one plant in the planning stage and one is on hold

Figure 2.4. Ethanol plant status and distribution in 2008
Source: DTN Ethanol Center, <http://www.dtnethanolcenter.com>

2008, less than one-half of the fifty U.S. states (23 states) had online ethanol plants and two other states had ethanol plants under construction (Table 2.2). Considering the 5,536 MGY ethanol production capacities under construction and expansion, total ethanol production capacity reaches to more than 13,424 million gallons per year.

2.2.2. Ethanol Prices

Ethanol prices are under the influence of several factors, with some factors having a positive effect and other factors having a negative effect on ethanol prices. From the positive side, boosts in ethanol demand resulting from mandatory ethanol use and sky-rocketing oil prices have been the most important variables that have increased ethanol prices in recent years. Historically, variables such as octane enhancement, federal and state tax credits, and the oxygenating capability of ethanol have had a positive impact on ethanol prices.

On the other hand, ethanol transportation difficulties, need of special equipment to blend ethanol with gasoline, engine modification requirements that are necessary in order to use gasoline that contains more than 10% ethanol, and increasing fuel volatility are factors that have had a negative impact on ethanol prices (Downstream Alternatives Inc., 2002).

In the U.S. ethanol market, the ethanol price is set by ethanol producers. Ethanol is typically used to enhance gasoline's octane grade from regular unleaded gasoline to midgrade or premium unleaded gasoline. When ethanol demand was weak, ethanol producers priced ethanol below the price of gasoline in order to encourage blenders to use more ethanol and, to further their market share, resorted to giving away some quantities of ethanol for blending with unleaded regular gasoline. Even with the Federal ethanol mandate in force, ethanol producers continue to set ethanol prices based on the supply of and demand for ethanol. A typical mechanism for determining the ethanol price is specified as follows: (Downstream Alternatives Inc., 2000)

$$GP + (10 * FETC) + (10 * SC) - MI = EP$$

Table 2.2. U.S. ethanol production capacity by state (million gallons per year)

State	Online	State Share (%)	Under Construction/ Expansion	Total	State Share (%)
Iowa	2059	26.10	1435	3494	26.03
Nebraska	1143.5	14.50	691	1834.5	13.67
Illinois	887	11.24	254	1141	8.50
Minnesota	619.6	7.85	457.5	1077.1	8.02
S. Dakota	683	8.66	283	966	7.20
Indiana	470	5.96	450	920	6.85
Ohio	68	0.86	470	538	4.01
Kansas	432.5	5.48	75	507.5	3.78
Wisconsin	408	5.17	90	498	3.71
Texas	100	1.27	255	355	2.64
N. Dakota	123	1.56	220	343	2.56
Michigan	215	2.73	50	265	1.97
California	73	0.93	155	228	1.70
Tennessee	67	0.85	138	205	1.53
Missouri	201	2.55	0	201	1.50
New York	50	0.63	114	164	1.22
Oregon	40	0.51	108	148	1.10
Colorado	125	1.58	0	125	0.93
Georgia	0.4	0.01	120	120.4	0.90
Arizona	55	0.70	0	55	0.41
Washington	0	0.00	55	55	0.41
Kentucky	35.4	0.45	0	35.4	0.26
New Mexico	30	0.38	0	30	0.22
Wyoming	5	0.06	0	5	0.04
Louisiana	0	0.00	1.5	1.5	0.01
Total	7888.4	100.00	5536	13424.4	100.00

Source: Renewable Fuels Association, January 2008

In the above equation, GP is gasoline price, FETC is Federal Excise Tax Credit, SC is state credit, MI is margin improvement, and EP is ethanol price. Currently, the FETC is equal to 5.1 cents for each gallon of gasoline is blended with 10% ethanol, this results in 51 cents for each gallon of ethanol blended into gasoline. State credit is different from state to state. For instance,

in 2000, tax credits were 6 cents per gallon and 1 cent per gallon in Alaska and Iowa, respectively (Downstream Alternatives Inc., 2000).

Margin improvement allows gasoline blenders to improve their product margin for each gallon of gasoline which they have blended with ethanol. To induce blenders to use ethanol, a blend margin incentive, traditionally provided by the unleaded price plus \$0.54, must be provided. This incentive is estimated to be \$0.05 per gallon of blended fuel.

As an example, if the gasoline price is \$3.00 per gallon, margin improvement is 2 cents per gallon of gasoline blended with ethanol at the 10% level, and state tax is 3 cents per gallon of blended gasoline, then the ethanol price would be determined as follows:

$$\text{Ethanol price} = \$3.00 + (10 \times \$0.051) + (10 \times \$0.03) - (10 \times \$0.02) = \$3.61$$

Figure 2.5 shows the ethanol price for each quarter from the first quarter of 1982 to the fourth quarter of 2007. The ethanol price first dropped off from \$1.70 per gallon in 1982 to \$0.79 per gallon in 1986. From 1987 to 2000, ethanol prices fluctuated between \$1.00 and \$1.50 per gallon. From 2002 to the summer of 2006 ethanol prices had an increasing trend and reached its historical record of \$3.02 per gallon before starting to decline.

2.2.3. Ethanol Feedstocks and Production Costs

Ethanol is usually produced from feedstock such as corn or sugarcane. Even though ethanol can be produced from different feedstock and biomass materials such as grasses, hay, and waste, the chemical breakdown processes of these materials are not fully developed to make them commercially viable (Outlaw et al., 2003). Therefore, sugarcane and corn have been, to date, the most efficient feedstocks for producing ethanol.

The United States and Brazil are the biggest ethanol producers in the world and rank first and second among countries which produce ethanol. Feedstock cost plays a critical role in ethanol plants' profitability and capacity. In the United States, corn is the cheapest feedstock for

producing ethanol and, therefore, more than 97% of total ethanol production is produced from corn. Brazil is the world's largest sugar producer with the lowest sugar cost of production. Brazil also enjoys the lowest sugarcane production costs in the world. Brazil, therefore, primarily uses sugarcane in domestic ethanol production.

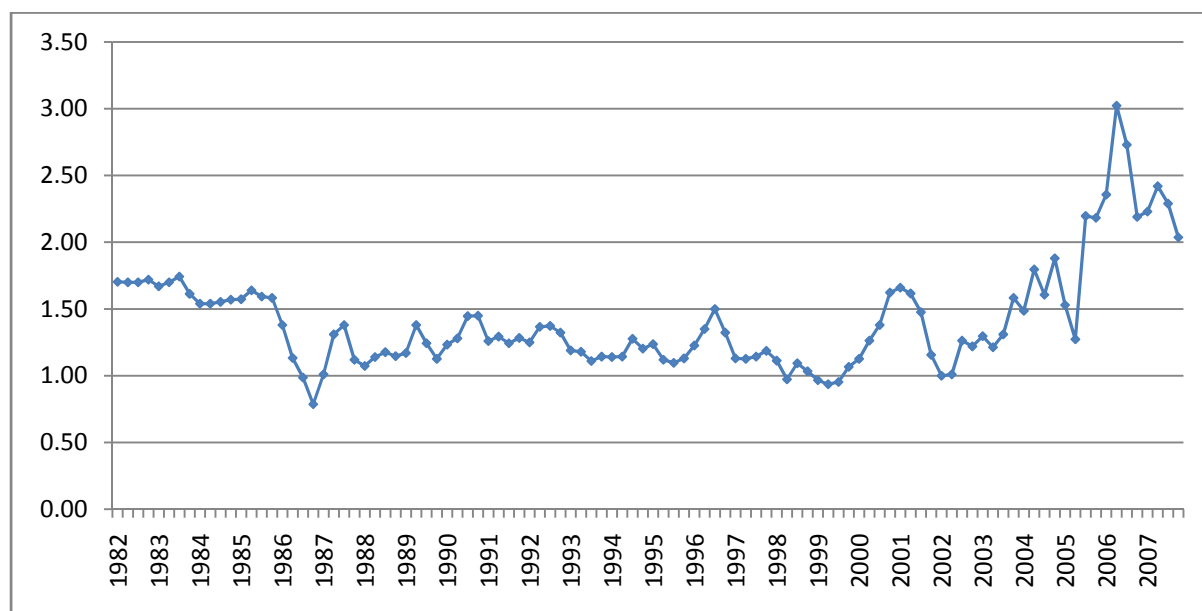


Figure 2.5. Quarterly average ethanol price trend (\$/gal)

Source: Nebraska Ethanol Board, Nebraska Energy Office, Lincoln, NE.

The United States and Brazil are the most efficient ethanol producers in the world and they have the lowest ethanol feedstock cost for corn and sugarcane, respectively (Kojima et al., 2007). In producing ethanol from sugarcane, the most important byproduct is bagasse, which can be used as an energy source to provide part of the energy needed to run an ethanol plant. Burning bagasse reduces ethanol plants' energy costs significantly, therefore reducing ethanol production costs. This is an advantage for producing ethanol from sugarcane as compared to producing ethanol from other feedstocks (Kojima et al, 2007).

Ethanol conversion factors for different feedstocks are shown in Table 2.3. Based on feedstock quantity per gallon of ethanol (the second column of Table 2.2) and 2007 domestic

U.S. prices for each feedstock, the gross feedstock per gallon cost (feedstock cost before subtracting byproduct ethanol) of producing ethanol in the United States from each feedstock is calculated and shown in the third column. As the results show, producing ethanol from molasses has the lowest gross feedstock cost (\$0.91 per gallon of ethanol) and ethanol from refined sugar has the highest gross feedstock cost (\$3.56 per gallon of ethanol). Since most of the ethanol production cost is attributed to feedstock costs, feedstock prices play a critical role in ethanol's economic margin and competitiveness.

Table 2.3. Ethanol conversion factors and gross feedstock cost of ethanol for different feedstocks

Feedstock	Gallons of Ethanol per unit of feedstock	Feedstock quantity per gallon of ethanol	Dollars per gallon*
Corn (wet mill)	2.65 gallons per bushel 94.64 gallons per ton	0.38 bushel per gallon 0.0106 tons per gallon	1.68
Corn (dry mill)	2.75 gallons per bushel 98.21 gallons per ton	0.36 bushel 0.0101 tons per gallon	1.62
Sugarcane	19.5 gallons per ton	0.051 tons per gallon	1.56
Sugar beets	24.8 gallons per ton	0.040 tons per gallon	1.81
Molasses	69.4 gallons per ton	0.0144 tons per gallon	0.91
Raw sugar	135.4 gallons per ton	0.0074 tons per gallon	3.10
Refined sugar	141.0 gallons per ton	0.0071 tons per gallon	3.55

Source: Salassi et al., 2006

* Calculated based on column 2 and 2007 U.S. domestic prices for each feedstock

As with other products, producing ethanol has two different types of production costs. These are capital costs and operation costs. Both kinds of costs vary depending on the feedstock and technology employed for producing ethanol as well as the location of the ethanol production facility. Ethanol production cost plays a critical role in the profitability of ethanol, and ultimately help determine ethanol production quantities and ethanol prices. Each type of feedstock requires

a specific technology (requiring special facilities, personnel, and equipment) to complete the production cycle from feedstock input to ethanol output and, therefore, both capital cost and operational cost are different from one feedstock to the next. Because of existing economies of scale in the ethanol industry, plant size also influences ethanol production costs. Table 2.4 shows net feedstock cost and total production cost of per gallon of ethanol from different feedstock in the United States based on U.S. domestic feedstock prices. Note that capital cost is not included in this table.

Table 2.4. Ethanol production cost, based on fourth quarter, 2007 U.S. domestic prices

	Corn (wet mill)	Corn (dry mill)	Sugar cane	Sugar beets	Molasses	Raw sugar	Refined sugar
Feedstock market price \$/gal*	1.68	1.62	1.56	1.81	0.91	3.10	3.55
Ethanol byproduct credit:							
DDG \$/gal		0.46					
Corn gluten feed \$/gal	0.17						
Corn gluten meal \$/gal	0.17						
Corn oil \$/gal	0.19						
Net feedstock cost \$/gal**	1.15	1.16	1.56				
Processing cost \$/gal***	0.63	0.52	0.92	0.77	0.36	0.36	0.36
Total Cost \$/gal****	1.78	1.68	2.48	2.58	1.27	3.46	3.91

* sugarcane and sugar beets prices are for 2006

** Only for corn is net feedstock cost and the others are gross feedstock cost

*** Processing cost is based on Salassi et al report, USDA 2006

**** Capital cost is not included

Source: Calculated based on USDA 2008 data.

Per gallon capital cost of producing ethanol from different feedstock for two different size of ethanol plants, 20 and 40 million gallons per year, is illustrated in Table 2.5. Calculations are based on a 20 year investment at 7 percent interest. Because of the existence of economies of size in the ethanol industry, a larger plant has a smaller capital cost per gallon of ethanol. Ethanol

plants which use molasses or sugar juice as a feedstock have the lowest capital cost while plants that use sugarcane or sugar beets have the highest capital cost per gallon of ethanol.

Table 2.5. Capital per gallon cost for producing ethanol from different feedstocks (\$/gal)

Feedstock	20 million gallons per year plant	40 million gallons per year plant
Corn	0.14	0.12
Sugarcane	0.20	0.16
Sugar beets	0.20	0.16
Cane/beet juice	0.13	0.10
Cane/beet molasses	0.13	0.10

Source: Salassi et al., USDA, 2006.

Feedstock and energy (natural gas and electricity) costs are the most significant factors in considering whether to produce ethanol. Both inputs have a major impact on ethanol production profitability. The share of feedstock in corn base ethanol production cost can be between 50 to 70 percent for corn prices ranging from \$1.60 to \$3.20 per bushel. The role of feedstock in ethanol production cost is so important that a \$0.25 increase in feedstock price can increase the annual cost of a 30 million gallon per year (MGPY) ethanol facility by as much as \$3 million annually (Coltrain, 2004).

Ethanol plants use natural gas and electricity to produce ethanol and dry the ethanol by-products, dry distillers' grains (DDGs) in particular. Therefore, energy consumption is a big factor in producing ethanol, so much so, that it accounts for 10 percent of ethanol plant operation cost (Coltrain, 2004).

Because an ethanol production facility involves significant capital investment, the interest rate is an important factor for decision makers regarding whether to invest in the ethanol

industry. Based on Coltrain's study, a 1% increase in the prime interest rate can increase the annual cost of a 30 MGPY ethanol plant by \$200,000.

2.2.4. Cellulosic Ethanol

Cellulosic ethanol is produced from converting cellulosic feedstocks such as wood, bagasse, straw, and switchgrass into ethanol. Producing cellulosic ethanol is not as easy as producing ethanol from corn and sugar and needs special treatment and therefore special technology. The difficulty with cellulose is that it has special polymer types of starch that requires extra steps to change it into a fermentable sugar. There are different approaches such as enzymatic conversion, acid hydrolysis, and gasification to convert cellulose to ethanol. Figure 2.6 demonstrates enzymatic conversion methods of producing cellulosic ethanol.

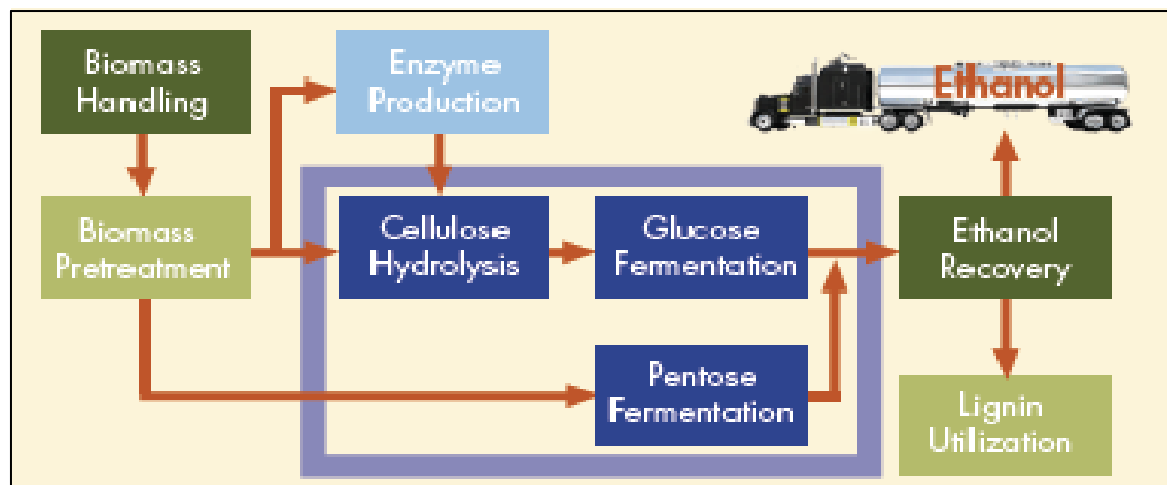


Figure 2.6. Production of ethanol from cellulosic biomass
Source: RFA, Ethanol Industry Outlook, 2008.

Even though scientists have discovered special enzymes to deal with this problem, current technology is still not advanced sufficiently to make cellulosic ethanol production commercially viable. It has been estimated that producing cellulosic ethanol from corn stover (leaves and stalks of maize plants left in a field after harvest) will cost \$1.65 per gallon by 2012

(EPA, 2006). Collins (2007) shows a current \$2.65/gallon production cost for cellulosic ethanol. This price is expected to decrease to around \$1.10/gallon between 2010 and 2012 (Table 2.6).

Table 2.6. Cost competitiveness of cellulosic ethanol in comparison with corn-based ethanol

Feedstock	Corn based	Cellulosic today (illustration)	Cellulosic 2010-12 (DOE target)
	\$1.17 @ \$3.22/bu 2.75 g/bu	\$1.00 @ \$60/dt 60 g/dt	\$0.33 @ \$30/dt 90 g/dt
By-product	-\$0.38	-\$0.10	-\$0.09
Enzymes	\$0.04	\$0.40	\$0.10
Other costs *	\$0.62	\$0.80	\$0.22
Capital cost	\$0.20	\$0.55	\$0.54
total	\$1.65	\$2.65	\$1.10

* includes pre-processing, fermentation, and labor
Source: Keith Collins, EIA energy outlook, 2007.

As of now, there are no commercial cellulosic ethanol plants operating in the United States. The only North American cellulosic ethanol plant is located in Canada and uses wood chips to produce one million gallons of ethanol each year (Renewable Fuel Standard Program, 2006).

Incentive for producing cellulosic ethanol is growing because the “Energy Independence and Security Act of 2007” mandates using cellulosic ethanol in fuel starting with a minimum of 0.1 billion gallons in 2010, increasing annually to 16 billion gallons by 2022. To reach these goals will require a great deal of research and study to make cellulosic ethanol production commercially possible and for Federal and state incentives and grants to make cellulosic ethanol production competitive with grain-based ethanol produced (RFA, 2008). In the first quarter of

2008, The U.S. Department of Energy announced that it would provide \$114 million in funding to build four cellulosic plants in Colorado, Missouri, Oregon and Wisconsin through 2010, in order to test the practical production of ethanol from cellulose (Environment News Service, 2008).

Based on U.S. Department of Energy (DOE) predictions, cellulosic ethanol can begin to compete with corn-based ethanol by 2012. However, it needs some time to establish sufficient plants to make it available to consumers (USDA, 2007).

In this study, cellulosic ethanol production is not included in the discussion because commercial production of ethanol from cellulose is a long range factor that needs more research and development that is currently not extant. Moreover, it is still uncertain which feedstock(s) will be used in cellulosic ethanol production. This depends on several different factors such as a feedstock's availability and production, harvesting, transportation, storing, and processing costs and the compatibility of these costs as compared with other feedstock costs (USDA, 2007).

Given the low cost of producing ethanol from corn in comparison with the cost of producing ethanol from cellulose, corn will likely be the main feedstock for producing ethanol for the next decade. This situation may change in the long run because of technological advancements that could serve to make cellulosic ethanol a lower cost alternative to corn-based ethanol (Lamp, 2007).

2.2.5. Corn-Based Ethanol Plants and Technologies

There are two kinds of corn-based ethanol plants: wet milling plants and dry milling plants. Wet milling plants are capable of producing ethanol and HFCS. So, dependent on the benefit margin for ethanol and HFCS, producers choose whether to produce ethanol or HFCS. Dry milling plants can only produce ethanol. Because of their higher efficiency, most ethanol is produced by dry milling plants and all newly constructed ethanol plants are dry milling plants. Wet milling

plants are larger than dry milling plants and their production capacity can vary from 50 million gallons per year (MGY) to 300 MGY. Old dry milling plants usually have a production capacity somewhere between 5MGY to 30 MGY but newer plants are larger and more efficient and have a production capacity ranging from 40 to 100 MGY (Gallagher et al., 2004). Corn oil, gluten meal (that contains about 60% protein), and gluten feed (which contains about 20% protein) are the most important byproducts of wet milling plants. These plants can produce 31.5 pounds liquid starch or 2.65 gallons of ethanol along with 1.6 pounds of corn oil, 2.5 pounds of gluten meal, and 12.5 pounds of gluten feed from one bushel of corn (Brendstrup et al., 2005). Because of the chemical gain in processing trend, 33.33 pounds of corn sweetener (HFCS) can be produced from 31.5 pounds of corn starch (USDA Sugar and Sweeteners Tables, 2008).

The share of dry mill ethanol plants in U.S. ethanol production was 79% in 2005 (Tokgoz and Elobeid, 2006). Since all newly constructed ethanol plants are dry mill in type, this share is now likely to be greater than 80%. Alternatively, dry milling plants can only produce ethanol. Their byproduct is distillers' grains (DGs) and distillers' grains with slob. Distiller's Grain is initially wet and can only be stored on shelf for a few days. Plants that are close to DGs consumers do not need to dry DGs because they can sell wet distillers' grains (WDGs) directly to the consumer. If the ethanol plant is far from DGs users or its production is more than the local market demand when wet, then DGs must be dried and changed to DDGs to be transferred to other markets. Dry milling ethanol plants can produce approximately 2.75 gallons of ethanol along with 17 pounds of dry distillers' grains (DDGs) from each bushel of corn (RFA, 2008). Figures 2.7 and 2.8 illustrate the ethanol production process for both wet and dry milling plants, respectively.

2.2.6. Governmental Support for Ethanol

The expansion of the ethanol market in the United States depends upon crude oil prices and the magnitude of ethanol demand. However, government policies related to other factors, especially air pollution, energy security, and rural development, have recently impacted the ethanol market. This trend in ethanol market expansion is expected to continue into the foreseeable future as long as government policies continue as they are.

Ethanol production has been federally supported by means of different policy tools. These include fuel tax reductions, federal and state producer subsidies, loan programs, import tariffs, and financial incentives for producing and buying vehicles which are capable of using biofuels. Since all ethanol produced in the United States comes from agricultural crops (mainly corn), governmental policy related to ethanol production affects agricultural markets and food production. Conversely, agricultural policies impact ethanol market (Kojima et al., 2007). In recent years, ethanol production in the United States has only been marginally economically viable because of these governmental supports and the spike in gasoline prices.

More than 38 states provide incentives for producing ethanol. Their measures also include requiring government agencies to use biofuels, buying public vehicles which are capable of using ethanol, providing grants, issuing production tax credits, producers payments, excise tax reductions, accelerating the depreciation for ethanol plants, loan guarantees, subsidizing loans, credit-grant hybrids, regulatory exemptions such as environmental regulations waivers, and providing support for land used through reduced property tax rates for on ethanol facilities (Kojima et al, 2007). In this regard, the 2005 Energy Act and its counterpart, the 2007 Energy Independence and Security Act, have had a tremendous impact on ethanol demand through the government mandating a minimum level of ethanol consumption.

The Environmental Protection Agency (EPA) is required to provide flexibility to fuel producers through creating a trading system. Based on this program, each gallon of ethanol produced from cellulose receives 2.5 times as much credit as does ethanol produced from corn (Tokgoz and Elobeid, 2006).

The Energy Tax Act of 1978 launched excise tax exemptions for ethanol in the United States for the first time. The full exemption was 40 cents for each gallon of ethanol blended with gasoline at a ratio of 90% gasoline, 10% ethanol (90:10). This is equivalent to 4 cents for each gallon of gasoline blended with ethanol at the 90:10 ratio. In 1980, this tax credit was extended to gasoline blended with ethanol in rates other than 10% such as E85 which contains 85% ethanol and 15% gasoline. Furthermore, as one can see in Table 2.7, the tax credit increased from 40 cents in 1978 to 60 cents in 1984, but then declined and reached 51 cents in 2007 (OECD, 2006).

Table 2.7. Federal taxes and tax exemption for ethanol/gasoline blends

Year	Prior to 1978	1978 to 1982	1982 to 1984	1984 to 1990	1990 to 1993	1993 to 2000	2001 to 2002	2003 to 2004	2005 to 2007
Federal gasoline excise tax (¢/gal)	4	4	9	9	14	18.3	18.3	18.3	18.3
Excise tax exemption for 10% ethanol blends (¢/gal)		4	5	6	5.4	5.4	5.3	5.2	5.1
Blender's income tax credit for ethanol (¢/gal)			40	60	54	54	53	52	51

Source: California Energy Commission. Costs and benefits of a biomass-to-ethanol production industry in California. March 2001.

2.2.7. The 2005 and 2007 Energy Policy Acts

The U.S Congress passed an energy bill in 2005 that included Renewable Fuel Standards (RFS).

The Energy Policy Act of 2005, signed by President Bush in 2005 and subsequently

implemented by the EPA, requires blending a minimum amount of biofuel with gasoline starting with 4 billion gallons of ethanol in 2006 and increasing to 7.5 billion gallons of ethanol blended with gasoline by 2012 (EPA, 2006). Any increase in ethanol blended with gasoline after 2012 must have a growth rate comparable to that of the increase in gasoline consumption.

This energy act also removed the reformulated gasoline oxygen standard (RFG), augmented clean air rules, and provided a situation that discouraged using MTBE in fuel (Lamp, 2006). The 2005 Energy Policy Act created some support for grain-based ethanol production and cellulosic ethanol production as well.

Historically record high oil prices made the blending of ethanol with gasoline beneficial for gasoline refineries and blenders. This, in turn, served to increase the demand for ethanol so that the amount of ethanol production surpassed levels required by the 2005 Energy Act and encouraged the government to introduce the Energy Independence and Security Act of 2007.

Under the “Energy Independence and Security Act of 2007”, renewable fuels must grow to almost 36 billion gallons by 2022. The program allows refiners to meet requirements through a credit and trading program. This Energy Act seeks to reduce gasoline consumption by 25% in 15 years through increased biofuels production and reduced gasoline consumption. Based on EIA Annual Energy Outlook projections, gasoline consumption will have a 0.4 percent growth rate between 2006 and 2030 (EIA, 2008). U.S. gasoline consumption was 3,389 million barrels (142,338 million gallons) in 2007, which with a 0.4 annual growth rate will reach 3,598 million barrels (151,116 million gallons) in 2022. If the 2007 Energy Independence and Security Act’s goal of 36 billion gallons ethanol production by 2022 is reached, then ethanol will contribute approximately 24 percent of motor fuel consumption in 2022. Furthermore, this legislation provides special promotion programs for using other feedstock, in particular cellulosic ethanol production.

The Energy Independence and Security Act of 2007, an amendment of the 2005 Renewable Fuels Standards (RFS), was signed into law on December 19, 2007 by President Bush. This energy act requires U.S. gasoline blenders/distributors to blend a minimum amount of ethanol with gasoline every year. Based on this Energy Act, the amount of ethanol blended with gasoline starts at 9 billion gallons in 2008 and reaches 36 billion gallons by 2022 (RFA, 2008). Corn and other grain-based ethanol production will grow to 15 billion gallons by 2015 and will be kept at this level thereafter. The rest of the required ethanol must be advanced biofuel, which is ethanol produced from any feedstock besides corn starch (Figure 2.9). This includes ethanol produced from waste and cellulosic materials. Advanced biofuel goes from zero in 2009 and is expected to increase to 21 billion gallons, almost 1.5 times as much as corn-based ethanol production, in 2022. Thus 58 percent of ethanol production in 2022 will be provided by advanced biofuels. Table 2.8 illustrates required ethanol production levels based on the “Energy Independence and Security Act of 2007.”

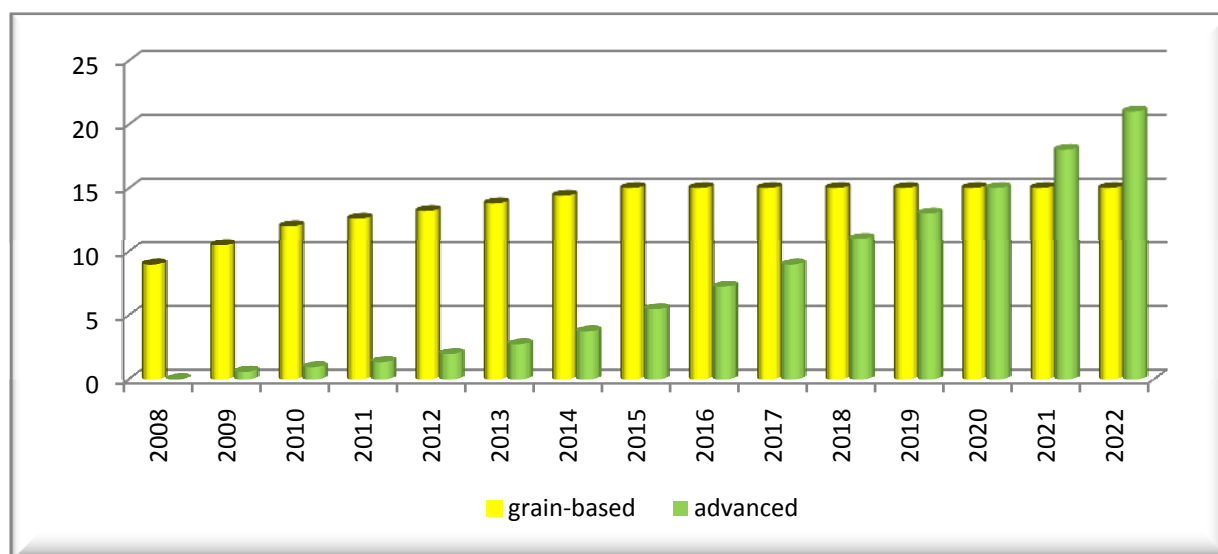


Figure 2.9. The 2007 Energy Act’s requirement ethanol production levels from different feedstocks

Source : Renewable Fuels Association (RFA). (2008) Changing the Climate, Ethanol Industry Outlook 2008.

Table 2.8. The 2007 Energy Act's requirement ethanol production levels from different feedstocks for years 2008 to 2025

Year	Corn and other grain-based ethanol	Advanced Biofuel				Total RFS
		Cellulosic Biofuel	Biomass -based Diesel	<i>Undifferentiated Advanced Biofuel</i>	<i>Total Advanced Biofuel</i>	
2008	9	0	0	0	0	9
2009	10.5	0	0.5	0.1	0.6	11.1
2010	12	0.1	0.65	0.2	0.95	12.95
2011	12.6	0.25	0.8	0.3	1.35	13.95
2012	13.2	0.5	1	0.5	2	15.2
2013	13.8	1		1.75	2.75	16.55
2014	14.4	1.75		2	3.75	18.15
2015	15	3		2.5	5.5	20.5
2016	15	4.25		3.0	7.25	22.25
2017	15	5.5		3.5	9	24
2018	15	7		4.0	11	26
2019	15	8.5		4.5	13	28
2020	15	10.5		4.5	15	30
2021	15	13.5		4.5	18	33
2022	15	16		5	21	36

Source: Renewable Fuel Standard (RFA), 2008.

2.2.8. U.S. Renewable Fuels Standards (RFS)

Based on the 2005 Energy Act, the U.S. Environmental Protection Agency (EPA) declared a renewable fuel standard of 4.66 percent, but later changed it to 7.76 percent in compliance with the Energy Independence and Security Act of 2007. The basis for calculation is for a 7.76 percent ethanol to gasoline share with a minimum of 9 billion gallons ethanol production for 2008, required by the Energy Independence and Security Act of 2007 (Environment News Service, 2008).

Under the Energy Independence and Security Act of 2007, ethanol producers must ensure that their ethanol production meets the lifecycle greenhouse gas (GHG) emissions reduction level

that is equal to 20% by 2008 – as compared to 2005 which serves as the base year – and whose level will be set annually by the EPA. The EPA sets an annual target level based on the RFS for the minimum amount of ethanol that must be blended with gasoline by each individual gasoline refiner, blender, and importer every year. To accomplish this, the EPA has established an identification number for each of these individuals by registering them and keeping requisite records. Furthermore, the EPA reports obligation for all gasoline fuel producers, blenders, and importers.

2.2.9. Ethanol and Gasoline

Ethanol is a renewable bio-fuel that can be produced in the United States, helping to reduce U.S. dependence on imported crude oil. Energy has played a significant role in economic growth in any major world economy. With the United States importing more than 70% of its oil, any weakness in the energy supply chain could pose potential threat to the U.S. economy. Only 3 percent of the world's known oil reserves are in the United States but the United States, accounts for more than 25 percent of world oil consumption (Natural Resources Defense Council and Climate Solutions, 2006).

On a daily bases, the United States consumes approximately 20 million barrels of oil while producing 6 million barrels (Woolverton, 2006). At \$50 per barrel, the United States pays more than \$250 billion annually to other countries in oil purchases. In fact, if we rank all countries based on the volume of their oil consumption, U.S. oil consumption alone is equal to the combined oil consumption of the next five biggest oil consumers (China, Japan, the Former Soviet Union, Germany, and Canada) (Therriault, 2006). The United States spends approximately \$35 billion dollars per year in defense expenditures in order to protect the flow of oil from the Middle East (Lauder, 2001). Producing ethanol is one way to change this situation

and reduce the need for these defense expenditures. The United States used 142.35 billion gallons of gasoline and 6.485 billion gallons of ethanol in 2007 (EIA, 2008).

United States annual ethanol production capacity was 7.89 billion gallons of ethanol in January 2008 with an additional 5.5 billion gallons production capacity scheduled to come on-line by way of new ethanol plant construction. This means that the United States could cut annual oil consumption by about 319 million barrels of oil relative to the situation of no ethanol production.

A question that has been raised is whether ethanol is a complement or a substitute for gasoline. Even though mandatory ethanol consumption laws and increased gasoline prices both increase demand for ethanol, the means by which these two factors manifest themselves on ethanol production are different. Federal mandates make ethanol a complementary product for gasoline, which gasoline blenders (oil refineries) are required to use if they want to supply gasoline. This means that fuel producers will blend ethanol with gasoline only to the required level, provided the gasoline price is lower than or equal to the subtotal of the ethanol production and blending costs. Therefore, in this case federal mandates will force refineries to use ethanol, resulting in ethanol being a complementary good for gasoline. On the other hand, when the gasoline price is significantly higher than ethanol production and blending costs, it encourages oil refineries to blend more ethanol in gasoline in order to take advantage of price differences between ethanol and gasoline. Subsequently, this allows producers to increase net profits. In this case, when the gasoline price is higher than the ethanol costs, ethanol will be a substitute for gasoline so that the quantity of ethanol blended with gasoline will be greater than the required level. We show these relationships between ethanol and gasoline in figure 2.10.

Based on above discussion, an increase in ethanol prices does not have significant negative impacts on the amount of ethanol demanded up to the federally mandated level, but

after that, reduces the demanded amount of ethanol. Thus we can summarize our discussion as follows:

- If ethanol price + blending costs \geq gasoline price \rightarrow mandatory law will be in force \rightarrow ethanol is a complementary good for gasoline
- If ethanol price + blending costs $<$ gasoline price \rightarrow refineries use ethanol in gasoline to make profit \rightarrow ethanol is a substitutionary good for gasoline

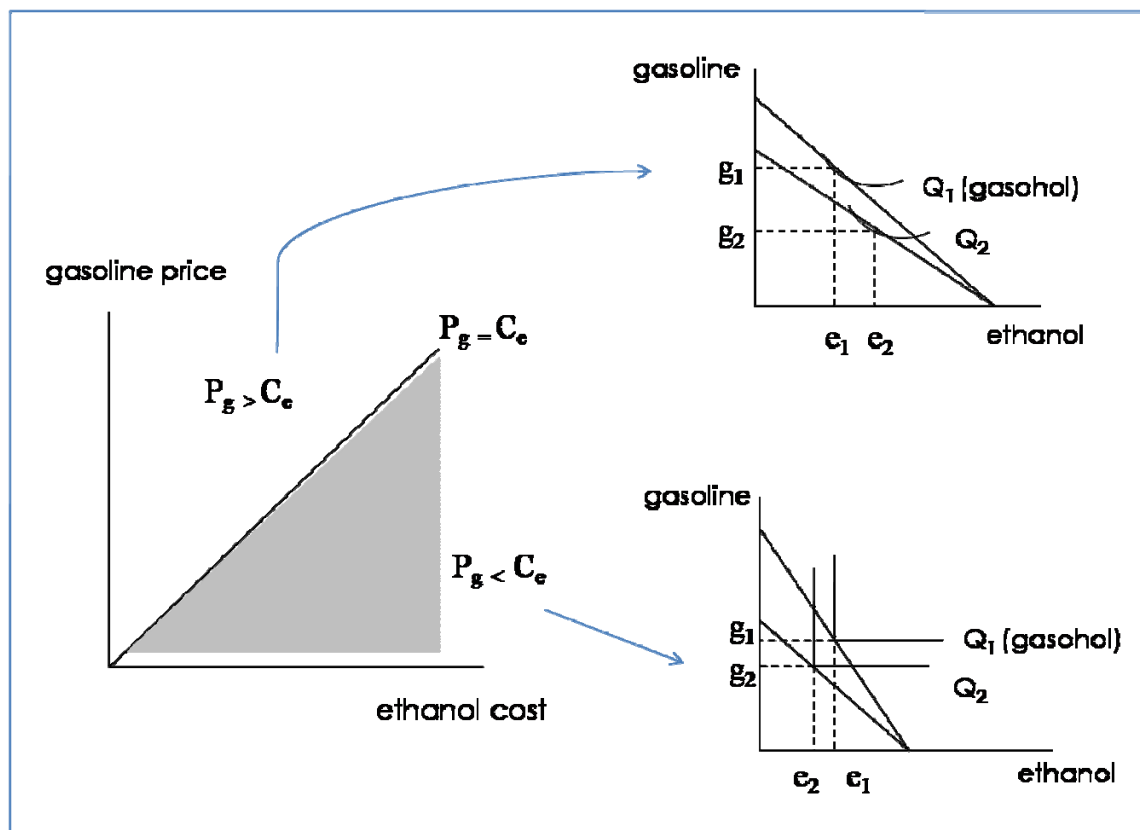


Figure 2.10. Relationship between ethanol and gasoline

Du and Hayes show that ethanol production has had a negative effect on gasoline prices to the extent that they suggest gasoline prices could be \$0.29 to \$0.40 per gallon higher if it were not for ethanol production (Du and Hayes, 2008). About 50% of gasoline consumed in the United States is blended with ethanol at the rate of 9 to 1. This means that for each gallon of blended fuel the ratio would be 90% gasoline and 10% ethanol.

Figures 2.11 and 2.12 demonstrate the relationship between ethanol prices and gasoline and crude oil prices from 1980 to 2007. Figure 2.11 is based on quarterly data while Figure 2.12 is based on annual data. As these figures show, gasoline and ethanol prices almost always move together so that when gasoline prices are down ethanol prices are down as well. Thus, it appears an increase in gasoline prices raises ethanol prices. This means that gasoline prices have a significant impact on the ethanol price and as seen before, ethanol prices appear to be determined based on gasoline price.

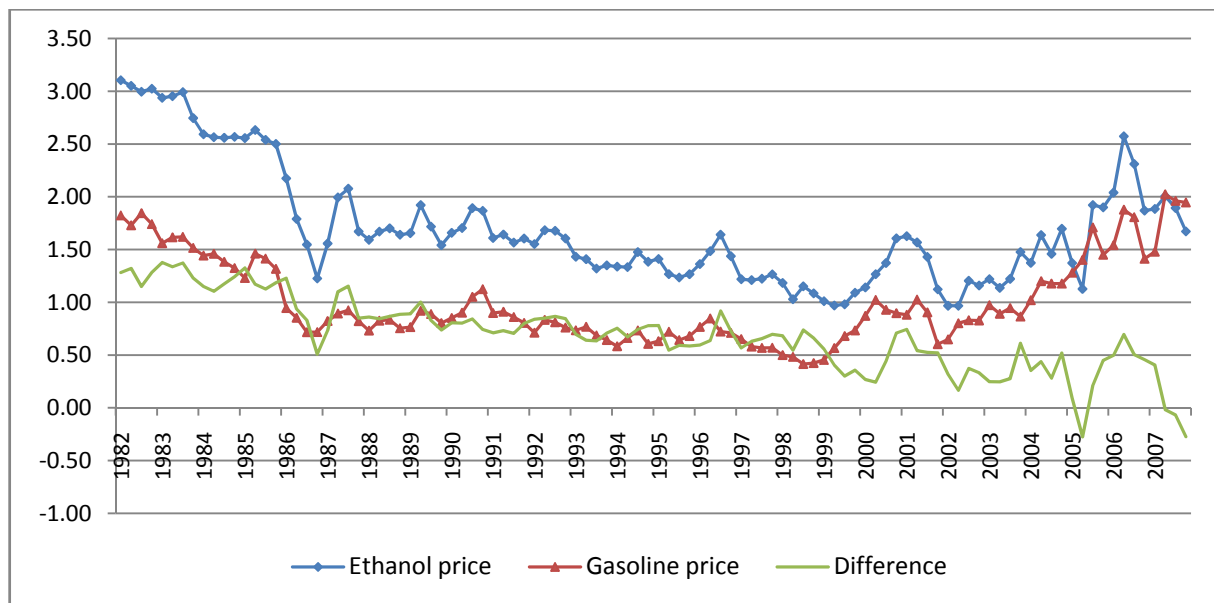


Figure 2.11. The average quarterly ethanol and gasoline prices and their differences (\$/gal)
Source: Nebraska Ethanol Board, Nebraska Energy Office, Lincoln, NE.

Another point is that, based on Figure 2.11, ethanol prices are usually around 50 to 70 cents higher than gasoline prices. A part of this difference comes from the ethanol excise tax that is 51 cents for each gallon of ethanol blended with gasoline. This tax credit which is paid to gasoline refineries and blenders allows them to pay for ethanol a price higher than gasoline prices. Since gasoline prices are dependent on crude oil prices, ethanol prices up and downs are coupled with crude oil prices too (Figure 2.12).

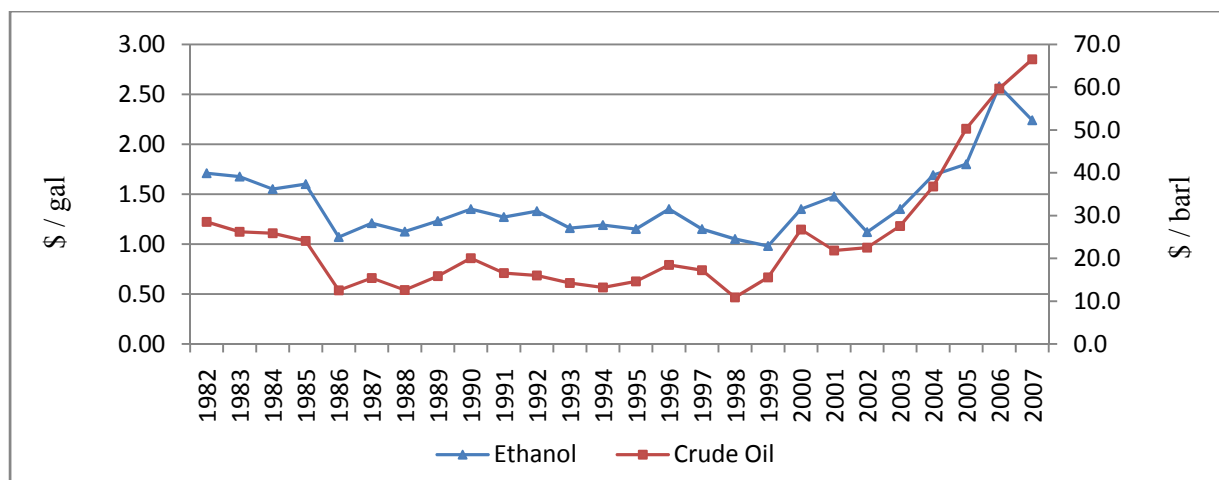


Figure 2.12. The average annual ethanol and crude oil prices

Source: Nebraska Ethanol Board, Nebraska Energy Office, Lincoln, NE

2.2.10. Ethanol Production Impact on the U.S. Agriculture Sector and Economy

Higher corn prices increase land used for corn production. A portion of this additional land used for corn production comes from other crops such as soybeans and cotton. The remaining part comes from cropland used as pasture, fallow, and expiring Conservation Reserve Program. Increases in corn prices raise the price of other crops that are used in food and feed, such as wheat, oats, and soybeans.

Increases in corn demand for ethanol production increase corn prices. This, in turn, reduces livestock production as corn normally used in the livestock industry is diverted into the production of ethanol (Figure 2.13). The reduction in different livestock categories will be different and depends on the role of corn in each category's feed ration and the possibility of substituting corn with DDGs (ethanol byproducts). An increase in ethanol production will result in an increase in distillers' grains supply which is ethanol's main byproduct in dry mill plants. For instance, the volume of DDGs increased from 0.32 million tons in 1980 to 7.8 million tons in 2005 (Markham et al., 2005). As Figure 2.13 illustrates, an increase in corn demand for ethanol

production increases livestock production cost and therefore, shifts livestock supply from S_1 to S_2 . On the other hand, increase in DGs production reduces DGs price, which can be a substitute for corn, and therefore reduces the livestock production cost and shifts back the livestock supply from S_2 to S_3 . The final position of S_3 depends on the degree of substitution between DGs and corn for different types of livestock, and also the overall impact of the increase in corn price and the decrease in DGs price on livestock supply.

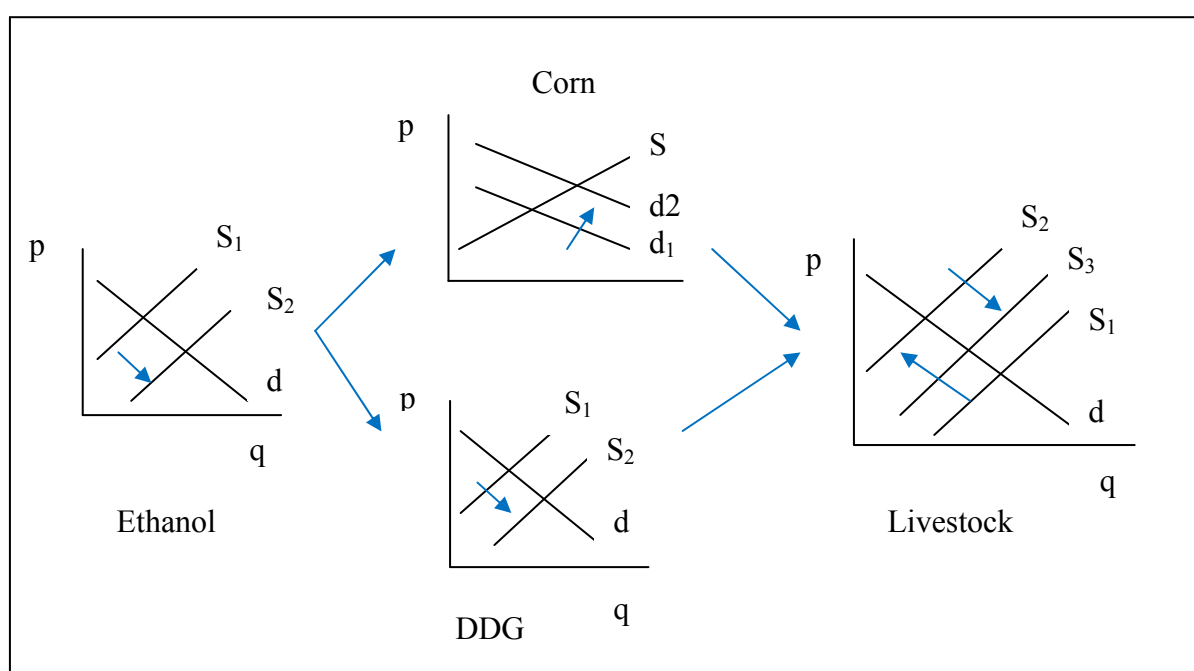


Figure 2.13. Impact of increase in ethanol supply on livestock market

In its basic form, DGs is wet and ready to use for feed. However, it cannot be stored for more than a few days and can only be used by consumers that are in close proximity to the ethanol plant. Therefore, ethanol plants usually dry DGs and change it to dry DGs (known as DDGs) for storage purposes and to increase shipping distance. In 2007, 64 percent of utilized distillers grains in the North America was dry DGs and the rest of that (36%) was wet DGs (RFA, 2008). While corn can be replaced with DDGs in a one-to-one ratio, this replacement rate

is 0.45 for dairy cattle (1 pound of DDGs for per 0.45 pound of corn) and 0.85 and 0.55 for hogs and poultry, respectively.

Considering this information, using each bushel of corn in ethanol production reduces the available corn for feed by only 0.2 bushels, given that the remaining 0.80 bushels is replaced by DDGs. So, it may be predicted that cattle bear the smallest impact because of the possibility of using DDGs while hogs and dairy bear the larger impact with respect to quantity and price adjustment (USDA, 2007). It is expected that both the pork and dairy industries will experience the largest increases in prices, resulting from increases in their production costs and reduction in their levels of production. The composition of different categories of livestock in using DGs as a feed is illustrated in Figure 2.14. As one can see, Cattle and Dairy are the main DGs consumers, while Poultry has the lowest share of DGs.

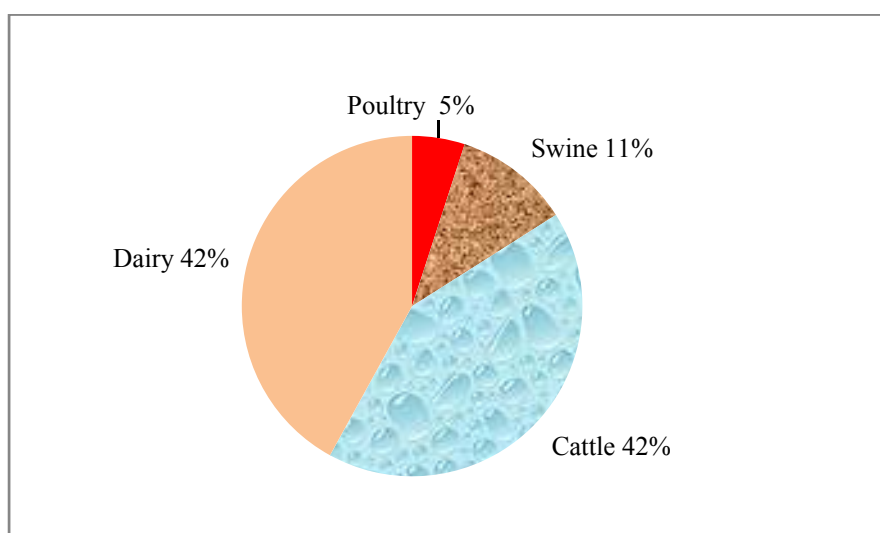


Figure 2.14. 2007 North American distillers grains consumption
Source: RFA, Ethanol Industry Outlook, 2008.

Ethanol production has a considerable impact on the U.S. economy, especially on rural development. Ethanol production boosts will increase farmers' incomes as a result of increases in agricultural crops' prices. The economic activity resulting from producing 6,485 million gallons

of ethanol along with investment in establishing new ethanol facilities in 2007 had notable consequences in different economic sectors. An ethanol plant with 100 MGY in ethanol production can contribute \$164.7 million in spending for goods, inputs and services each year with \$108.9 million of that \$164.7 million being spent at the local level. Such a plant adds more than \$300 million to the state's GDP and more than \$76 million to household income each year. It also creates 1137 jobs with 50 of those jobs being direct jobs. All these changes combined make the state's economy larger and create more taxes for both the Federal and state governments (Urbanchuk, 2008).

Based on the above argument which was only for one ethanol plant, we can now picture the impact of the entire ethanol industry on the U.S. economy. The U.S. ethanol industry added \$47.6 billion to the 2007 U.S. GDP as a result of ethanol plant operations, capital expenditures, and the transportation of ethanol. In 2007 it also improved American households' incomes by as much as \$12.3 billion and created 338,541 direct and indirect jobs in all economic sectors in 2007. All these new activities, expenditures, and incomes resulted in increased in Federal government tax revenue by as much as \$4.6 billion, and State and Local government tax revenue increased by \$3.6 billion. If we compare all tax revenue created by the ethanol industry, which is \$8.2 billion, with the \$3.4 billion estimated amount of the two major Federal incentives for producing ethanol, including the VEETC and ethanol Small Producer Credit, there is still \$1.2 billion surplus to the federal government alone (Urbanchuk, 2008).

Finally, the economic impact stemming from the production and consumption of 36 billion gallons of renewable fuel on the U.S economy for the period between 2008 and 2022 is an additional \$1.7 trillion in GDP and \$436 billion in income for American households, the creation of 1.1 million new jobs in all economic sectors, and \$209 billion in Federal tax revenue. It also reduces U.S. dependence on imported oil and increases U.S. energy security by replacing 11.3

billion barrels of imported crude oil with domestically produced/sourced ethanol between 2008 and 2022 (RFA, 2008). Based on the “Energy Independence and Security Act of 2007”, the United States will produce 313.70 billion gallons of ethanol from 2008 to 2022 which is the equivalent of 11.1 billion barrels of crude oil. If we once again assume that the average price of crude oil will be \$50 per barrel for this period, then substituting 11.1 billion barrels of gasoline with ethanol decreases U.S. dollars outflow to other countries as much as 555 billion dollars.

2.2.11. Ethanol Trade Policy

The United States has two different ethanol import policies. One policy is for Caribbean Basin Economic Recovery Act (CBERA) countries (including: Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, the British Virgin Islands, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Montserrat, Netherland's Antilles, Nicaragua, Panama, St. Kitts-Nevis, St. Lucia, St. Vincent-Grenadines, Trinidad and Tobago, Nicaragua, and Panama) under Caribbean Basin Initiative (CBI). The other policy is for other countries. Based on the CBI, if ethanol produced in a CBERA country uses at least 50% of feedstocks from that country, then that ethanol can be imported into the United States duty free. If the local feedstock used in the produced ethanol is less than 50%, the quantity of duty-free imported ethanol will have some limitation and will be 60 million gallons or 7% of the U.S. ethanol market, whichever is greater. Based on this agreement, a CBI country can import hydrous ethanol from countries like Brazil and export it to the United States after Dehydrating (Elobeid and Tokgoz, 2006).

The tariff on imported ethanol from other countries is an import duty of 54 cents per gallon of ethanol plus an ad valorem tariff of 2.5 percent (Elobeid and Tokgoz, 2006). The main goal of imposing a tariff on ethanol imports is to make sure that the 51 cents (formerly was 54

cents) excise tax credit that gasoline blenders/distributors receive on every gallon of ethanol blended with gasoline, does not go to foreign ethanol producers (Elobeid and Tokgoz, 2006).

U.S. ethanol imports increased from 45.5 million gallons in 2002 to 653.3 million gallons in 2006, equivalent to a 1436 percent increase. Brazil is the United States' largest ethanol exporter (RFA, 2008). Tariff rate quotas on ethanol imports from CBI countries are shown in Table 2.9. As can be seen, with one exception, imports from the Caribbean were less than 50 percent of the maximum allowed. This highlights the fact that these countries did not have enough ethanol for export to fill the import quota and therefore they cannot use their quota opportunity. The 2006 CBI countries tariff rate quota (TRQ) was 268.1 million gallons (Tokgoz and Elobeid, 2006).

Table 2.9. Caribbean Basin tariff rate quota (mill gal)

year	TRQ	ethanol entered	Fill rate (%)
2000	92.3	59.9	64.9
2001	112.7	43.3	38.4
2002	120.3	45.5	37.8
2003	132.5	60.9	46.0
2004	186.9	69.9	37.4
2005	240.4	103.3	43.0

Source: Simla Tokgoz and Amani Elobeid, Spring 2006

2.2.12. Ethanol and Air Quality

Automobile emissions are responsible for killing 30,000 people in the United States each year. In 2002, U.S. cars and trucks released 314 million metric tons of CO₂ emissions into the atmosphere (Car Almanac, 2006). The most majority of air pollutants released are Carbon Dioxide (CO₂), Carbon Monoxide (CO), Nitrous Oxides (NO_x), and hydrocarbons. Each year

thousands of tons of these pollutants are released into the atmosphere and most come from cars and trucks. Based on Federal Highway Administration statistics, on-road motor vehicles in 2002 were responsible for 34% of Nitrous Oxides (NO_x), 34% of Volatile Organic Compounds (VOC), 51% of Carbon Monoxide (CO), 10% of Particulate Matter (PM₁₀), and 33% of Carbon Dioxide (CO₂) (EPA, 2002).

Using ethanol as fuel or as a fuel additive helps reduce air pollution and greenhouse gases by reducing automobile tailpipe emissions. Ethanol has been used as an octane enhancer in the United States for years. Blending gasoline with ethanol oxygenates the gasoline. This allows the fuel to burn slower and more completely, thus producing smaller amounts of carbon monoxide. Therefore, blending gasoline with ethanol reduces air pollution. A university of California MTBE report confirms that adding 10% ethanol to gasoline decreases exhaust emissions of CO by 13% and VOC by 6% (California Environment Protection Agency, 1999).

There has been much study and discussion about environmental impact of replacing gasoline with ethanol or at least adding ethanol to gasoline as an oxygenate. Therefore, it seems logical that using ethanol as a motor fuel could have a positive impact on environment through reducing CO₂, Ozone, lead, nitrogen oxides, and particulate matter, thus reducing greenhouse gases (Bryant and Outlaw, 2006). Using fossil fuels results in air pollution which is considered by many to be a leading cause of global warming, acid rain, and smog in urban areas. Air pollution is a significant cost to society.

Based on a report prepared for the “Western Regional Biomass Energy Program” in 1994, it was calculated that the environmental externality costs for each barrel of petroleum consumed is \$2.29; for N₂O, CO₂, and CH₄; and \$42.78 for SO₂, NO_x, CO, PM₁₀, and VOC (Energetics and Neos Corporation, 1994). The total externality costs of using each barrel of petroleum is \$45.07. Based on this information, replacing each barrel of petroleum with ethanol

could decrease environmental degradation costs by \$30 (because each barrel of ethanol contains 66% of energy contained in comparable amount of gasoline).

2.2.13. Ethanol and Energy Security

The consumer purchase price for gasoline is not the true gasoline price that consumers pay because there are latent costs associated with gasoline consumption (for example, oil security costs that are born by taxpayers). If we add these types of latent costs to the price that consumers pay, gasoline prices would far exceed current prices. The U.S. Defense Department spends between \$44 and \$96 billion annually to protect oil-rich regions of the world. In addition, the United States maintains a Strategic Petroleum Reserve as a safety margin for emergency situations, such as natural disasters or military conflict, so that in the event of a catastrophic event the nation's oil supply would not be totally cut-off. Maintenance of the Strategic Reserve costs taxpayers \$5.7 billion per year (International Center for Technology Assessment, 1998).

Based on statistics from the U.S. Congressional Research Service, protection of oil rich areas costs the United States from between \$56 to \$73 billion annually (Congressional Research Service, 1992). Based on this information, the annual military cost of energy security for the United States is around \$50 billion. This averages out to be \$100 to \$150 per barrel of oil produced. Based on National Defense Council Foundation (NDCF) findings, the United States spends more than \$49 billion per year to ensure the uninterrupted flow of oil from the Persian Gulf. This defense burden adds more than \$1 to the cost for each gallon of gasoline (Clean Fuels Development Coalition (CFDC), 2007).

2.3. The U.S. Corn Market

Corn is the most important feed grain in the United States. It is the primary U.S. agricultural export crop, the link between crops and livestock, one of the most significant sources of cash receipts and income for farmers, and connects a collection of crops in the agriculture sector

(Westcott and Hoffman, 1999). Furthermore, by using corn in producing ethanol and corn sweeteners, it has been a major industrial crop in the United States in recent years. According to the Nebraska Corn Board, corn is used in more than 3500 different industrial items ranging from shaving cream and latex to aspirin and disposable diapers (Nebraska Corn Board, 2008).

The United States produced more than 13.1 billion bushels of corn in 2007. With 43% of world corn production and 66% of world corn exports in 2007, the United States is the largest corn producer and exporter in the world (NCGA, 2008a). As Figure 2.15 demonstrates, almost half of the 2007 world corn production was produced in the United States.

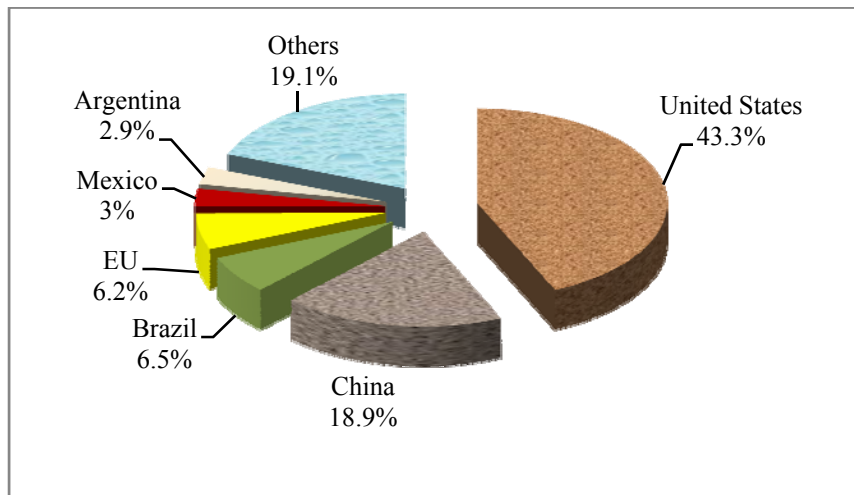


Figure 2.15. World corn production in 2007
Source: National Corn Growers Association (NCGA), 2008a

Figure 2.16 illustrates the role of the United States in the world corn market. Two thirds of world corn exports were provided by the United States in 2007. If the United States decreases corn exports and uses it domestically, for instance to produce ethanol, then it can have a significant impact on world corn prices. In fact, corn plays such an important role, not only in the U.S. agricultural sector but also in the global corn market, to the point that the U.S. corn price is utilized as the base price for the world corn price. The top U.S. corn exporting destinations are

shown in Table 2.10. Japan and Mexico are the largest importers of U.S. corn. The sum of the shares of these two countries for U.S. corn exports in 2007 accounts for more than 44 percent of total U.S. corn exports (NCGA, 2008a).

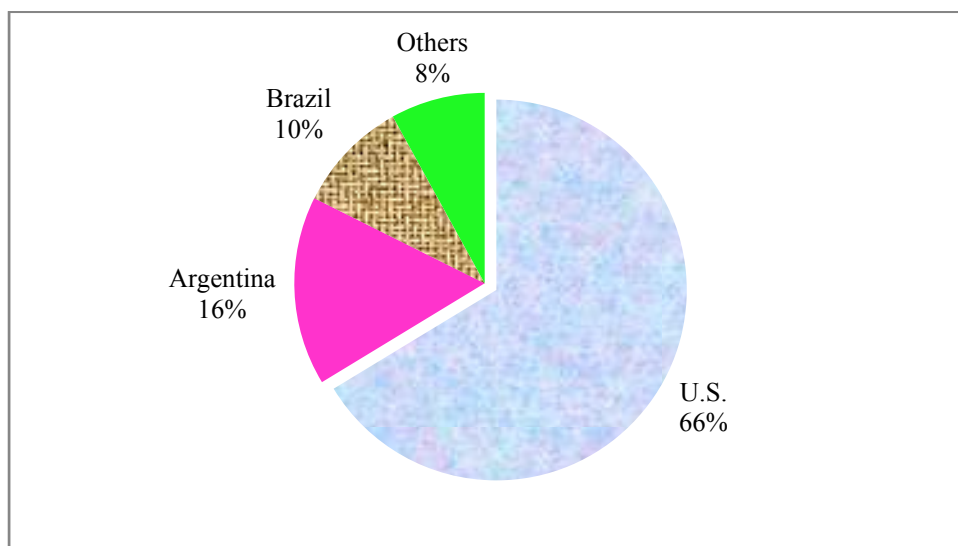


Figure 2.16. World corn exporters in 2007

Source: National Corn Growers Association (NCGA), 2008a

Table 2.10. Leading U.S. corn export markets (million bushels)

Country	2004-05	2005-06	2006-07
Japan	611	628	597
Mexico	232	249	345
South Korea	83	220	159
Taiwan	171	183	170
Egypt	152	159	130
Colombia	80	106	128
Canada	93	74	81
Syria	51	33	58
Dominican Rep	39	41	47
Algeria	42	49	34
Other	307	440	376
Total	1,818	2,134	2,125

Source: National Corn Growers Association (NCGA), 2008a

Corn can be consumed in its natural state or used as an input to produce other products (e.g., ethanol). Therefore, any change in the market for products involving corn (or its derivatives) will result in changes in the corn market itself. Corn occupies a central position in the U.S. food, feed, sweetener, and bio-fuel markets as well as the world corn market.

2.3.1. Corn Production

Corn is the number one U.S. crop, leading all other crops in value and volume of production. With 28.4% of all crop acres harvested in the United States in 2007, corn had the largest harvested acreage (Figure 2.17).

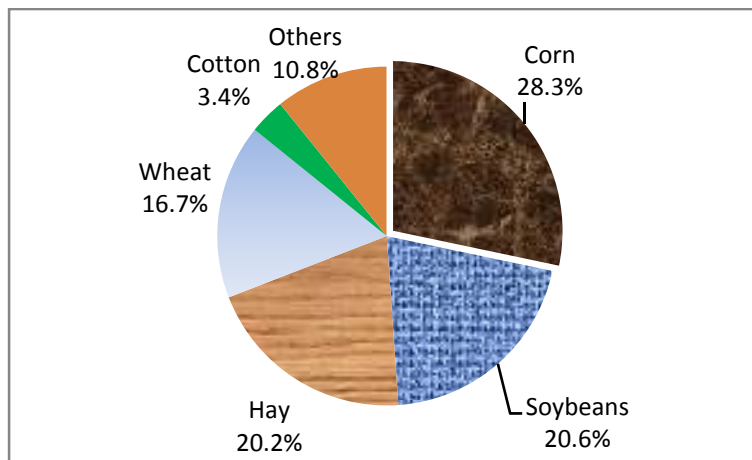


Figure 2.17. U.S. all crop acres harvested in 2007
Source: National Corn Growers Association (NCGA), 2008a

Corn production has experienced significant growth in the past 30 years. Volume of production increased from 5840.7 million bushels in 1975 to 13,073.8 million bushels in 2007, displaying a 124 percent increase (Figure 2.18). Only 28 percent of the increase in corn production is attributed to an increase in harvested acreage. The rest is the result of a boost in corn yield. Yield has played a significant role in the growth of corn production. Corn yield increased from 85.3 bushels per acre in 1975 to 149.3 bushels per acre in 2007, a 75 percent increase. Corn yield made an all time record of 158.4 bushels per acre in 2004 (Figure 2.19). A

set of different factors impact corn yield, including crop variety, soil type, technology, management skills, climatic conditions, and weather (Westcott and Hoffman, 1999). Weather conditions are also very important because by its very nature, weather is unpredictable and can have serious consequences for the corn market.

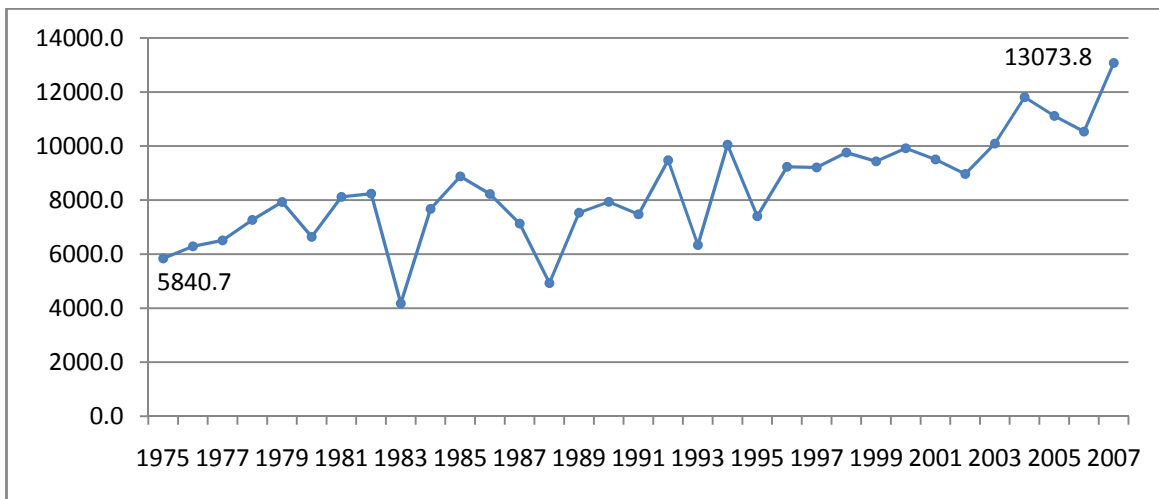


Figure 2.18. Corn production (million bushels)
Source: USDA, 2008.

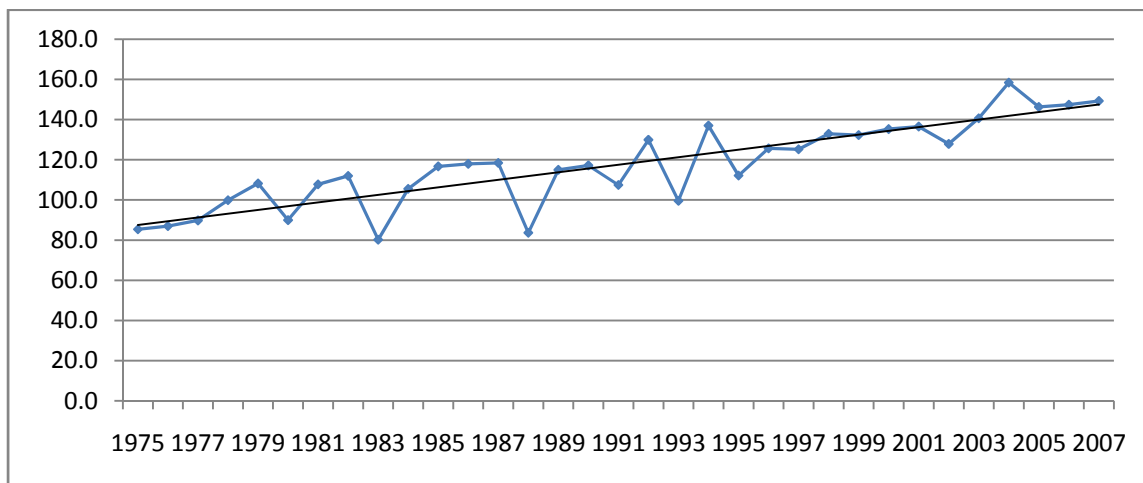


Figure 2.19. Corn production yield (bushel per acre)
Source: USDA, 2008.

Increased ethanol production requires more corn production than can be achieved from just increases in yield, but could also come about as a result of an increase in planted area. An

increase in demand for corn, for ethanol production, raises prices and encourages farmers to increase corn production by converting land from competing crops such as soybeans, wheat, cotton, hay, and pasture. It could also come from land enrolled in the USDA's Conservation Reserve Program (CRP), or idled land (Hoffman et al., 2007).

Based on planted area and production statistics, Iowa and Illinois rank first and second, respectively, in U.S. corn production for 2007. These two states along with Nebraska, Minnesota, and Indiana compose 63.1 percent of total U.S. produced corn in 2007 (Table 2.11). Corn production has also been benefited from government support programs such as direct payments, nonrecourse marketing assistance loans, and counter –cyclical payments. A nonrecourse loan is a short-term (9 months) loan to corn producers that helps farmer provide for their production costs. A farmer pledges his production as collateral for the loan. At the end of 9 months the farmer has to either pay back the loan or forfeit the pledged collateral to the Commodity Credit Corporation (CCC).

Direct payments for corn (feed grains) are available to eligible corn producers who sign the annual agreement. Based on the 2008 Farm Bill, the direct payment rate for corn producers is \$0.28 per bushel from 2008 to 2012 (NCGA, 2008b). Because these payments are not fixed to production or price, they are considered as decoupled payments and go to owners of feed grain base acres who don't produce feed grains. The amount of direct payment for an eligible corn producer is calculated as follow (Hoffman et al, 2007):

$$\text{Direct payment} = \text{national payment rate} * \text{farm's payment acres} * \text{farm's direct payment yield}$$

Counter –cyclical payments are paid to a corn producer if corn's "effective price" is less than its target price. Corn's "effective price" is equal to the national average farm price received for the marketing year plus the direct payment rate, or national loan rate plus the direct payment rate, with the effective price being whichever of the two is highest (Hoffman et al, 2007).

Table 2.11. The U.S. corn production in 2007

State	Harvested area 1,000 acres	Yield bushels	Production 1,000 bushels	State's share percent
Iowa	13850	171	2368350	18.12
Illinois	13050	175	2283750	17.47
Nebraska	9200	160	1472000	11.26
Minnesota	7800	146	1138800	8.71
Indiana	6370	155	987350	7.55
South Dakota	4500	121	544500	4.16
Ohio	3610	150	541500	4.14
Kansas	3700	140	518000	3.96
Missouri	3250	142	461500	3.53
Wisconsin	3280	135	442800	3.39
Texas	2000	148	296000	2.26
Michigan	2350	124	291400	2.23
North Dakota	2350	116	272600	2.09
Kentucky	1360	129	175440	1.34
Colorado	1060	142	150520	1.15
Mississippi	940	150	141000	1.08
Pennsylvania	980	128	125440	0.96
Louisiana	730	165	120450	0.92
North Carolina	1020	100	102000	0.78
Arkansas	590	168	99120	0.76
Tennessee	785	106	83210	0.64
New York	550	127	69850	0.53
Georgia	450	130	58500	0.45
Maryland	455	103	46865	0.36
Oklahoma	270	145	39150	0.30
South Carolina	370	100	37000	0.28
California	200	180	36000	0.28
Virginia	405	85	34425	0.26
Washington	120	210	25200	0.19
Alabama	280	79	22120	0.17
Delaware	185	97	17945	0.14
Idaho	105	165	17325	0.13
New Jersey	82	125	10250	0.08
New Mexico	55	175	9625	0.07
Wyoming	60	129	7740	0.06
Oregon	35	195	6825	0.05
Montana	38	145	5510	0.04
Arizona	23	185	4255	0.03
Florida	35	95	3325	0.03
Utah	22	148	3256	0.02
West Virginia	27	111	2997	0.02
United States	86542	151.1	13,073,893	100

Source: USDA, 2008.

2.3.2. Corn Utilization and Prices

The U.S. feed grain sector, including corn, sorghum, barley, and oats, is the dominant component of the U.S. field crop sector and continue to grow because of the demand for corn as a result of the recent boost in ethanol production. This sector contributes nearly one-third of all cash receipts for field crops and composes approximately one-third of principle crop acreage (Hoffman et al, 2007).

Ethanol production in recent years has changed the face of corn utilization, elevating the share of ethanol in corn utilization from less than 0.5% in 1980 to more than 23% in 2007 (USDA data, 2008). This share is still rising. This can have a negative impact on the feed and exports' share of corn utilization which had traditionally ranked first and second in corn utilization.

As one can see in Figure 2.20, in 2007 the amount of corn used for ethanol surpassed the amount of corn exported for the first time. This figure highlights some interesting issues related to corn utilization for the period of 1975 to 2007. Corn feed utilization has increase from 3.6 billion bushels in 1975 to more than 6.0 billion bushels in 2007, amounting to a 72 percent increase in using corn to feed livestock. The amount of exported corn has had a stable trend, fluctuating around 2.0 billion bushels per year for the period. Using corn for producing ethanol and HFCS rose together from 1975 to 1999, starting close to zero and reaching nearly 0.55 billion bushels per year. But after 1999, corn used for HFCS production maintained a relatively stable level while the amount of corn used for ethanol production was boosted substantially in 2007, reaching 3.0 billion bushels.

Figures 2.21 and 2.22 show the amount of corn used for producing ethanol and HFCS, respectively. Corn used in ethanol production increased from 35 million bushels in 1980 to 3.0

billion bushels in 2007. The fast growth in demand for corn to produce ethanol started in 2002 (Figure 2.21).

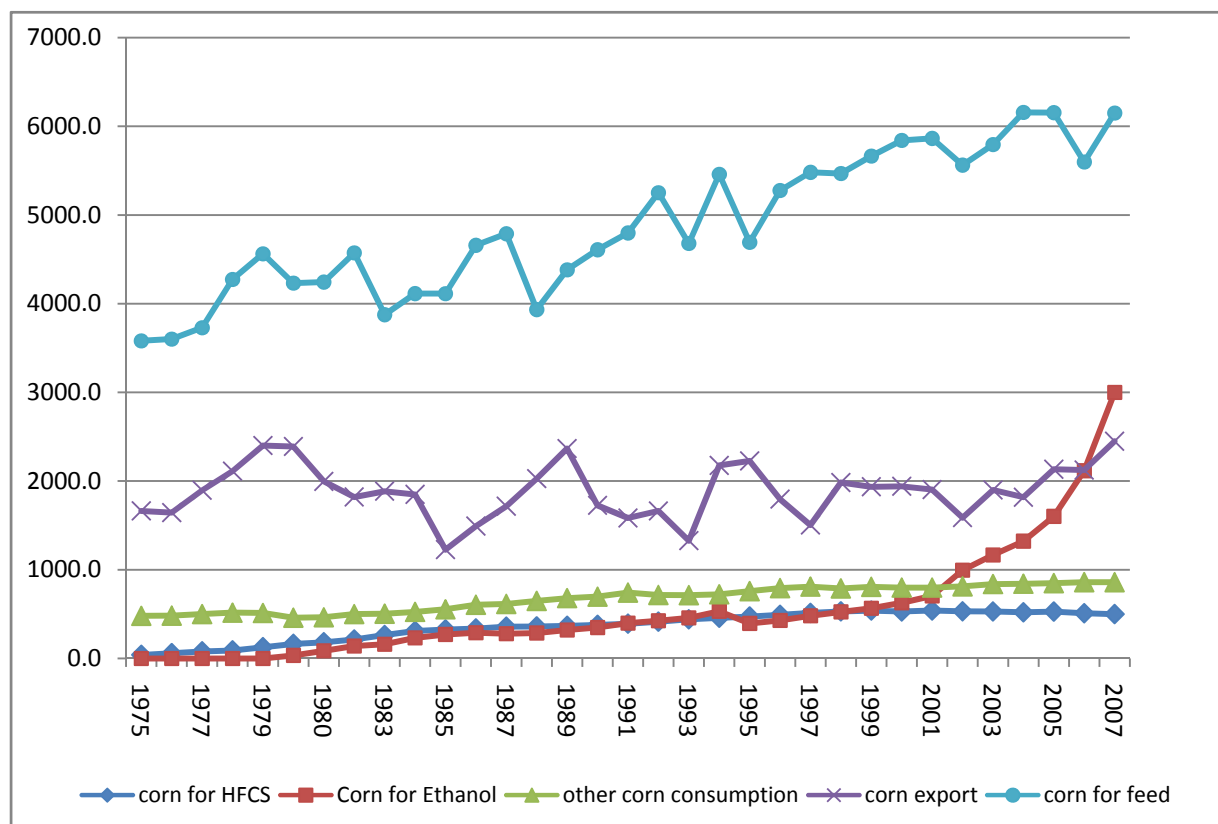


Figure 2.20. United States use of field corn, by crop year (million bushels)
Source: USDA, 2008.

Figure 2.23 gives perspective regarding ethanol's share along with other sectors' shares for the total amount of corn produced in the United States in 2007. Corn demand for food and residual uses consist of 47 percent of total corn production. Ethanol for fuel and HFCS accounts for 23% and 4%, respectively, of total corn production (USDA, 2007).

Figure 2.24 demonstrates the amount of corn used for food, feed, HFCS, fuel, and exports between 1990 and 2006. The share of corn for fuel (out of the total U.S. corn crop) has increased from less than 5% in 1990 to more than 20% in 2006. In this sixteen year period (1990-2006), total U.S. corn production increased by 33% from 7.9 billion bushels in 1990 to 10.5 billion

bushels in 2006. Part of this increase comes from increases in planted corn acreage, going from 67.7 million acres to 71.5 million acres. The other part comes as a result of increased corn yields stemming from the use of genetically improved corn varieties, going from 117.2 bushels per acre to 147.4 bushels per acre (USDA, 2007).

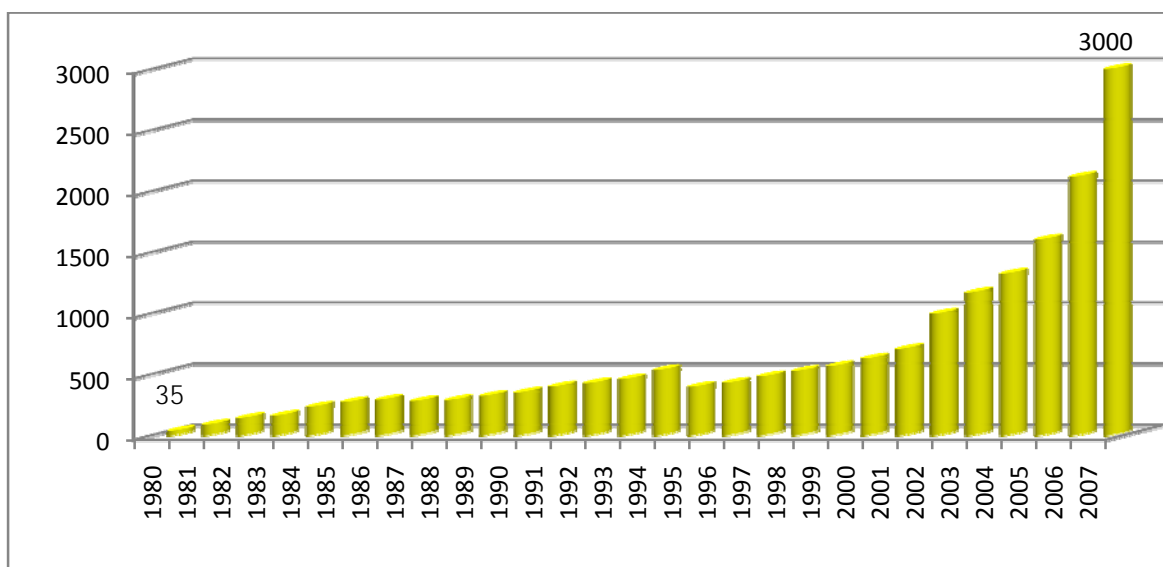


Figure 2.21. Corn used for ethanol production in the United States (million bushels)
Source: USDA, 2008.

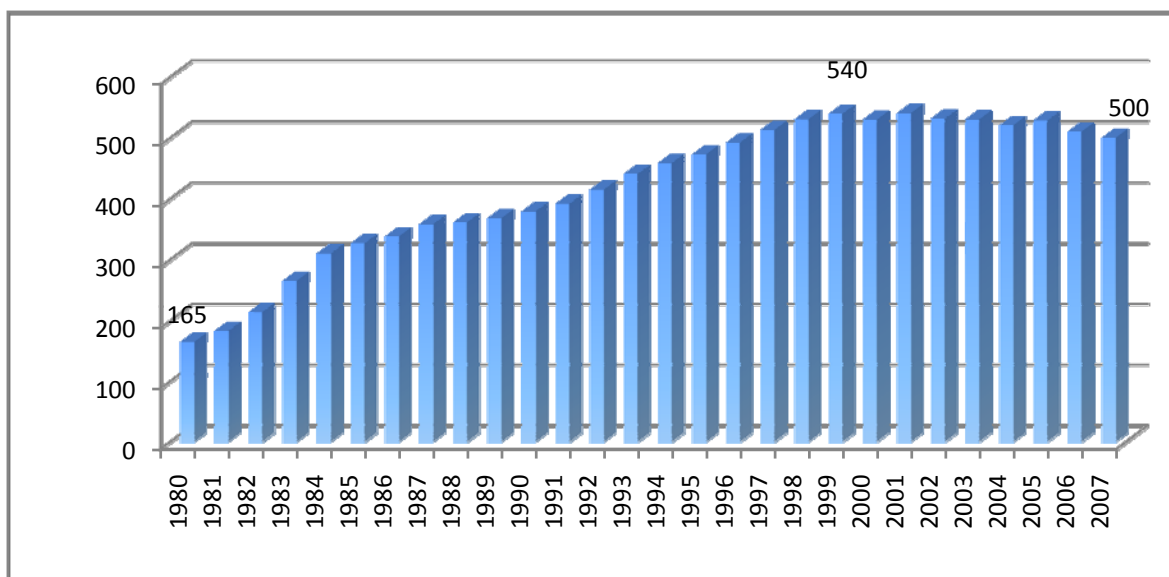


Figure 2.22. Corn used for HFCS production in the United States (million bushels)
Source: USDA, 2008.

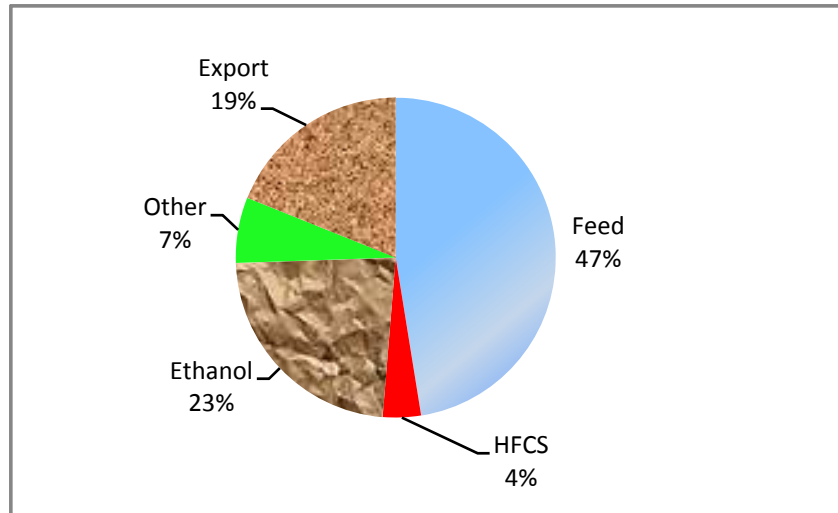


Figure 2.23. U.S. corn usage by sector in 2007
Source: USDA, 2008.

As Figure 2.24 illustrates, up until now, increases in demand for corn for the sole purpose of producing ethanol have mostly been compensated for by increases in corn production. As a result, its negative impact on other sectors, from the standpoint of volume, not price, has not been significant. However, increases in corn production can increase corn production costs. For example, land prices have increased dramatically in Corn Belt states in recent years as demand for land to produce corn, resulting from boosts in ethanol production, have shot up substantially (Winsor, 2007). Increases in corn production cost, in turn, may increase corn prices and, therefore, increase production costs in other industries which use corn as a primary input. The corn price has increased from \$1.85/bushel in 2000 to more than \$4.00 in 2007. This increase in price amounts to an over 100% increase in the price of corn (USDA, 2008).

At this time, corn is the bridge between the ethanol and the U.S. sugar program. As mentioned earlier, the U.S. sugar program has encouraged some U.S. industries that were using sugar as a primary input to adopt HFCS as a sugar substitute, thus serving to further inflate corn demand. Therefore, the U.S. sugar program can influence ethanol production costs, and subsequently ethanol prices. It must be kept in mind that any evaluation of the U.S. sugar

program must take into account the impact(s) of the U.S. sugar program on the U.S. ethanol market as well.

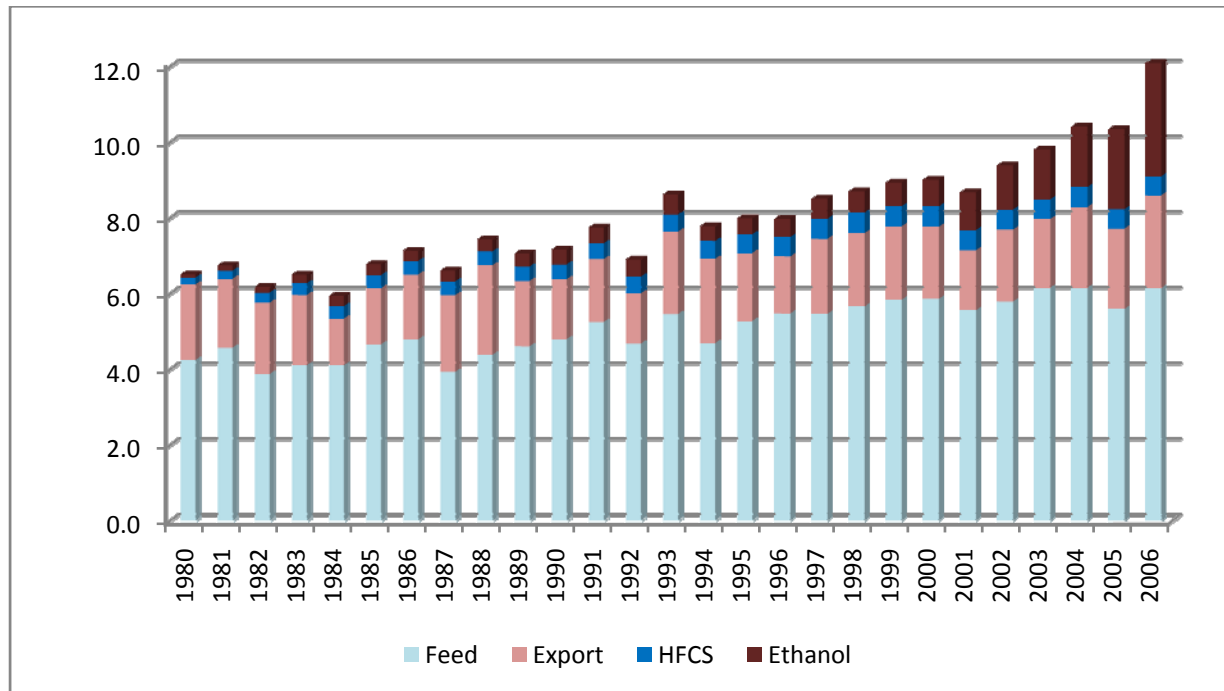


Figure 2.24. U.S. corn usage by sector (billion bushels)
Source: USDA, 2008.

As Figure 2.25 reveals, real corn prices (based on the year 2000) shrank from \$9.00 per bushel in 1975 to \$2.00 per bushel in 2005 and after that increased to around \$3.70 per bushel in 2007. From 1975 to 2005, with the exception of 1995, nominal corn prices were between \$2.00 and \$3.00 per bushel. After that, corn prices increased and reached more than \$4.00, resulting from increased corn demand for ethanol production.

Corn plays a critical role in the U.S. feedstock market and, therefore, plays a prominent role in the production cost of meat and dairy products. Corn is used to feed beef and dairy cattle, hogs, and poultry. Thus, if enhancements in using corn decrease the amount of corn available for feed or increase corn prices, then it can increase U.S. meat and dairy production costs and could have a negative impact on the U.S. meat industry. Even though a part of the reduction in corn

available for feed can be compensated for by ethanol byproducts (DDGs), the other portion can still be problematic for the U.S. meat industry. A reduction in corn available for food and feed purposes will increase the demand for other crops such as wheat and soybeans which can be used as a substitute for corn. This, in turn, drives up the demand and, therefore, the price of these crops as well.

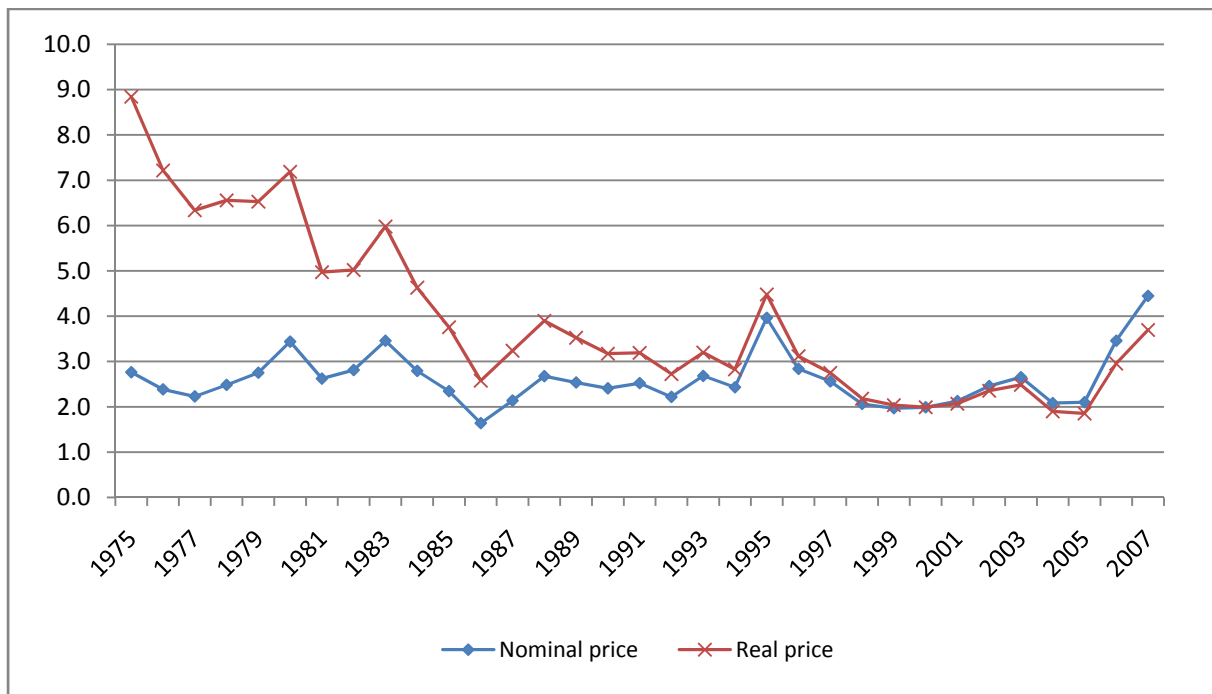


Figure 2.25. The U.S. domestic corn prices (\$/bushel)
Source: USDA, 2008.

The United States is a major player in the world feed grain market and, particularly, in the world corn market. Increase in corn, and in turn other U.S. crop prices caused by the recent boost in ethanol production, will increase competition from other corn exporters with the United States in the world market. Non-EU countries in Eastern Europe, the Republic of South Africa, Ukraine, Argentina, and Brazil are corn exporters that can potentially increase their corn production as a result of high market prices for corn and will possibly challenge the U.S. position in the world corn market (Hoffman et al., 2007).

2.4. The U.S. HFCS Market

High fructose corn syrup (HFCS) is a liquid sweetener which can be produced from corn. HFCS is produced by wet milling plants. In these plants each bushel of corn is converted to 33 pounds of HFCS along with 1.6 pounds of corn oil, 12.5 pounds of gluten feed, and 2.5 pounds of gluten meal as byproducts of the HFCS production process (Figure 2.26).

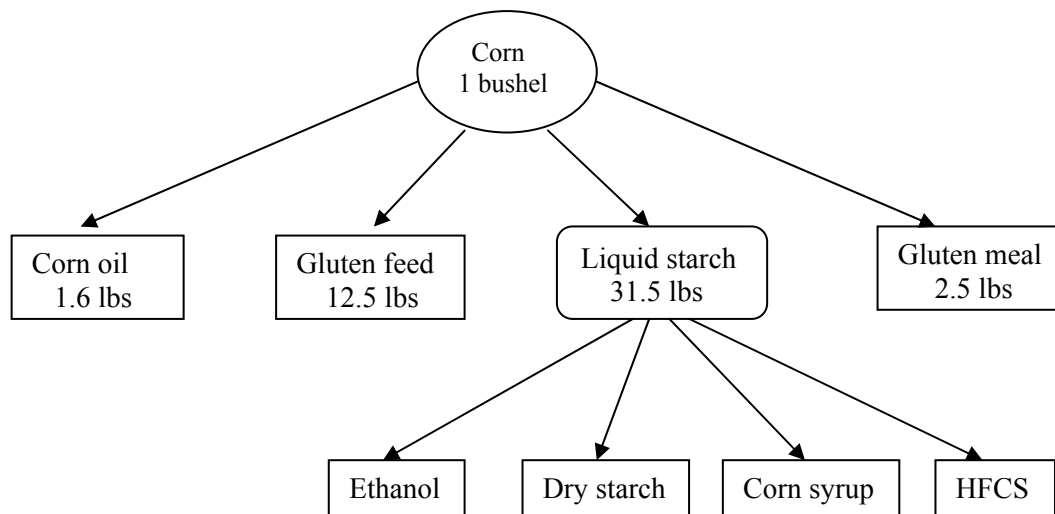


Figure 2.26. Schematic plan of wet mill plants
Source: Brendstrup et al., 2005.

When the demand for HFCS is low, these plants can produce liquid corn starch, dry corn starch, corn syrup, or ethanol, instead of producing HFCS (Brendstrup et al., 2005). Not only is HFCS utilized as a sweetener, but it has other uses in the food industry so that most foods and beverages consumed in the United States today contain HFCS to some degree.

HFCS is a near perfect substitute for liquid sugar and has from its initial introduction been widely used in the United States in items manufactured for human consumption such as soft drinks, bakery items, canned food, and cookies that originally required sugar. The vast utilization of HFCS in the U.S. food industry resulted from HFCS' low production cost in the United States. It is due to these low production costs for HFCS that the United States is the largest HFCS

producer in the world, accounting for 71% of total world HFCS production (Figure 2.27). After the United States, Japan, with 7% of world HFCS production, ranks second among countries.

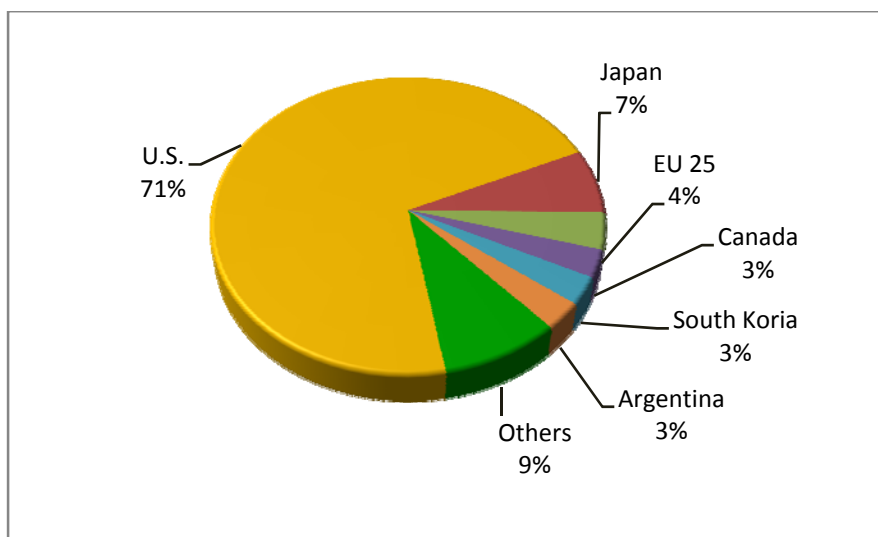


Figure 2.27. 2004 HFCS production by country
Source: International Sweetener Colloquium, 2005.

As Figure 2.28 demonstrates, between 1975 and 1999 HFCS production grew at a fast rate, reaching 9.4 million tons of production in 1999, up from just 0.5 million tons in 1975; an almost 19 fold level of production in only 14 years time. HFCS production dropped slightly after 1999.

Some reasons for the fast growing use of HFCS in food items are that using HFCS in canned food helps maintain freshness for longer time periods. By using HFCS in baked products, these products possess a better appearance/finish that customers find appealing.

The most important reason, however, for using HFCS instead of sugar, especially in beverages and soft drinks, is that HFCS is cheaper than sugar in the United States.

The U.S. sugar program has increased domestic sugar prices in the United States and, as a consequence, forced those industries that used sugar as a primary product input to look for a lower-cost substitute. With the situation of the United States being the world's largest producer

of corn, corn based sweeteners (e.g. HFCS) were a relatively cheap alternative to more costly sugar.

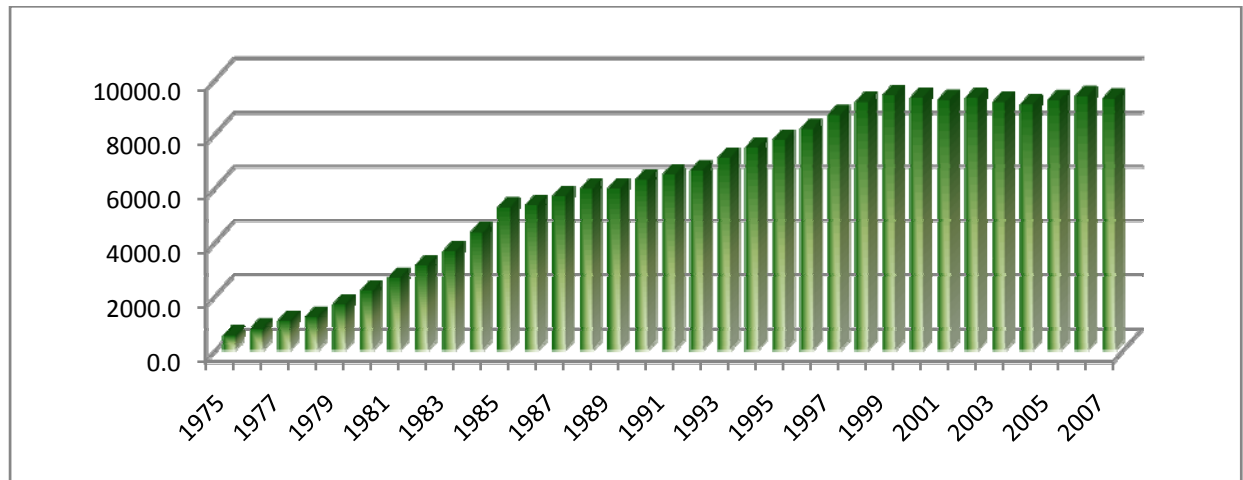


Figure 2.28. U.S. HFCS production (1000 tons)
Source: USDA, 2008.

HFCS was introduced into the market in the 1970s and is a substitute for sugar in many cases. HFCS consists of approximately 50 percent fructose and 50 percent glucose. There are two different types of HFCS, HFCS55 and HFCS42. HFCS55 contains 55 percent fructose and 45 percent glucose and is sweeter than sugar while HFCS42 has 42 percent fructose and 58 percent glucose and is less sweet than sugar. HFCS55 is primarily used in carbonated soft drinks while HFCS42 is used mostly in non-carbonated beverages and food items (CRA, 2007).

As stated earlier, HFCS is an almost ideal substitute for liquid sugar and therefore its demand and price are both closely correlate to those of sugar. The U.S. sugar program has created a unique situation for the HFCS market by maintaining high sugar prices (compare to Caribbean sugar prices) in the United States. Figures 2.29 and 2.30 show the U.S. domestic raw and refined sugar prices and world (Caribbean) sugar prices in comparison with U.S. HFCS prices from 1975 to 2007. As can be seen, refined sugar prices have been higher than HFCS prices for the whole period. Raw sugar prices have been higher than HFCS prices, with

exceptions being for 1975, 1976, 1977, 1981, and 2007. Between 1997 and 2005, U.S. sugar prices were much higher than HFCS prices so that in a number of these years sugar prices have been twice that of HFCS prices.

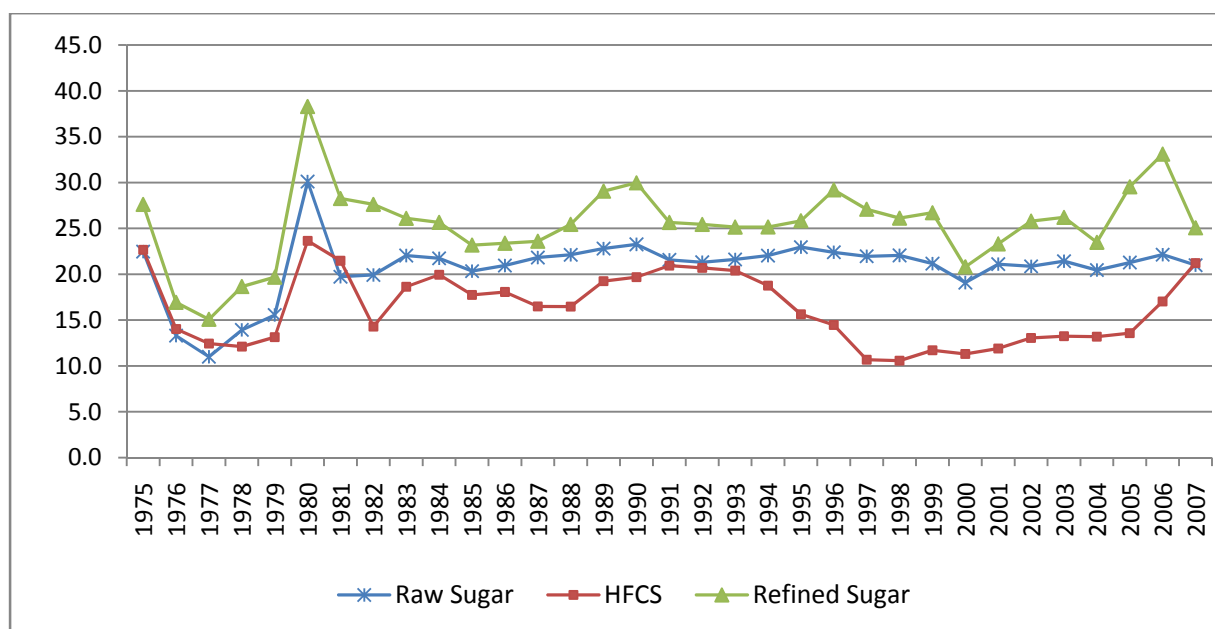


Figure 2.29. U.S. sugar and HFCS prices 1975-2007 (Cents per pound)
Source: USDA, 2008.

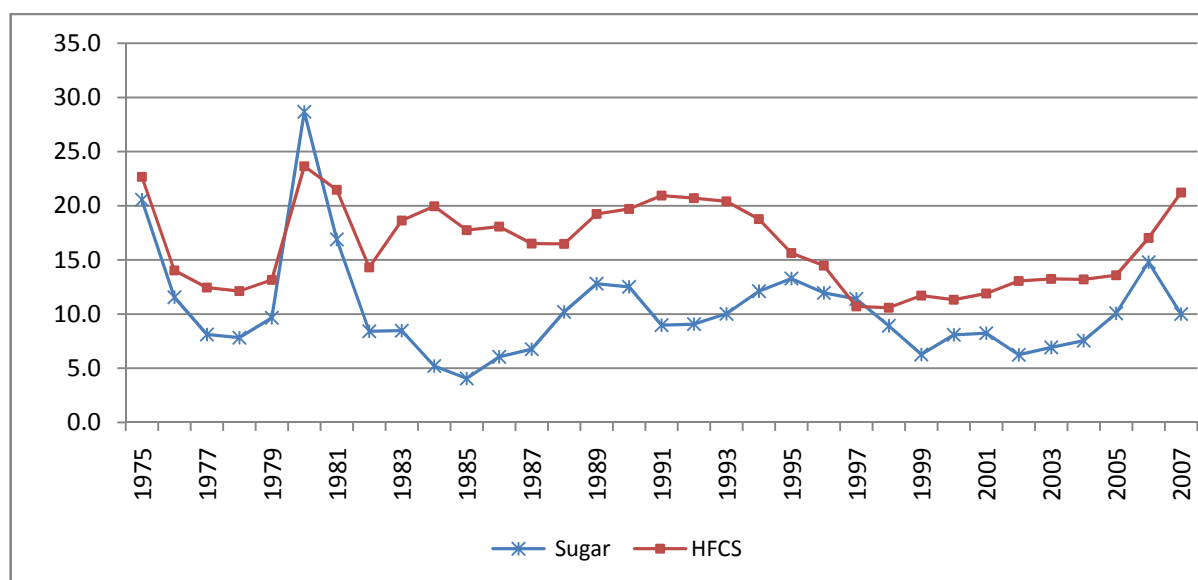


Figure 2.30. World (Caribbean) sugar and HFCS prices 1975-2007 (Cents per pound)
Source: USDA, 2008.

On the other hand, Figure 2.30 illustrates that U.S. domestic HFCS prices have been higher, except for in 1980, than world (Caribbean) raw sugar prices. This means that in the case where the sugar import quota and tariff are removed, HFCS may not be as competitive to sugar in the sweeteners market.

As Figure 2.31 illustrates, HFCS prices move with corn prices for the time periods 1975-1981 and 1995-2007, but there is no specific correlation between the two prices for the other years (1982-1994). Increases in corn prices resulted from increased ethanol production, increased HFCS cost production and, therefore, HFCS prices significantly. As a result, HFCS price which was less than 15 cents per pound in 2005 reach more than 20 cents per pound in 2007.

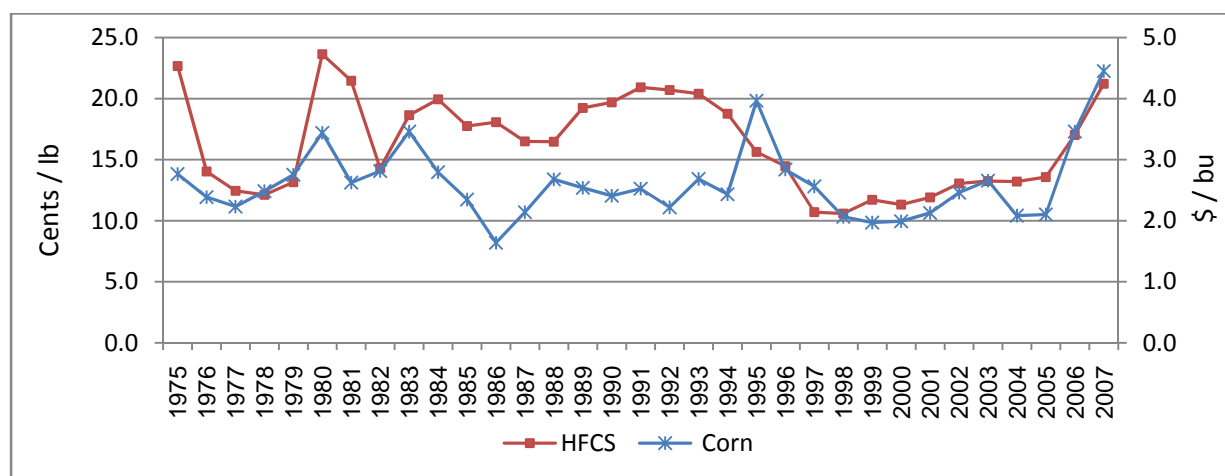


Figure 2.31. U.S. domestic corn and HFCS prices 1975-2007
Source: USDA, 2008.

The relative low cost of HFCS along with its attribute of being an almost perfect substitute for liquid sugar encouraged food processors and beverage producers (especially soft drink producers) to substitute HFCS for sugar. Soft drink producers began to use HFCS in 1980. Coca-Cola partially replaced sugar with HFCS in 1980 and by 1983 was using HFCS in 75% of their caloric cola soft drinks, ultimately attaining 100% usage by 1984 (Williams and Bessler, 1997). Substituting HFCS for sugar has been so significant that per capita sugar consumption

decreased from 102.1 pounds in 1971 to 62.1 pounds in 2007 while per capita HFCS consumption increased from 0.8 pounds in 1971 to 56.3 pounds in 2007 (Figure 2.32). The share of HFCS in total U.S. sweetener deliveries rose from 0.6 percent in 1971 to 37.6 percent in 2007 (USDA, 2008). One interesting point in Figure 2.32 is that from 1971 to 1999, per capita sugar consumption decreased and per capita HFCS consumption increased steadily. However, after 1999, consumption of both sugar and HFCS has remained relatively constant until 2007.

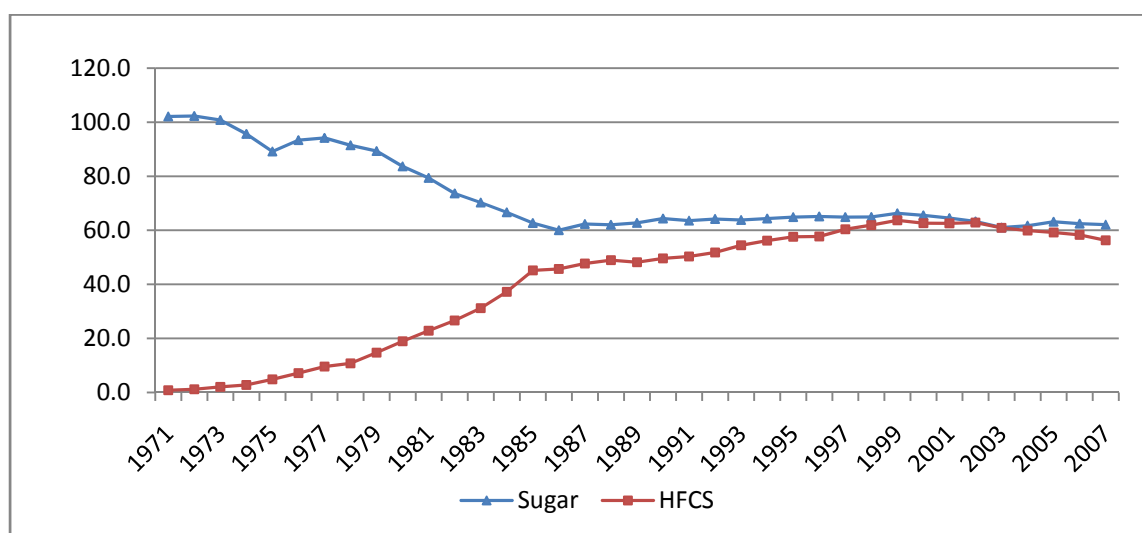


Figure 2.32. The U.S. per capita sugar and HFCS consumption (pounds)
Source: USDA

Looking at Figure 2.33, from 1971 to 2007 changes in U.S. sweetener consumption have occurred because of changes in HFCS and sugar consumption, while consumption for glucose and other sweeteners have not changed considerably. U.S. sweetener consumption from 1971 to 2007 can be divided into three distinct periods and are delineated as follows:

- Period one, 1971 to 1986: In this period sugar consumption decreased from 10.6 million tons in 1971 to 7.2 million tons in 1986, but HFCS consumption increased from 0.086 million tons to 5.5 million tons. The total volume of sweetener consumption increased from 12.5 million tons to 15.0 million tons. Not only did sweetener users substitute sugar with HFCS

because sugar consumption decreased, but also additional sweetener consumption is provided by an increase in HFCS use, from 12.5 million tons to 15.0 million tons (Figure 2.33).

- Period two, 1987 to 1999: In 1986 the decreasing trend of sugar consumption stopped. From 1987 sugar consumption starts to grow and reaches 9.4 million tons in 1999 from its initial amount of 7.6 million tons in 1987. The increase in the use of HFCS continues in this period as well, up 3.5 million tons from 5.8 million tons to 9.3 million tons. Total sweetener consumption increased from 15.6 million tons in 1987 to 21.1 million tons in 1999 as a result of the enhancement in both sugar and HFCS consumption. Even though both sugar and HFCS consumption are growing in this period, increases in HFCS consumption (3.5 million tons) is almost twice that for sugar consumption (1.8 million tons).
- Period three, 2000 -2007: HFCS consumption experienced a small rise of 0.2 million tons in consumption in the period of 2000-2002, from 9.1 million tons in 2000 to 9.3 million tons in 2002. After 2002 it experienced a decrease in consumption with consumption reaching 8.8 million tons in 2007. Sugar consumption was relatively stable in this period, fluctuating around 9 million tons per year. As a result, total sweetener consumption was relatively stable, fluctuating around 20.8 million tons between 2000 and 2007 (Figure 2.33).

2.5. The U.S. Sugar Market

The U.S. sugar market not only comprises an important share of the U.S. agricultural sector, it also plays a significant role in the world sugar market. U.S. sugar production ranks fourth in the world while the United States is the third largest sugar consumer in the world (Buzzanell, 1997). Based on USDA data, the United States produced 8.3 million tons of sugar in 2007. Around 60 percent of U.S. sugar production comes from sugar beets with the remainder (40%) coming from sugar cane (USDA data, 2007). Since sugar beets have a higher production cost than sugarcane,

on average, the United States is a high cost sugar producer relative to world sugarcane average cost and subsequently does not have a comparative advantage in producing sugar.

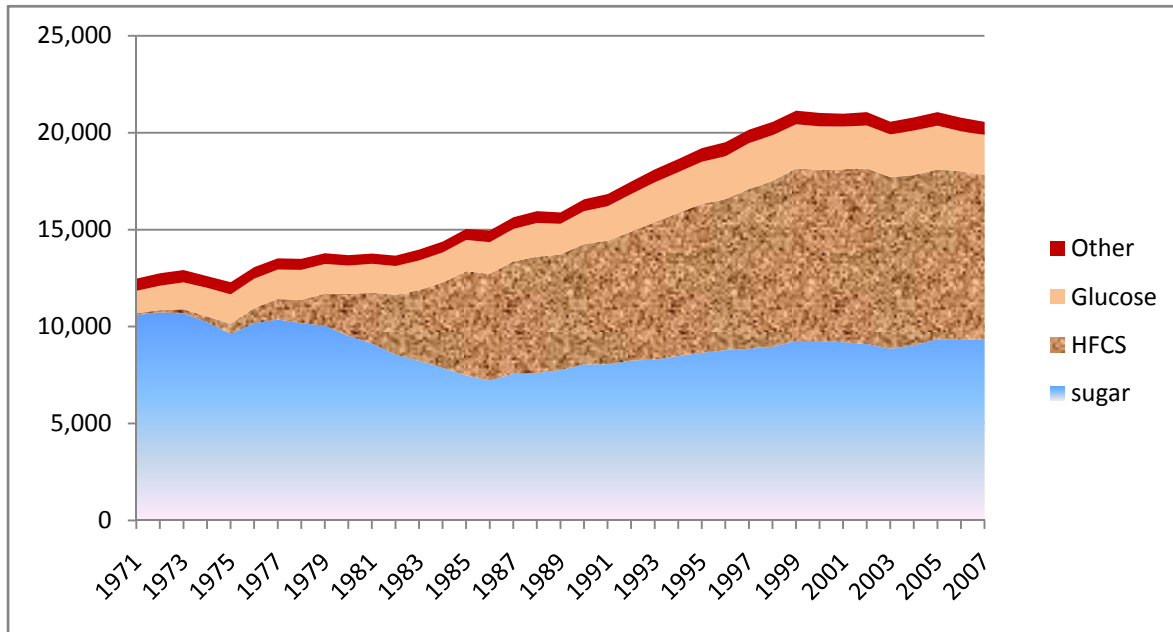


Figure 2.33. Total sweeteners consumed in the United States (1000 tons)
Source: USDA, 2008.

Even though the U.S. population increased more than 30% between 1980 and 2007, U.S. sugar consumption was less in 2007 than in 1980. Imposing barriers on sugar imports in the 1980s, which increased sugar prices and established HFCS as a viable substitute for sugar, changed the face of the U.S. sweetener market. As a result, the amount of sugar imported during this period decreased by 45 percent, from 4.9 million tons in 1980 to 2.2 million tons in 2007, while sugar production increased by 34 percent (Table 2.12 and Figure 2.34). The share of sugar imports in U.S. sugar consumption decreased sharply from 51 percent in 1980 to 23 percent in 2007 (Table 2.12). The share of sugar imports for consumption in the U.S. sweetener market decreased from 31 percent in 1980 to 9.5 percent in 2007. Also, sugar's share of total U.S. sweetener consumption declined by 77 percent, from 73.4 percent in 1971 to 41.4 percent in 2007.

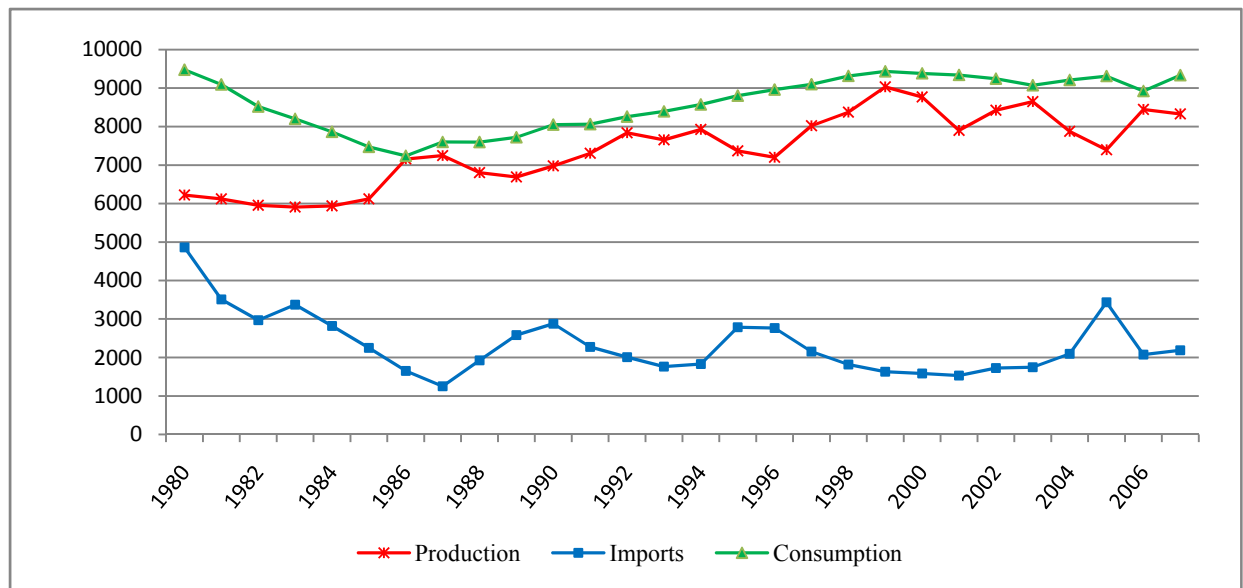


Figure 2.34. U.S. sugar production, consumption, and Imports (million tons)
Source: USDA, 2008.

The United States ranks as one of the largest sugar importers in the world, having imported approximately 2.07 million tons of sugar in 2007 (Table 2.12).

The U.S. support program for sugar is one of the oldest and strongest agricultural support programs in the United States and has always enjoyed broad governmental and political support. The U.S. sugar program has had different impacts on U.S. sugar consumption and production over time. While this program has increased U.S. sugar production, it has had a negative impact on sugar consumption. The U.S. sugar program has increased sugar prices in the United States and encouraged industries that traditionally used sugar as an input to look to HFCS as a replacement for sugar. With the introduction of HFCS, the vast majority of beverage and food industries substituted HFCS for sugar, since HFCS was the cheaper alternative to sugar. Studies have shown that the U.S. sugar program has had a negative impact on social welfare because the increases in sugar producer surplus are less than consumer losses in consumer surplus and that efficiency losses have resulted from restricted trade (GAO, 2000b).

Table 2.12. U.S. sugar production, consumption, import, and prices

Year	Total Sugar Production (1000 tons)	Total Import (1000 tons)	Total Supply (1000 tons)	Total Consumption (1000 tons)	Per capita Consumption (pounds)	Domestic Raw Sugar Price cents/lb	Caribbean Sugar Price cents/lb
1980	6221	4863	11084	9477	82	30.1	28.7
1981	6122	3513	9635	9095	78	19.7	16.9
1982	5955	2971	8926	8519	72	19.9	8.4
1983	5910	3373	9283	8199	69	22.0	8.5
1984	5940	2822	8762	7863	65	21.7	5.2
1985	6124	2252	8376	7472	61	20.3	4.1
1986	7159	1653	8812	7239	59	21.0	6.1
1987	7247	1254	8501	7599	61	21.8	6.8
1988	6804	1928	8732	7598	61	22.1	10.2
1989	6691	2586	9277	7723	61	22.8	12.8
1990	6978	2881	9859	8051	63	23.3	12.5
1991	7306	2278	9584	8063	62	21.6	9.0
1992	7838	2010	9848	8259	63	21.3	9.1
1993	7655	1764	9419	8394	63	21.6	10.0
1994	7927	1830	9757	8575	64	22.0	12.1
1995	7370	2790	10160	8804	65	23.0	13.3
1996	7204	2769	9973	8961	66	22.4	12.0
1997	8021	2158	10179	9100	66	22.0	11.4
1998	8374	1821	10195	9316	67	22.1	8.9
1999	9032	1632	10664	9434	67	21.2	6.3
2000	8769	1587	10356	9383	66	19.1	8.1
2001	7900	1532	9432	9341	65	21.1	8.2
2002	8426	1726	10152	9244	64	20.9	6.2
2003	8649	1750	10399	9073	62	21.4	6.9
2004	7876	2096	9972	9210	62	20.5	7.5
2005	7399	3435	10834	9312	62	21.3	10.1
2006	8446	2076	10522	8922	59	22.1	14.8
2007	8329	2188	10517	9336	61	21.0	10.0

Source: USDA, 2008

U.S. sugar producers have an effective Congressional lobby and have been able to convince the government to restrict sugar imports. This has resulted in higher sugar prices in the United States relative to those of the world sugar price. As shown in Figure 2.35, raw and refined sugar prices in the United States are more than twice that of the world sugar price.

The U.S. government uses different tools to control sugar supply in order to support U.S. sugar producers while avoiding forfeitures (surrendering the collateralized sugar to the government instead of paying back the loan) at the same time. These tools include: a loan program for producers; an import quota system on foreign sugar; and marketing allotments for domestic sugar (American Sugarbeet Growers Association, 2006).

Loan Program: The loan program works as a price floor mechanism in the U.S. sugar program. The loan program determines the loan rate which guarantees a minimum price to sugar producers through refineries and processors. Using import tariff rate quotas (TRQ) and marketing allotments to control sugar imports and production keeps sugar prices roughly above the loan rate (Beghin, 2007).

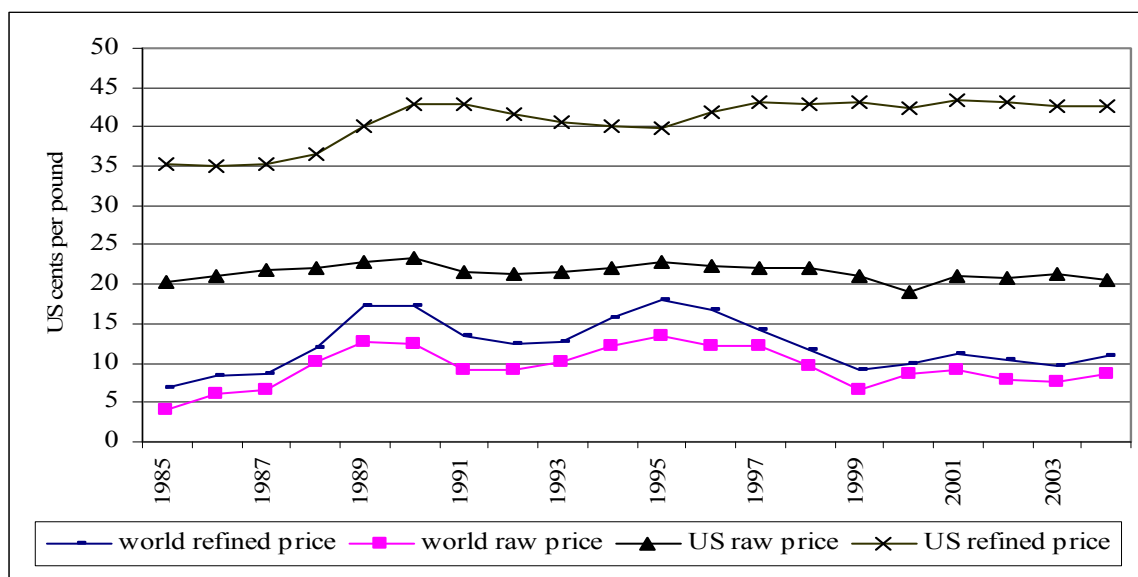


Figure 2.35. World and U.S. raw and refined sugar prices 1985 – 2004
Source: International Sugar Organization, 2005.

The non-recourse loan program was established by the Food and Agriculture Act of 1977. Based on this program, sugar processors can obtain a loan by using their sugar as collateral and paying sugar (cane and beets) producers a price no less than a minimum price set by the government. Sugar processors can keep the loan for up to 9 months (to the end of fiscal year) but after that they have to pay back the loan along with its interest charges or forfeit their sugar crop as collateral to the Commodity Credit Corporation (CCC) (Beghin, 2007).

Import Quota System: An import tariff rate quota (TRQ) system was established to control the amount of sugar being imported into the United States in 1982. This system was created in order to manage a balance between GATT requirements for U.S. sugar imports on the one hand and U.S. sugar supply and demand on the other hand to achieve specific price support objectives and help prevent sugar prices from falling below the loan rate. TRQs are a two-tier tariff system imposed imports based on specific amount of imports (quota) so that imports to the specified level (under quota imports) have a lower tariff rate and imports over specified level (over quota imports) have a higher tariff rate. These two tariff rates are usually called ‘in-quota’ tariffs and ‘out-of-quota’ tariffs, respectively (Beghin, 2007). An out-of-quota tariff is set high in order to prevent sugar imports from being more than their specified amount or TRQ in order to keep supply and thus sugar prices at their target levels.

The USDA is responsible for setting the import quota and price support loans each year. The U.S. Trade Representative allocates the import quota to countries that are eligible to export to the United States. About 40 countries have access to the U.S. sugar market through this system. Table 2.13 shows U.S. sugar import quota allotments by country.

Marketing Allotments: A marketing allotment is used to prevent the sugar market from being oversupplied by domestic producers. The Secretary of Agriculture can limit domestic sugar sales in order to balance the market and prevents the domestic sugar price from falling

below the loan rate. If raw sugar mills produce more than their allotments they then have to store the additional amount at their own expense, referred to as “blocked stocks”.

Table 2.13. The U.S. raw sugar tariff quota in 2007 (YF) (1000 metric tons raw value)

Country	Quota Share	Country	Quota Share	Country	Quota Share
Argentina	55.1	Fiji	11.5	Panama	37.2
Australia	106.4	Gabon	7.3	Papua New Guinea	7.3
Barbados	9.0	Guatemala	61.5	Paraguay	7.3
Belize	14.1	Guyana	15.4	Peru	52.5
Bolivia	10.3	Haiti	7.3	Philippines	173.0
Brazil	185.8	Honduras	12.8	South Africa	29.5
Colombia	30.8	India	10.3	Saint Kitts & Nevis	7.3
Congo	7.3	Jamaica	14.1	Swaziland	20.5
Cote d Ivoire	7.3	Madagascar	7.3	Taiwan	15.4
Costa Rico	19.2	Malawi	12.8	Thailand	17.9
Dominican Rp	225.6	Mauritius	15.4	Trinidad & Tobago	9.0
Ecuador	14.1	Mozambique	16.7	Uruguay	7.3
El Salvador	33.3	Nicaragua	26.9	Zimbabwe	15.4
				Total	1,336.7

Source: USDA, 2007.

The U.S. sugar market is in equilibrium if sugar supply, including domestic sugar production, in-quota imports, out-of-quota imports from Mexico, and stocks change is equal to the U.S. sugar demand (Beghin, 2007). Domestic sugar producers provide around 80 percent of U.S. sugar demand each year with the remaining 20 percent coming from imports. Domestic sugar production depends upon weather conditions and other agricultural factors (e.g., disease, market prices, etc.) and usually is between 68 to 85 percent of the total (domestic plus import) amount of sugar supply (USDA, 2007). Each year after specifying the level of domestic sugar

production, the USDA determines the amount of sugar that must be imported to make up the shortfall in domestic production (American Sugarbeet Growers Association, 2006).

Based on the GATT requirement, the in-quota rate on sugar imports is 0.625 cents per pound. The out-of-quota rate is 15.36 cents per pound for raw sugar and 16.21 cents per pound for refined sugar. The TRQ was 1.29 million tons in 2002 (Elobeid and Beghin, 2005).

2.5.1. History of the U.S. Sugar Program

The economic basis of the current sugar program was established in 1934, through the Jones-Costigan Act. But, U.S. governmental involvement in the sugar market started in the early 18th century and since then, the U.S. government has used different tools including tariffs, producer support programs, and import quotas to increase domestic sugar production and decrease foreign access to the U.S. sugar market.

In 1789, the first congress of the United States imposed a tariff on sugar imported from other countries in order to provide revenue for the government. To stimulate the sugar industry and encourage sugar production, Congress passed the McKinley Bill in 1890 as the first piece of national legislation that dealt with sugar production (American Sugarbeet Growers Association, 2006).

The Jones- Costigan Act in 1934 was the first sugar program to become law. The most important points of this Act were: (Alvarez and Polopolus, 2002)

1. determination of the amount of sugar that a country needed to maintain an appropriate price for both consumers and producers
2. using import quotas to specify the share of domestic producers and imported sugar in the sugar supply
3. allocation of quotas to different domestic processors
4. the adjustment of production in each domestic area to the established quota

5. imposing a tax on sugarcane and sugar beet processors in order to increase producers' income through direct payments
6. making returns to beet and cane farmers more consistent with the returns to processors.

The Act was amended in 1937, 1948, and 1960 and with the last one expiring in 1974. In 1977, the U.S. Secretary of Agriculture initiated a price support program equating the amount of support sugar processors could receive to the difference between the price objective (13.5 cents per pound) and average market price. In return, processors had to pay at least \$22.84 per ton to sugar beets producers and \$17.48 per ton to sugarcane producers. This program set a loan rate for sugar beets and sugarcane; the level of support was to be between 52.5 and 65 percent of the parity price, not to be less than 13.5 cents per pound (Alvarez and Polopolus, 2002). During 1980 and 1981 sugar prices were high and therefore there was no price support program (American Sugarbeet Growers Association, 2006).

The Agriculture and Food Act of 1981 required the sugar price support program for the 1982 to 1985 crops years through a loan rate system and barriers on imports. Therefore, sugarcane received a loan rate between 17 to 18 cents per pound in this period. It was supposed that sugar beets were to receive a support price commensurate with the sugar cane support level (Alvarez and Polopolus, 2002). Also, a market stabilization price (MSP) higher than the loan rate was established for raw sugarcane to minimize the risk of the CCC acquiring sugar during periods of low sugar prices. In 1982 a new system of bilateral tariff rate quotas, based on historical trade with other countries and country by country basis, was established by the Reagan administration. It also modified the fee system and increased import duties.

The Refined Sugar Re-export program was established in 1983 to increase the competitive power of U.S. sugar cane refiners. Under this program, refiners could import raw

sugar at world prices and export refined sugar in 90 days (American Sugarbeet Growers Association, 2006).

In 1985 a new Food Security Act was introduced that was the same as the previous act but included a new provision that required that the sugar program should be operated at “no cost” to the federal government. This meant that sugar supply would be managed in a way that processors would not forfeit sugar, ensuring that the government would not accumulate stocks of sugar. To reach this goal, the USDA has to manage the program so that sugar market prices remain above the loan rate to prevent processor from forfeiting their sugar (Beghin, 2007).

One of the biggest considerations behind “The Food, Agriculture, Conservation, and Trade Act of 1990” was the reduction in sugar imports. In order to control the price level, a new supply control mechanism was created in this Farm Act. It also established a minimum import quota of 1.25 million short tons (raw value) with a two-tiered tariff scheme. The 1990 Farm Act provided for marketing allotments on domestically produced sugar if expected sugar imports are less than 1.25 million tons (raw value). The estimate is not actual imports of sugar, but the result of a formula. The Secretary of Agriculture calculates “estimated imports” for a fiscal year by adding estimated consumption and reasonable ending stocks and then subtracting domestic production and beginning stocks. The estimates included Puerto Rico and were recalculated quarterly. If allotments were announced, they applied to sugar marketed for the fiscal year, and to crystalline fructose at a level of 159,757 tons, though crystalline fructose is not included in the trigger formula.

With respect to implementing allotments, the Secretary sets the overall allotment quantity by adding consumption and reasonable ending stocks, and subtracting from that beginning stocks plus 1.25 million short tons sugar import. The allotment is then allocated between beets and cane sugar based on three factors: past marketing, processing and refining capacity, and the ability to

market. If either beets or the cane sector cannot fill its allocation, imports must fill the gap. The same three factors are used to allocate the cane and beet sugar allotments among producers. This Sugar Act kept the loan rate (18 cents per pound) and Market Stabilization Price (21.95 cents per pound) at the level of the previous Sugar Act.

The 1996 Farm Bill, known as the “Federal Agricultural Improvement and Reform (FAIR) Act,” covered agricultural crops (including sugar) from 1996 to 2002. This farm bill did not change the sugar loan rate or the import quota system but instead eliminated the marketing controls on domestic sugar and increased the CCC’s interest rates by 1 percent. Based on this 1996 farm bill, loans were divided in to two different groups known as recourse and nonrecourse. Loans were nonrecourse and sugar producers could keep the loan and forfeit the sugar if the tariff rate quota (TRQ) on sugar imports was more than 1.5 million tons. Loans would be recourse and sugar producers were obligated to repay their loans if the TRQ was less than that amount. A recourse loan means that the U.S. Department of Agriculture can demand repayment of the loan at maturity, regardless of the price of sugar. In contrast, nonrecourse loans require that the government accept the sugar when the loan matures in lieu of loan repayment in cash, at the option of the processor.

This farm bill required cane and beet processors to pay a penalty for each pound of sugar forfeited to the government. The amount of penalty for cane processors and beet processors was 1 cent and 1.07 cents, respectively (Alvarez and Polopolus, 2002). The loan interest rate was set 1 percentage point higher than the CAC’s cost of borrowing.

President Bush signed the 2002 U.S. Farm Bill in May 2002. This was in effect for six years and with a few differences, its fundamentals were the same as the 1996 Farm Bill. The new changes can be summarized as: elimination of marketing assessments, re-consideration of the "no-cost" requirement, eligibility requirements of in-process sugars for loans, capping the minimum

payment requirement for sugar beets growers, elimination of interest rate payment (that is one percentage point above the CCC's cost of borrowing) for sugar loan recipients, and terminating of the forfeitures penalty.

The new Farm Bill, titled the 'Food, Conservation, and Energy Act of 2008' was implemented in 2008 and will continue in effect to 2013. The foundation of the sugar program in this farm bill will be the same as in the 1996 and 2002 farm bills with a few changes. These include sugar-ethanol production and rise in loan rates. Also important is the minimum domestic allotment set at 85% of domestic consumption. Table 2.14 compares select sugar component of 2002 and 2008 farm bills. The loan rate for raw cane sugar will increase from 18 cents per pound in fiscal year 2009 to 18.25 cents per pound in 2010, 18.50 cents per pound in 2011, and 18.75 cents per pound in 2012-13. The loan rate for refined beet sugar will increase from 22.9 cents per pound in 2009 to 128.5% of loan rate for raw cane sugar in years 2010-13 (Table 2.14).

2.5.2. Sugar and Ethanol

The sugar and ethanol markets have interaction with each other so that change in one market will influence the other market. One of the more obvious relationships between sugar and ethanol is that if a boost in ethanol production increases corn prices, this serves to make HFCS uncompetitive with sugar. As a result, wet plants will gradually switch from HFCS production to ethanol production. In this case, to keep sugar prices at the current level, the government has to import an additional 8.8 million tons sugar each year to replace HFCS (U.S HFCS consumption was 8.8 million tons in 2007). This is almost equal to current total U.S. sugar consumption which was 9.3 million tons in the 2007 (Table 2.12). The net cost of corn to produce corn sweetener rose from 3.21 cents per pound in the second quarter of 2006 to 9.22 cents per pound in the second quarter of 2008 (USDA, 2008). If this trend in the cost of corn continues, then in the near future producing HFCS will not be profitable and producers may discontinue producing HFCS,

resulting in a need for additional sugar imports. The other and more important issue regarding the relationship between sugar and ethanol is the possibility of using sugar crops for producing ethanol.

U.S. sugar policy-makers take into account four different concerns when evaluating and establishing U.S. sugar policy. These issues are: stage of minimum price guarantees provided for sugar producers; managing U.S. sugar supply at no cost for the government; allowing ethanol plants to use sugar surplus for producing ethanol in case of excess supply in the market; and accounting for the costs involved with sugar program (Jurenas, 2008).

Technically, producing ethanol from sugarcane is straight forward while producing ethanol from corn requires taking additional steps to convert corn starch to sugar. This makes processing costs for corn-based ethanol higher than ethanol produced from raw and refined sugar. Furthermore, next to feedstock cost, the energy cost is the most restrictive component of ethanol production cost which can be removed or lowered in the case of producing ethanol from sugarcane. Bagasse is the byproduct of sugarcane based ethanol production and can be burned to produce a part of necessary energy for operating ethanol plants instead of buying electricity or natural gas (Jurenas, 2008).

The 2008 Farm Bill requires the USDA to manage excess sugar supply to be used for ethanol production under the Feedstock Flexibility Program for Bioenergy Producers. Based on this program, the USDA must sell its excess sugar stocks, obtained as a result of balancing the sugar market or loan forfeitures, to ethanol producers for use as a feedstock for biofuels production. As mentioned before, feedstock cost for producing ethanol from sugar is far more than producing ethanol from corn, therefore, the “Feedstock Flexibility Program for Bioenergy Producers” necessitates sizeable subsidies in order to be implemented (Jurenas, 2008). Corn-based ethanol plants which are close to sugarcane or sugar beets locations are the main targets

Table 2.14. Comparison between 2002 and 2007 farm bills

Provisions	2002 Farm Bill	2007 Farm Bill
Sugar		
Price support	Reauthorized nonrecourse loan program for processors of domestically grown sugar through fiscal year (FY) 2008 at 18 cents/lb for raw cane sugar and 22.9 cents/lb for refined beet sugar.	<p>Reauthorizes nonrecourse loan program through FY 2013. Loan rate for raw cane sugar is:</p> <ul style="list-style-type: none"> • 18 cents/lb in FY 2009 • 18.25 cents/lb in FY 2010 • 18.50 cents/lb in FY 2011 • 18.75 cents/lb in FY 2012-13 <p>Loan rate for refined beet sugar is:</p> <ul style="list-style-type: none"> • 22.9 cents/lb in FY 2009 • 128.5% of loan rate for raw cane sugar in FY 2010-13
	<p>Loans could not be made earlier than beginning of fiscal year. Loans matured at earlier of end of 9 months or end of fiscal year in which loan was made.</p> <p>For loans made in last 3 months of a fiscal year, processor could repledge sugar as collateral for second loan in subsequent fiscal year. These supplemental loans were made at loan rate in effect at time first loan was made, and matured in 9 months minus period of time that first loan was in effect.</p>	Retains provision.
	Nonrecourse loans were extended to in-process beets and cane syrups. Loan rate was set at 80% of loan rate applicable to raw cane sugar or refined beet sugar, depending on source material for the in-process sugars and syrups.	Retains provision.
	Loan rates could be reduced, at Secretary's discretion, if foreign producers reduced export subsidies and support levels below their current World Trade Organization (WTO) commitments.	Does not extend authority to reduce loan rates.

Table 2.14. Continued

Bioenergy Feedstock	No similar provision.	If reduction in production is necessary to avoid forfeitures, quantity of sugarcane and sugar beets that has already been planted may not be used for any commercial purpose other than as a bioenergy feedstock. See Title IX, Feedstock Flexibility Program for Bioenergy Producers .
Information Reporting	Required sugarcane processors, cane sugar refiners, and sugar beet processors, on a monthly basis, to furnish such information as Secretary may need to administer the sugar programs. Such information included quantity of purchases of sugarcane, sugar beets, and sugar, and production, importation, distribution, and stock levels of sugar.	<p>Extends provision.</p> <p>Requires Secretary to collect information on production, consumption, stocks, and trade of sugar in Mexico, including U.S. exports of sugar to Mexico; and publicly available information on Mexican production, consumption, and trade of high-fructose-corn syrups.</p> <p>Data on Mexico must be published in each edition of USDA's monthly World Agricultural Supply and Demand Estimates.</p>
Flexible Marketing Allotments	<p>Overall allotment quantity (OAQ) was to be divided between beet processors (54.35%) and cane producers (45.65%), including cane producers of Hawaii and Puerto Rico.</p> <p>Allotments did not apply to sugar produced for export or for use in production of ethanol or other bioenergy products.</p>	Retains provision. Allotment quantity may not be less than 85% of estimated deliveries for food and human consumption
	<p>Allotments were to be automatically suspended when estimates of imports for domestic food use exceeded sum of:</p> <ul style="list-style-type: none"> • 1.532 million short tons and • quantities of sugar reassigned to imports from unfilled allocations of beet sugar or cane sugar overall allotment quantity (OAQ) 	Eliminates provision.

Table 2.14. Continued

Tariff-Rate Quotas (TRQs)	<p>U.S. Trade Representative, in consultation with Secretary, was to determine amount of cane sugar quota used by each qualified supplying country for that crop year, and could reallocate unused quota for that crop year after June 1 among other qualified supplying countries.</p>	<p>TRQs for raw cane sugar and refined sugars must be established at the minimum level necessary to comply with obligations under international trade agreements.</p> <p>If a sugar shortage occurs due to an emergency situation such as natural disaster or war or similar event prior to April 1 of crop year, domestic marketing allotments, along with necessary reassignments, including those made to imports, can be increased. If these actions are insufficient to meet the emergency situation, then further increases in refined sugar TRQ may be made. After April 1, if there is a shortage of sugar (whatever the cause) domestic marketing allotments, along with necessary reassignments, including those made to imports, can be increased. If there is still a shortage of sugar in U.S. market, and marketing of domestic sugar has been maximized, Secretary may increase TRQ for raw cane sugar if further increase does not threaten to result in forfeiture of sugar pledged as loan collateral.</p>
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Source: The 2008 Farm Bill: Title 1- Commodity Programs. Economic Research Service, United States Department of Agriculture, Washington, D.C.
<http://www.ers.usda.gov/Features/farmbill/titles/title1commodities.htm>

for this program. Nonetheless, they need to install additional equipment to be able to use sugar along with corn in their plants. This is another factor beyond feedstock costs that requires significant subsidy to encourage corn-based ethanol producers to use sugar for producing ethanol (Jurenas, 2008).

The ethanol production boost and increase in corn prices have created potential incentive for using sugar crops as feedstock to produce ethanol. The cost of producing ethanol is very

diverse for different sugar crops and ranges from \$1.27 per gallon ethanol for molasses to \$3.97 per gallon ethanol for refined sugar based on 2006 estimations (Haley and Mir Ali, 2007).

Processing costs of producing ethanol from molasses, raw sugar, and refined sugar are lower than the processing costs of producing ethanol from corn. However, corn feedstock cost is low, relative to feedstock cost of all sugar crops, so that the total cost of producing ethanol from corn is much lower than the total cost of producing ethanol from sugar crops. As Figure 2.36 demonstrates, molasses is the most competitive sugar crop relative to corn, while U.S. refined sugar incurs the highest cost in producing ethanol. Producing ethanol from U.S. refined sugar (\$3.97 per gallon ethanol) costs almost four times as much as producing ethanol from corn in dry mills (\$1.03 per gallon ethanol). It is worth noting that 2008 prices change this figure and results are incrementally higher because of the relatively recent sharp increase in corn prices resulting from the increase in corn demand for producing ethanol. As a result, the cost of producing ethanol from molasses is less than the cost of producing ethanol from corn.

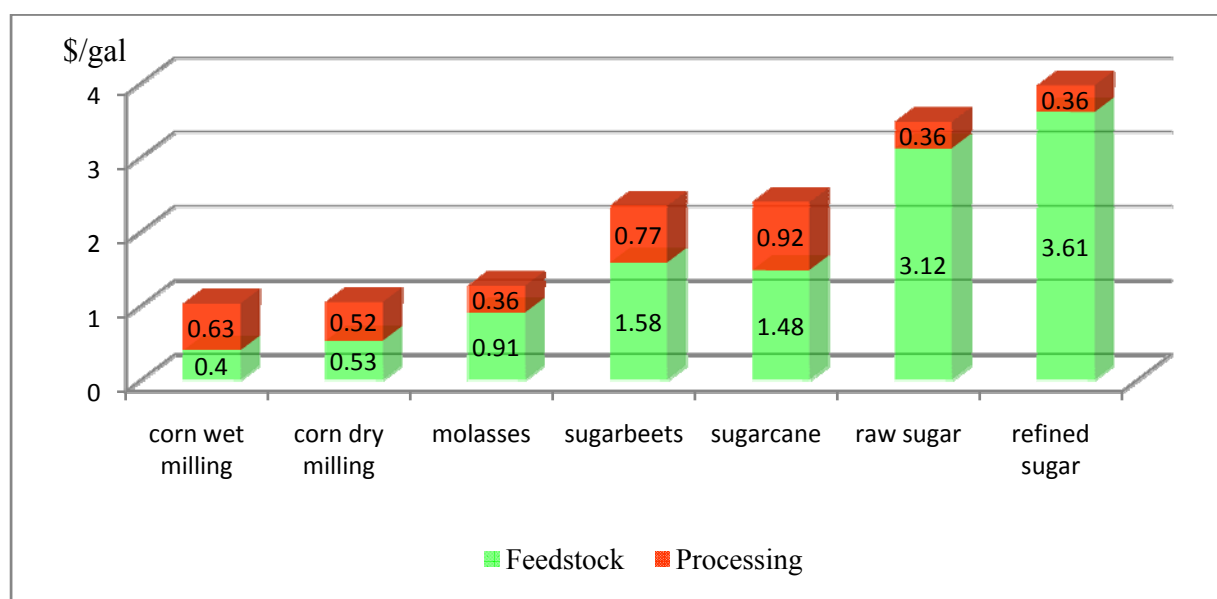


Figure 2.36. Estimated ethanol production costs for different feedstocks
Source: Sugar Backgrounder, Stephen Haley and Mir Ali, 2007.

In the same way, with further increases in ethanol production, based on the 2007 Energy Independence and Security Act requirement, further increases in corn prices may serve to make other sugar crops cost competitive with corn for producing ethanol in the United States.

Using sugar for producing ethanol is more straightforward and has smaller operation costs than using ethanol from corn. High U.S. sugar prices (relative to world sugar price) make using sugar-based ethanol unprofitable in the United States. But, high sugar prices are not the only problem related to producing ethanol from sugar as there are other practical obstacles such as which sugar will be converted into ethanol. There are three different sources of sugar that can be converted to ethanol including domestic sugar, under quota imported sugar, and sugar imported from other countries (Promar International, 2007a).

From a policy and market management point of view, using domestic sugar for producing ethanol is not without difficulty. On one hand, sugarcane producers are usually vertically integrated with cane sugar mills and will not willingly sell their sugarcane to ethanol producers. If producing sugar has a larger margin than producing ethanol there will be a smaller amount of sugar available for producing ethanol. On the other hand, using sugar beets for producing ethanol means sugar beets producers have to give up their traditional customers, which is not something they are willing to do. Again, having a higher margin in the sugar industry than in the ethanol industry could be an obstacle for using sugar beets for producing ethanol rather than producing sugar.

Using domestic sugarcane or sugar beets raises another issue related to feedstock availability for the entire year, because ethanol plants cannot operate for just a few months. Considering all these issues, the feasibility of using domestic sugar for producing ethanol in the near future is doubtful, if not impossible (Promar International, 2007a).

Using sugar imported from quota holding countries for producing ethanol has difficulties as well. First of all, a governmental agency, like the Commodity Credit Corporation (CCC), needs to be involved in buying raw sugar from these countries and reselling it to ethanol producers at a discounted price so that it makes ethanol production from sugar profitable. Even if this is possible, an agency still has to compete with U.S. refiners to obtain a suitable amount of sugar. This approach introduces more complexity into the steps the USDA has to go through to determine the amount of sugar that should be imported so that sugar prices do not fall below the sugar loan rate (Promar International, 2007a).

It appears that importing sugar specifically for producing ethanol at free market prices (Caribbean prices) is the only way sugar can be a competitive feedstock with corn in the foreseeable future. This issue will be discussed in chapter IV where the statistical estimation results will be used for predicting corn-based ethanol production.

2.5.3. Liberalization in the U.S. Sugar Market

Sugar market liberalization can have numerous effects on the sugar market specifically and on the entire sweeteners market in general. It can even impact the ethanol market by providing sugar at a competitive price with corn to produce ethanol. Using sugar for producing ethanol, in turn, decreases corn demand for producing ethanol, thereby decreasing corn prices and impacting the corn market.

There have been several studies which have investigated the impact of liberalization in the U.S. sugar market through removing sugar imports barriers on the U.S. sugar market. The results of all these studies share a common outcome, showing that sugar imports increase and domestic sugar prices and production decrease. However, the magnitude of change in these variables is different from one study to the next. The results are dependent on the data, time period, assumptions, and methods used in each study.

A study by Salassi et al. shows that an additional 3 million tons of sugar imports would increase world raw sugar prices by 2.97 percent, from 7.70 cents per pound to 7.93 cents per pound, while decreasing U.S. raw sugar prices by 63.3 percent from 22.92 cents per pound to 8.41 cents per pound (Salassi et al., 2003). Beghin et al. states that removal of U.S. sugar program price controls in 1998 could decrease domestic raw sugar prices from an actual 22.06 cents per pound to an expected 12.46 cents per pound and could raise world raw sugar prices from 9.68 cents to 10.96 cents per pound. It also could increase sugar imports by 1.6 million tons from 1.7 million tons to 3.3 million tons (Beghin et al., 2001).

A study by Haley shows that the elimination of the U.S. sugar program decreases domestic raw sugar prices by 23.4 percent, from 18.43 cents per pound for the base case to 14.16 cents per pound. This raises world sugar prices by 98.2 percent, from 7.32 cents per pound to 14.51 cents per pound. Based on this study, domestic sugarcane and sugar beet production declined 38 and 18.8 percent, respectively and sugar imports increased by 5.2 million tons. The share of domestic sugar in domestic sugar delivery decreased from 89 percent to 51 percent. Total demand for sugar rose by 1.5 million tons or 17 percent (Haley, 1998a).

Koo used actual data for 1999 and predicted sugar prices, consumption, import, and domestic production for 2004, with and without sugar trade liberalization. This study shows that trade liberalization could decrease beet sugar production by 1.04 million tons and cane sugar production by 0.58 million tons while sugar imports could increase by 2.46 million tons. Trade liberalization could lower domestic retail prices from 24.70 cents per pound to 16.75 cents per pound and could increase Caribbean sugar prices from 11.45 cents per pound to 12.53 cents per pound (Koo, 2000).

As these studies demonstrate, removing sugar programs, especially the tariff rate quota, sharply decreases domestic sugar prices. This impacts the ethanol market in two distinctly

different ways. The lesser impact is that a decrease in sugar prices eliminates the advantage of HFCS over sugar and, therefore, most of the corn used in HFCS production will be used for ethanol production. But the greater and more important consequence of a decline in domestic sugar prices is that imported sugar will be more competitive with corn in producing ethanol.

2.5.4. U.S. Sugar Production Costs

High costs of producing sugarcane in the United States decreases the competitiveness of the U.S. sugar industry relative to lower-cost sugar producing countries, such as Brazil and South Africa. U.S. sugarcane production costs are higher than the production-weighted world average of all cane-producing countries. The cost of producing sugar beets for low cost producers is between 14 and 24 cents per pound, while U.S. sugar beet production costs are between 18 and 32 cents per pound (Haley and Jerardo, 2007). Sugar production cost is not the same for all regions in the United States, so that the eastern regions sugar beets producers, including the Great Lakes and the Red River Valley, have a lower production cost than those western regions sugar beets producers including the North Great Plains, Central Great Plains, the Northwest, and the Southwest. Beet sugar production cost is between 16.77 and 25.19 cents per pound in eastern regions. The production cost of beet sugar in western regions is between 18.65 and 32.57 cents per pound (Haley and Ali, 2007).

Cost of producing raw cane sugar in low cost producer countries is as much as half of the production cost of raw cane sugar in the United States. Cost of producing raw cane sugar is between 5.42 and 11.53 cents per pound for Low-cost producers and between 12.55 and 20.08 cents per pound for U.S. producers. Weighted world average cost of raw cane sugar for all worlds' sugarcane producers is between 10.76 and 12.26 cents per pound (Haley and Ali, 2007).

Figure 2.37 and 2.38 show the field costs and processing and refining factory costs of sugar production, in compare with world average for cane and beet sugar, for time period

1999/00 – 2004/05. As Figure 2.37 illustrates, sugarcane production field costs in the United States are higher than world cane sugar average. Florida has the lowest field production cost while Hawaii has the highest field production cost. U.S. processing and refining factory costs are lower for sugarcane than sugar beets (Figure 2.38).

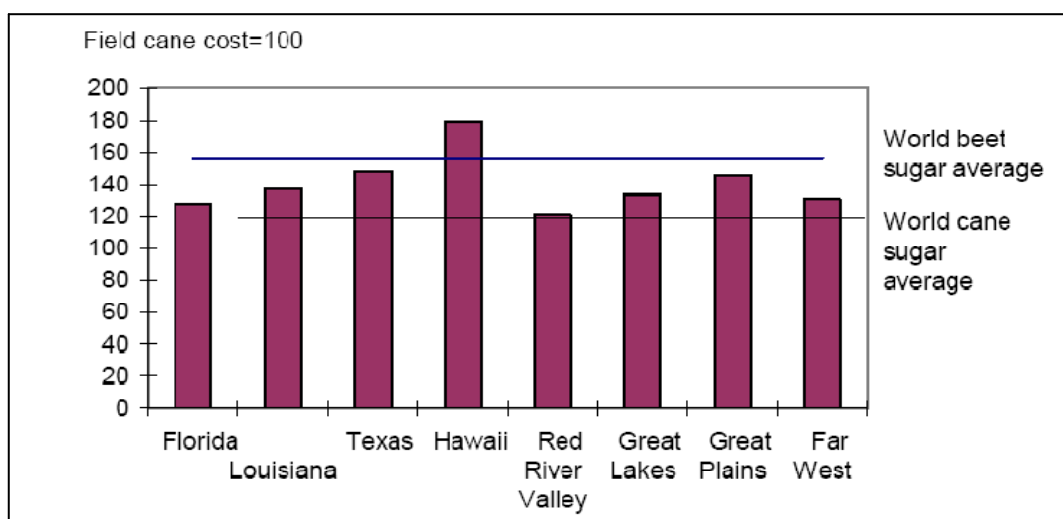


Figure 2.37. U.S. field costs of sugar production, relative to world average for cane and beet sugar, 1999/00 – 2004/05
Source: Sugar Backgrounder, Stephen Haley and Mir Ali, 2007.

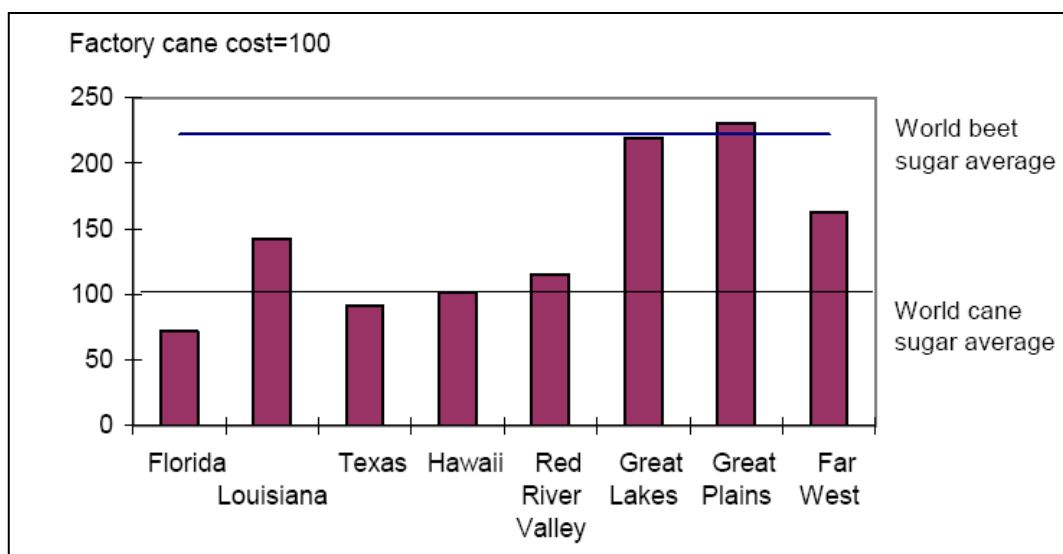


Figure 2.38. U.S. processing and refining factory costs of sugar production, relative to world average for cane and beet sugar, 1999/00 – 2004/05
Source: Sugar Backgrounder, Stephen Haley and Mir Ali, 2007.

2.6. Some Statistical Results from Other Studies

In this part, the estimation result of some studies which are related to Ethanol, Corn, HFCS, and sugar markets are summarized. Most of these results deal with supply and demand price elasticity.

Lopez estimates supply elasticities for sugarcane and sugarbeets. The short-run supply price elasticity is 0.231 for sugarcane and 0.479 for sugar beets. This estimation is different from Gemmill's estimation for sugar beets (1.57). Sugar beet supply elasticities estimated by Gemmill and Jesse are 0.49 and 0.40, respectively. Based on this study, the short-run and long-run demand elasticities of sugar are -0.111 and -0.597, respectively which again are different from those demand price elasticities estimated by Gemmill (-0.04) and Gorge and king (-0.24). The sugar demand elasticity of income estimated by Lopez for the short-run is 0.092 and for the long-run is 0.494 (Lopez, 1989).

Beghin et al.'s estimation results show that the short-run and long-run domestic elasticities for sugarcane are 0.05 and 0.20, respectively. Also, based on this study, the short-run and long-run domestic sugar beets supply elasticities are 0.10 and 0.26, respectively (Beghin et al., 2001).

Tokgoz and Elobeid analyze the effect of corn price shocks on ethanol production in the United States. They show that a 20% increase in the U.S. corn price would decrease ethanol production by as much as 3.7% and increase ethanol price by 2.3% in the United States (Simla Tokgoz and Amani Elobeid 2006).

Evans estimates corn price as a function of corn production, corn exports, ethanol demand, and the 1961-1995 corn support price. Based on this report, every 100 million gallon increase in the demand for ethanol increases the corn price by as much as 9 cents per bushel. This report shows corn exports, ethanol demand, and corn support prices have positive impacts

on the corn price with corn production having a negative impact. The increase in corn price is projected to be 7.5 cents per bushel after adjusting for the increase in corn production, having resulted from higher corn prices. This report claims that the corn price elasticity of demand is around - 0.36 and is consistent with other studies that have shown corn price-inelastic (Evans, 1997).

Holt applies a structural model for the U.S. corn and soybean markets consisting of aggregate supply and demand for both crops (four equations). Demand for corn is estimated as a function of the farm price of corn, farm price of soybeans, index of prices received for livestock, commercial corn exports, and a trend variable. Corn supply is estimated as a function of rational expectations of the effective producer price of corn, rational expectations of the effective producer price for soybeans, corn acres diverted, seasonal growing condition indices for corn, a binary variable equaling 1 only during 1983, and a trend variable. By using U.S. data for 1950-85, estimated corn own-price elasticity of demand and cross price elasticity of demand with respect to soybeans are - 0.696 and - 0.057, respectively. Short-run corn own price elasticity of supply is 0.223 and is - 0.076 for cross price elasticity of demand with respect to the price of soybeans (Holt, 1992).

Williams and Bessler found a dynamic relationship between refined sugar prices and HFCS prices for the period from 1984 to 1991. They found that HFCS pricing levels had been set by HFCS producers who based these pricing levels on that of refined sugar pricing levels for much of the period (Williams and Bessler, 1997).

Evans and Davis set up a supply and demand model for HFCS in the United States. In their model, HFCS demand is a function of the HFCS price, refined sugar price, soft drink price, and flour price. Based on their model, HFCS price is a function of corn price, energy price, interest rate, sugar price, soft drink price, and flour price. They found that only two of the

explanatory variables, electricity and flour prices, were significant at the 5% level using the OLS method. Estimating the model using Maximum Likelihood, the price of sugar was significant at the 5% level while reducing the significance level of the previous variables to 10%. The results show that all three variables, corn price, sugar price, and flour price, have a positive impact on the HFCS price. Based on this study, the HFCS own-price elasticity of demand is -1.64. This indicates that HFCS demand is price elastic (Evans and Davis, 1999).

Based on the Brendstrup et al. study, the point demand price elasticity of HFCS at mean price and quantity for the period starting in the first quarter of 1980 to the last quarter of 2000 has a range of 0.10 to 0.26 (Brendstrup et al., 2005).

CHAPTER III

METHODOLOGY

3.1. Introduction

The objective of this dissertation is to determine the economic effects of domestic and trade policies, in particular sugar and ethanol policies, on the U.S. ethanol, HFCS, sugar, and corn markets. This will be accomplished by developing a model to determine the impact of the sugar program, ethanol production, and import policies (especially 2007 Energy Act requirements) on the U.S. ethanol, corn, HFCS, and sugar markets. This model will include factors that impact U.S. ethanol, corn, HFCS, and sugar supply and demand. To set up this model, we first identify the supply and demand frameworks for these commodities.

3.2. Ethanol Supply and Demand

3.2.1 Ethanol Supply

Based on economic theory, the profit margin is the factor which encourages ethanol producers to produce ethanol. Since profit is equal to the difference between the producer total revenue (TR) and producer total costs (TC), any changes in the variables which constitute ethanol revenues and costs impact ethanol profits and thus ethanol production. Ethanol producer total revenue is equal to the product of ethanol prices and ethanol quantities ($P \times Q$), both of which are determined by the ethanol supply and ethanol demand equilibrium and also any revenues resulting from the selling of byproducts. Therefore, ethanol and its byproduct prices impact ethanol producer profit margins, thus ethanol production and supply. Producing ethanol from corn allows the extraction of other useable byproducts such as corn oil, corn gluten feed, and corn gluten meal (in wet milling plants) and distillers' grains (in dry milling plants). As Figure 3.1 illustrates, theoretically, any increase in the demand for these byproducts can stimulate their

prices, increasing ethanol producer profit thus serving to boost ethanol production (in order to obtain said byproducts).

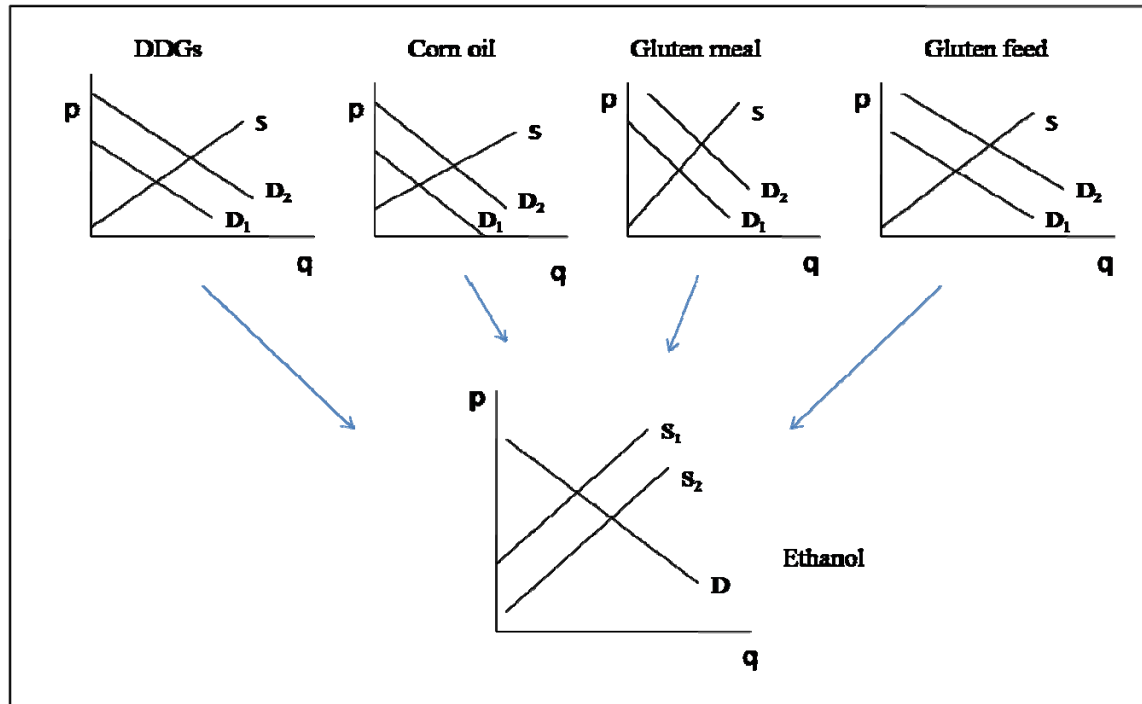


Figure 3.1. Impact of increased demand for ethanol byproducts on ethanol production

Ethanol production costs consist of capital costs (fixed costs) and input costs. The most important inputs in producing ethanol are feedstock and energy, especially natural gas. Ethanol can be produced from different feedstocks and was, until recently, manufactured most cheaply from corn, as corn had been the cheapest ethanol feedstock in the United States. In the United States, corn is the most popular input for producing ethanol (Figure 3.2). Domestic corn prices have a negative impact on ethanol production. After feedstocks, energy is the most important factor in producing ethanol. Most U.S. ethanol is produced in dry milling factories which need a significant amount of energy (usually natural gas) to extract the moisture from wet distillers' grains to produce dry distiller's grains. Thus, any increase in natural gas prices will have a negative impact on ethanol production, all else being equal. The interest rate is used in the

ethanol supply model framework to capture capital cost. Ethanol is a capital intensive product, and investors in this industry must compare the rate of return in this industry with the rate of return in alternative investments. Investors may also borrow a part of their investment from financial institutions. Therefore, any increase in interest rates not only makes investing in the ethanol industry less attractive to investors, it also increases investors' borrowing cost, thereby reducing profit margins. Any increase in the interest rate will be an important factor for investors in this industry and it is expected that increases in interest rates will reduce investment (Figure 3.2).

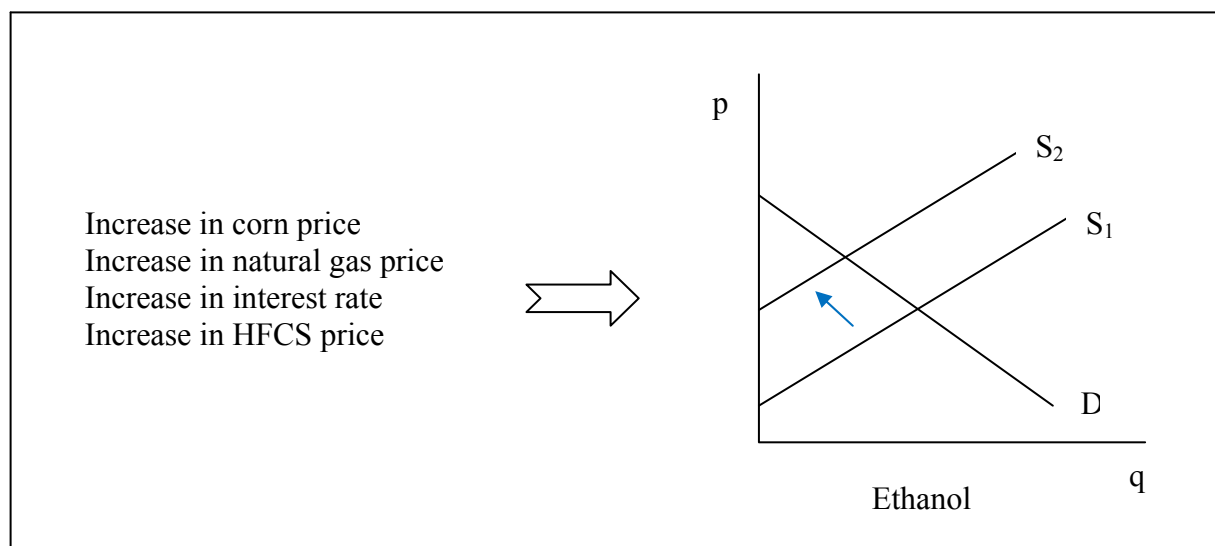


Figure 3.2. Impact of increased HFCS and ethanol input prices on ethanol supply

As previously mentioned, wet milling industries are capable of switching between producing ethanol and HFCS from corn starch, depending upon which product yields more profit. Thus, a sufficient increase in HFCS prices can increase HFCS profit margins comparable to ethanol and induce wet milling factories to produce HFCS instead of ethanol. Thus, increases in HFCS prices can have a negative impact on ethanol production (Figure 3.2).

Notice that ethanol production and demand for corn to produce ethanol are two faces of the same coin. The ethanol production equation can be seen as corn demand for the ethanol

equation. On average, each bushel of corn used for ethanol production yields 2.70 gallons of ethanol (2.65 gallons per bushel in wet mills and 2.75 gallons per bushel in dry mills). Therefore, if we estimate the ethanol supply function and divide the right hand side of the estimated equation by 2.70, we obtain the demand for corn for ethanol production as well.

Based on the above discussion, Equation (3.1) is constructed to model U.S. ethanol supply:

$$(3.1) \text{ Ethanol Production} = f(\text{ethanol price, domestic HFCS price, domestic corn price, natural gas price, interest rate, corn oil price, DDGs price, gluten feed price, , gluten meal price})$$

This equation is formulated in Equation (3.2).

$$(3.2) \text{ EthPr} = a_1 + a_2*\text{EthP} + a_3*\text{DHfP} + a_4*\text{DCoP} + a_5*\text{NgP} + a_6*\text{GfP} + a_7*\text{GmP} + a_8*\text{DdgP} + a_9*\text{CoOilP} + a_{10}*\text{Ir}$$

$$\text{Expected signs: } a_2, a_6, a_7, a_8, a_9 \geq 0 \quad \text{and} \quad a_3, a_4, a_5, a_{10} \leq 0$$

In this equation, EthPr and EthP show Ethanol production and price, respectively. DCoP and DHfP, represent the domestic corn price and domestic HFCS price; and Gfp, GmP, NgP, DdgP, and CoOilP represent gluten feed, gluten meal, natural gas, DDGs , and corn oil price, respectively. Ir is used to represent the interest rate.

3.2.2. Ethanol Demand

Based on the “law of demand,” there is an inverse relationship between the price of a good and the amount of the good that is demanded. Thus, if the price of a commodity increases, then the quantity demanded of that commodity falls, resulting in a downward-sloping demand curve. (Mowen, 1990) Demographic variables (income and population), related goods (either as substitutes and complements to one another), and changes in consumers’ tastes and preferences are other factors that influence demand (exogenously) and shift the demand curve. Increases in

income shift the demand curve to the right, indicating that a consumer can afford more of that product given a constant product price. Increases in population also increase the number of buyers for a particular product and therefore population increases shift the demand curve to the right. Reduction in related commodity prices, depending upon the substitutionary or complimentary nature of the commodity in question, will shift the demand curve.

Based on basic demand principles, we expect that any increase in ethanol prices has a negative impact on ethanol demand. Related (substitute and complementary) goods' prices are other factors which impact ethanol demand. Ethanol is closely related to gasoline. Not only is ethanol used as a gasoline additive, it can also be used as a substitute for gasoline. Therefore, as was seen in Chapter Two's literature review, ethanol can be viewed as both a substitute and complement product for ethanol. As a result, increases in gasoline prices can have a positive or negative impact on the demand for ethanol. Estimation results in the next chapter will show which of these two effects, substitutionary or complementary, have been more prevalent in time period under analysis.

Governmental rules and policies such as the 2005 and 2007 Energy Acts and the EPA's mandatory replacement of MTBE with ethanol both have a significant impact on the demand for ethanol. The model attempts to capture the impacts of these policies on ethanol demand by using dummy variables in the model. Furthermore, any increase in GDP and population serves to increase ethanol demand. Finally, an increase in the number of cars on America's roads exacerbates fuel demand, and is thus expected to increase demand for ethanol as both a fuel source and a fuel additive.

Equation (3.3) shows the suggested ethanol demand function:

$$(3.3) \text{ Ethanol Consumption} = f(\text{Ethanol Price, Gasoline Price, GDP, POP, Number of Cars, Government policies})$$

Equation (3.3) can be formulated as follows:

$$(3.4) \quad EthCon = b_1 + b_2*Ethp + b_3*GasP + b_4*GDP + b_5*Pop + b_6*Car + b_7*GR$$

Expected signs: $b_2 \leq 0$, $b_4, b_5, b_6, b_7 \geq 0$, and b_3 can be positive or negative

In this equation, EthCon and EthP represent ethanol consumption and price, respectively. Car is used to represent the number of cars and trucks used in the United States, GR is used to represent U.S. Government policies (mandatory ethanol consumption), and GasP indicates the domestic U.S. gasoline price.

3.3. Corn Supply and Demand

3.3.1. Corn Supply

As mentioned before, the framework incorporates two different models, one based on annual data and the other based on quarterly data. The main reasons for using two models are to increase the results reliability and also to address the problem associated with estimation of the corn production equation in a quarterly model. Since we have corn production for only one quarter per year, it is not possible to estimate an equation for corn supply based solely on corn production in the quarterly model. Therefore, we estimate the corn supply equation in the quarterly model based on the corn stock, instead of the corn production that is in the annual model. These two equations have different dependent variables and some of their independent variables are different as well.

3.3.1.1. Corn Supply in the Annual Model

The amount of annual corn production is the dependent variable of the corn supply equation in this model. Since the United States is the world's largest corn exporter, one could expect that world corn prices as well as domestic corn prices would play a significant role in the amount of corn produced. In fact, the world corn price is the specific price for number 2 U.S. yellow corn.

As previously mentioned, the loan rate can also influence farmers' crop production decisions. Fertilizer and fuel are the most important inputs in producing corn. Given this, their prices are subsequently included in the corn supply function specified herein.

Soybeans, cotton, rice, barley, and wheat are the most significant crops that compete with corn for production resources, especially arable land. Therefore, we have to take into account the price for these crops in the supply function. Other factors that impact corn production are corn yield and technology. Both variables are expected to positively impact corn production. To include weather data we considered the weather conditions in the United States to determine the years with extraordinary weather conditions such as flooding, hurricanes, and/or drought. In the model, a dummy variable is employed to account for the weather conditions for the given time period. If, in a specific year, the weather conditions have been sufficiently inclement corn production was negatively impacted, a value of one is assigned. Otherwise, a value of zero would be assigned. It is expected that the "weather" dummy variable has a negative impact on corn supply.

The corn supply equation (3.5) is specified as follows:

$$(3.5) \text{ Corn Supply} = f(\text{domestic corn price, world corn price, corn loan rate,} \\ \text{corn yield, fertilizer price, fuel price, soybeans price, cotton price,} \\ \text{rice price, wheat price, barley price, technology, weather condition})$$

In this equation we expect all variables except soybeans price, cotton price, rice price, wheat price, and weather condition to have a positive impact on supply quantity. Equation (3.6) shows the formulated corn supply equation.

$$(3.6) \text{ CoPr} = c_1 + c_2 * DCoPl + c_3 * WCoP + c_4 * CoLR + c_5 * CoY + c_6 * FeP + c_7 * FuP \\ + c_8 * BaP + c_9 * SoyP + c_{10} * CotP + c_{11} * RicP + c_{12} * WhP + c_{13} * WeCo + c_{14} * T$$

Expected signs: $c_2, c_3, c_4, c_5, c_{14} \geq 0$ and $c_6, c_7, c_8, c_9, c_{10}, c_{11}, c_{12}, c_{13} \leq 0$

In this equation CoPr represents corn production and DCoP1 represents the lagged domestic corn price. BaP, SoyP, CotP, RicP, WhP, Fep, FuP, and WCoP are used to represent barley, soybeans, cotton, rice, wheat, fertilizer, fuel and world corn prices, respectively. CoLR, CoY, T, and WeCo represent the corn loan rate, corn yield, technology, and weather condition, respectively.

3.3.1.2. Corn Supply in the Quarterly Model

The dependent variable in the quarterly model is the change in corn stock from one quarter to the other. In fact, similar to a supply and demand system for a good which uses the equilibrium quantity as both the supply and demand quantity, here we use the same corn quantity to estimate corn supply and demand. In this model, the quantity of corn is a function of current corn price, lagged corn price, and corn production which is different from zero just for the first quarter of the fiscal year. Equations (3.7) and (3.8) illustrate the corn supply equation.

$$(3.7) \text{ Corn Supply} = f(\text{current corn price, lagged corn price, corn production})$$

$$(3.8) \text{ CoSup} = d_1 + d_2 * \text{DCoP} + d_3 * \text{DCoP1} + d_4 * \text{CoPr}$$

$$\text{Expected signs: } d_2, d_4 \geq 0 \quad \text{and} \quad d_3 \leq 0$$

In this equation, CoSup represents corn supply, DCoP is used to represent current domestic corn price, DCoP1 represents the lagged domestic corn price, and CoPr is used to represent corn production.

3.3.2. Corn Demand

Corn and corn products (e.g. corn oil, HFCS, ethanol, and dried distillers' grains (DDG)) are used as an input to produce many products that are edible either for direct human consumption or indirect consumption. Therefore, corn demand is partially derived and subsequently depends upon the prices of these products derived from corn. Any increase in demand for these products can serve to increase their prices and, in turn, boost producer profits leading to their increased

production. Consequently, this increases the demand for corn (as corn is the primary input for these products).

Corn is utilized in a variety of different ways in the United States. It can be used as an input to produce human food, as animal feed, and to produce ethanol and corn sweeteners (Figure 3.3). As a result, any change in one of these markets impacts the demand for corn, and thus the corn market quantity and price equilibrium.

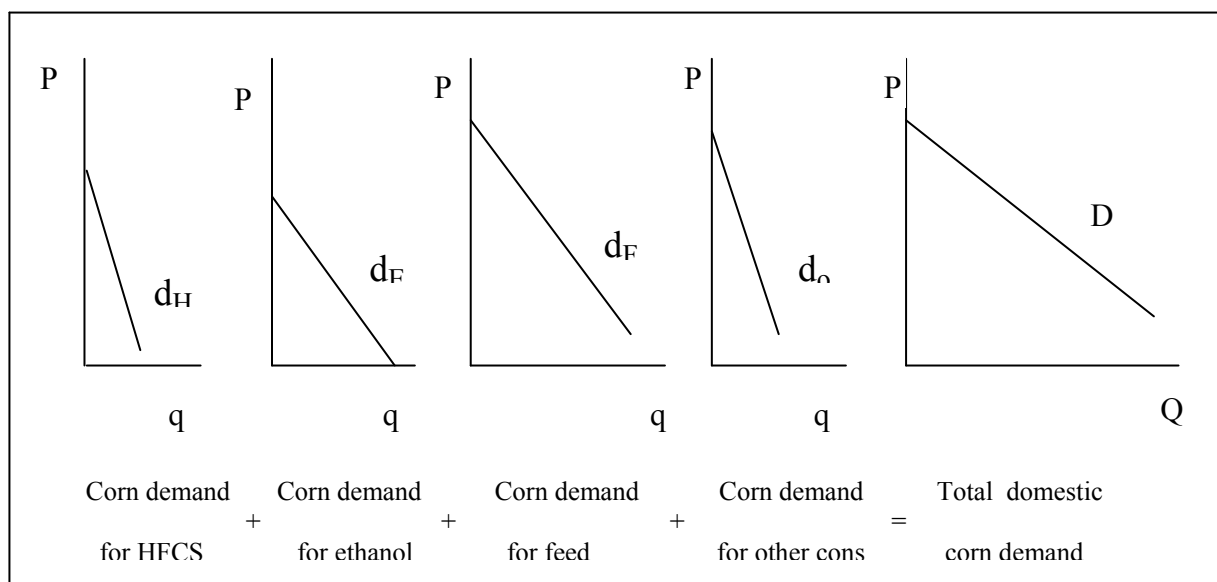


Figure 3.3. U.S. domestic corn users

However, not all variables that impact corn demand for one use, such as feed, are the same as variables that impact corn demand for another use, like ethanol. These differences in variables which influence different types of demand, urge us to decompose the total corn demand equation into several sectoral demand equations for corn. Not only does this approach give us more precise equations for corn demand, it also makes the estimated parameter for each variable more reliable and stable.

We have specified four different sectoral corn demand equations in our econometric model. One of these sectoral corn demand equations (demand for corn for producing ethanol) is

for implicit corn demand in the form of the ethanol supply equation and the other three sectoral corn demand equations are for explicit demand for corn for HFCS production, demand for corn for feed, and demand for corn for other uses. We have already discussed corn demand for ethanol (in the form of the ethanol supply equation) in previous sections (section 3.3.2). So we discuss the other three corn demand equations in this section.

3.3.2.1. Corn Demand for Feed

As seen in Chapter Two, corn demand for feed contributes to almost half (47 percent) of total utilized corn in 2007. Feed driven demand for corn is quite significant. Like other elements of corn demand, the feed demand for corn is a derived demand and is tied directly to meat demand. It is expected that meat prices have a positive impact on the demand for corn through the increase in meat production, thereby inducing a greater demand for feed. The number of cattle on feed is the other variable which has a positive impact on feedstock demand for corn. This is consistent with theory because greater numbers of cattle on feed mean that more corn is required to feed the cattle. Even though we don't expect that income and population have direct impacts on the feedstock demand for corn, they can still have indirect impacts through changing the demand for meat.

Equation (3.9) illustrates the suggested demand equation for demand for corn as a feed.

$$(3.9) \text{ Corn for Feed} = f(\text{domestic corn price, meat price, number of cattle on feed, GDP, population})$$

We can formulate this part of corn demand as Equation (3.10):

$$(3.10) \text{ CoFeed} = e_1 + e_2 * DCoP + e_3 * MeatP + e_4 * Cattl + e_5 * GDP + e_6 * Pop$$

Expected signs: $e_2 \leq 0$ and $e_3, e_4, e_5, e_6 \geq 0$

In this equation, CoFeed represents the quantity of corn demanded for feed. DCoP and MeatP represent domestic corn and meat prices, respectively. Cattl is used to represent the number of cattle on feed.

3.3.2.2. Corn Demand for HFCS Production

Based on Figure 2.23, around 4 percent of total U.S. corn utilized in 2007 was used to produce HFCS. HFCS and corn prices are expected to be the two factors which impact HFCS profit margins the most, and in turn HFCS production and the amount of corn demanded for producing HFCS. We expect that an increase in HFCS prices enlarges the corn demand for HFCS production, while an increase in corn prices decreases corn demand for HFCS production.

Ethanol price is another variable which impacts HFCS production, and therefore corn demand for the HFCS production. An Increase in ethanol prices can divert corn from HFCS production to ethanol production, and thus have a negative impact on corn demand for the HFCS production.

Increases in energy prices, especially natural gas prices, is another factor which has a negative influence on corn demand for HFCS because higher energy prices result in higher HFCS production costs, serving to reduce HFCS production. Interest rate as a proxy for capital cost and HFCS byproduct prices are other variables that impact HFCS production, and the demand of corn for producing HFCS. As Figure 3.4 shows, we must account for the fact that changes in the corn price decreases the quantity of corn demanded for HFCS from E_1 to E_2 , while changes in other variables shifts the demand curve from D_1 to D_2 . Considering all these variables, the corn demand for producing HFCS can be illustrated in Equation (3.11) as follows:

$$(3.11) \quad \text{Corn used in HFCS} = f(\text{domestic corn price, domestic HFCS price, ethanol price, natural gas price, interest rate, corn oil price, gluten feed price, gluten meal price})$$

Equation (3.11) is formulated in Equation (3.12) as follows:

$$(3.12) \quad HfCo = f_1 + f_2*DHfP + f_3*DCoP + f_4*EthP + f_5*NgP + f_6*GfP + f_7*GmP + f_8*CoOilP + f_9*Ir$$

Expected sign: $f_2, f_6, f_7, f_8 \geq 0$ and $f_3, f_4, f_5, f_9 \leq 0$

In this equation, HfCo and DHfP represent HFCS consumption and domestic price, respectively. GfP, Gmp, EthP, NgP, CoOilP, and DCoP are used to represent gluten feed, gluten meal, ethanol, natural gas, corn oil, and domestic corn prices, respectively. The interest rate is represented by Ir in this equation.

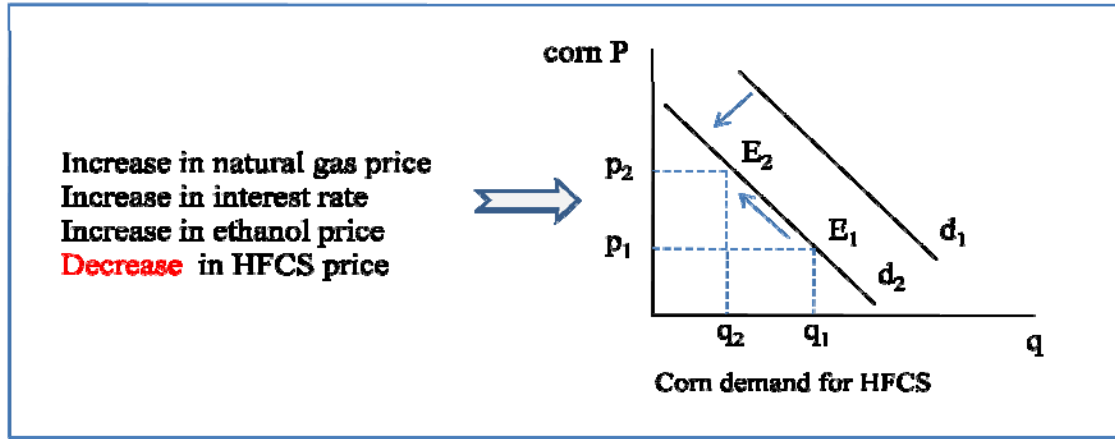


Figure 3.4. Factors which impact corn demand for HFCS production

3.3.2.3. Corn Other Consumption

In this model, the variable “corn other consumption” is defined as “the total U.S. domestic corn consumption minus the amount of corn used for feed and for ethanol and HFCS production.”

Based on this definition, most of the corn for other consumption is the corn used for producing foods for human consumption such as cereals and bakery goods. Thus, we expect that food prices, GDP, and population have positive impacts on this part of demand for corn. On the other hand, based on demand theory, we anticipate that increases in corn prices have negative impacts on corn demand for other types of consumption. Equations (3.13) and (3.14) demonstrate the suggested equation of the corn demand for other consumptions.

(3.13) *Corn Other Consumption* = $f(\text{domestic corn price, bakery price, GDP, population})$

(3.14) $CoOthCon = g_1 + g_2 * DCoP + g_3 * BakP + g_4 * GDP + g_5 * POP$

Expected signs: $g_2 \leq 0$ and $g_3, g_4, g_5 \geq 0$

In Equation (3.14), *CoOthCon* represents “other corn consumption” which is the quantity of corn used for other consumption beside feed, ethanol and HFCS. *DCoP*, *BakP*, *GDP*, and *POP* represent domestic corn prices, bakery good prices, gross domestic production, and population, respectively.

3.4. HFCS Supply and Demand

3.4.1. HFCS Supply

The United States is the largest HFCS producer in the world and exports a portion of its HFCS production to other countries (especially to its neighbors, Canada and Mexico). However, not many plants and producers are involved in producing ethanol in the United States. Based on the International Sweetener Colloquium report, 97 percent of total U.S. HFCS production capacity belongs to only 4 producers (Tucson, 2005). This means that the U.S. HFCS industry is extremely concentrated in the hands of a few producers. Therefore there is no justification for the argument of market competition among producers in the HFCS industry. In fact, the HFCS market has an oligopoly framework with few producers. As a result, in this market we do not have a supply function for industry and we can only have a reaction function (Evans and Davis, 1999). Consequently, Evans and Davis suggested Figure 3.5 as the market framework for the U.S. HFCS industry.

In a competitive market, the short-run marginal cost (SMC) curve is the short-run supply. However, in this figure we cannot take the HFCS SMC as a supply curve because of the oligopolistic framework of the HFCS market. P_T is the sugar controlled price which has always

been above HFCS prices. If the U.S. HFCS market was a competitive market, HFCS prices could then be determined by HFCS demand and HFCS supply at E . Nevertheless, since this market is an oligopoly market and there is no supply function in this market, the price is not determined at point E . Instead, in this market, HFCS users are price takers and thus subsequently HFCS prices are set by producers.

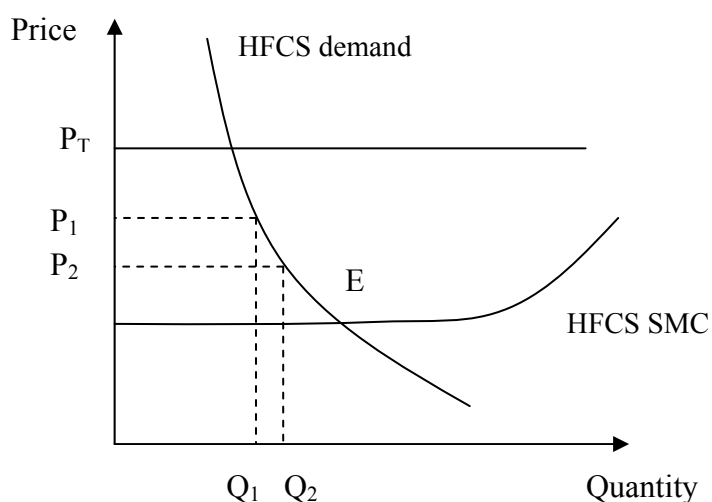


Figure 3.5. The U.S. HFCS market framework

Source: Dynamics of the United States High Fructose corn sweetener market, Evans and Davis, 2005.

In this market, HFCS producers work together as a group and maximize their profit based on their reaction function relative to sugar producers. As long as HFCS prices are lower than sugar prices, sweetener users consume HFCS instead of sugar. Thus, HFCS producers can obtain the economic rent of setting HFCS prices over their average cost of production. Therefore, HFCS supply does not exist and cannot be estimated (Evans and Davis, 1999).

3.4.2. HFCS Demand

HFCS demand is a derived demand. HFCS is used as an input in other industries. Therefore, increases in the production of commodities that use HFCS can increase the demand for HFCS.

For example, the beverage and soft drink markets can have enormous influence on HFCS demand, so we have to include their prices in the HFCS demand equation. Sugar (especially in liquid form) is an almost perfect substitute for HFCS, and because of this we have to also include sugar prices into the HFCS demand equation. Based on the law of demand, we expect increases in sugar prices to have a positive impact on the HFCS demand (Figure 3.6).

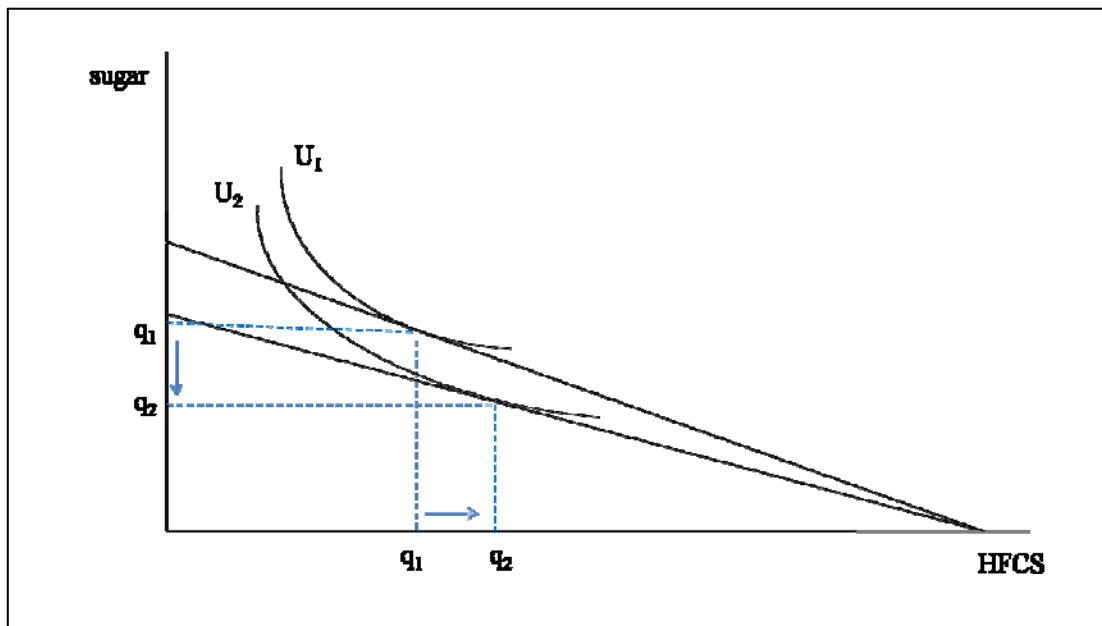


Figure 3.6. Impact of increased sugar price on HFCS consumption

Bakery goods are among the biggest users of HFCS so we include flour prices as a representative for the bakery industry in the HFCS demand equation as well. We expect that an increase in the prices for bakery products increases HFCS demand.

Sugar import barriers, such as sugar import quotas, decrease accessible sugar for sweetener users and force them to substitute sugar with other types of sweeteners, including HFCS. We expect these barriers to have a positive impact on HFCS consumption. Also, based on demand theory, we expect that GDP and population have positive impacts on the demand for HFCS. Derived from these arguments, HFCS demand can be expressed in the Equation (3.15) as:

$$(3.15) \text{ HFCS Demand} = f(\text{HFCS price, sugar price, beverage price, flour price, sugar import barriers, GDP, POP})$$

Equation (3.15) can be formulated in Equation (3.16) as follows:

$$(3.16) \text{ HfCon} = k_1 + k_2 * \text{DHfP} + k_3 * \text{DRaSuP} + k_4 * \text{BvP} + k_5 * \text{FlP} + k_6 * \text{Qp} + k_7 * \text{GDP} + k_8 * \text{POP}$$

$$\text{Expected signs: } k_2 \leq 0 \text{ and } k_3, k_4, k_5, k_6, k_7, k_8 \geq 0$$

In this equation, HfCon and DHfP represent quantity of demand and domestic price of HFCS, respectively. DRaSuP is used to represent domestic raw sugar price and BvP, FlP, and QP show beverage price index, flour price index, and sugar quota premium, respectively.

3.5. Sugar Supply and Demand

3.5.1. Sugar Supply

Sugar can be produced from sugarcane and/or sugar beets. Sugar produced from either sugarcane or sugar beets is identical and indistinguishable. Since the variables that influence sugarcane production are different from those that affect sugar beets production, it is necessary to specify two different sugar supply functions to account for these differences.

3.5.1.1. Sugarcane Supply

Sugarcane is a tropical crop that grows in a tropical to semi-tropical climate. Different factors impact sugarcane supply. Among these are: sugar price; the sugarcane loan rate; and production yields. The sugarcane loan rate is the minimum price that sugar growers can receive, in case sugar prices are low. Loan rates are expected to have a positive impact on sugarcane production because they reduce farmers' risk. Increases in sugar yields produce more sugarcane for a specific amount of inputs (especially land) thus increasing sugar production and supply. Yield is expected to have a positive impact on sugarcane supply. Because of its nature, sugarcane does

not have strong competition among other agricultural products, especially in the Louisiana. But we can consider rice as a proxy for agricultural products that may compete with sugarcane for acreage allocation and for other production resources as well. A high rice price, results in increased rice production, leaving less available agricultural land for sugarcane production. It is expected then, that high rice prices will have negative impact on sugarcane supply.

Weather is another factor that directly influences sugarcane supply. Again, as in the above specified models for sugar and sugarcane, a dummy variable for growing conditions, “weather condition”, is employed (with the variable equal to one (1) in those years that experienced bad weather, zero otherwise) in order to account for climatic conditions in the corn production process.

Technological improvements result in productivity gains, so it is expected that technological improvements are positively correlated with sugarcane production. The “technology” variable is introduced into the model to account for the effect technology gains have on sugarcane supply. A time trend is used as a proxy for technology. Given the above, we specify the sugarcane supply Equation (3.17) as:

$$(3.17) \text{ Sugarcane Supply} = f(\text{sugar price, sugarcane loan rate, sugarcane yield, rice price, technology, weather condition})$$

Based on what has been stated, in this equation we expect that all variables, with the exception of “rice price” and “weather condition”, have a positive impact on sugarcane supply. Therefore we formulate sugarcane supply in Equation (3.18).

$$(3.18) \text{ SuCaPr} = m_1 + m_2 * \text{SuCaP} + m_3 * \text{SuCaLR} + m_4 * \text{SuCaY} + m_5 * \text{RicP} + m_6 * T \\ + m_7 * \text{WeSuCa}$$

$$\text{Expected signs: } m_2, m_3, m_4, m_6 \geq 0 \quad \text{and} \quad m_5, m_7 \leq 0$$

SuCaPr, SuCaP, SuCaY , and SuCaLR are used to represent sugarcane production (supply), price, yield, and loan rate, respectively. RicP represents the rice price, and T and WeSuCa represent technology and weather condition, respectively.

3.5.1.2. Sugar Beets Supply

Factors that influence sugar beets supply are similar, except for other alternative crops (wheat and barley for sugar beets and rice for sugarcane), as the factors in the sugarcane supply equation. Therefore, a model similar to the above specified model for sugarcane supply is specified for sugar beets supply as:

$$(3.19) \text{ Sugar Beets Supply} = f(\text{sugar price, sugar beets loan rate, sugar beets yield, wheat price, barley price, technology, weather condition})$$

In this equation, wheat and barley are the proxies for agricultural commodities which compete with sugar beets for acreage allocations. Thus, any increases in these products' prices will tend to negatively impact sugar beets supply. The effects of other variables in this equation are the same as Equation (3.18). We formulate sugar beets supply in Equation (3.20) as follows:

$$(3.20) \text{ SuBePr} = n_1 + n_2 * \text{SuBeP} + n_3 * \text{SuBeLR} + n_4 * \text{SuBeY} + n_5 * \text{Whp} + n_6 * \text{BaP} + n_7 * T + n_8 * \text{WeSuBe}$$

$$\text{Expected signs: } n_2, n_3, n_4, n_7 \geq 0 \quad \text{and} \quad n_5, n_6, n_8 \leq 0$$

In this equation, SuBePr, SuBeP, SuBeY and SuBeLR are used to represent sugar beets supply, price, yield, and loan rate, respectively. WhP, BaP, WeSuCa, and T represent wheat price, barley price, weather condition, and technology, respectively.

3.5.2. Sugar Demand

Sugar is a product which can be used directly as a final good, like using sugar with coffee. Sugar can also be used as an input to produce other products such as ice cream and confectionary products. Therefore, sugar demand has two different components: derived demand and final

demand. Based on basic demand principles, own price, related goods prices, GDP and population are the factor that influence demand for a product. Given this, U.S. sugar demand is specified as Equation (3.21):

$$(3.21) \text{ Sugar Demand} = f(\text{domestic sugar price, world sugar price, quota premium, domestic HFCS price, glucose price, dextrose price, GDP, population})$$

In this equation, Sugar demand is the amount of sugar demanded by U.S. sugar consumers (and users). Domestic and world sugar prices are expected to have a negative impact on sugar demand so that any increase in these prices reduces the amount of sugar demanded. A tariff rate quota is another factor that has a negative impact on sugar demand because it increases domestic sugar prices. To show the impact of the tariff rate quota we use quota premium (QP) in the model.

HFCS, glucose, and dextrose are sugar substitutes, so any increase in the prices of these commodities will potentially increase sugar demand. Among these commodities, HFCS is the most important substitute for sugar in the United States. As Figure 3.7 shows, increases in the HFCS price decreases HFCS consumption from q_1 to q_2 while increases sugar consumption from q_1 to q_2 at the individual level. However at the industry level, increases in HFCS price shift the sugar demand to the right side and increases sugar demand (Figure 3.8). Based on the law of demand, any increase in gross domestic product (GDP) and/or population can have a potentially positive impact on sugar demand.

The USDA collects sugar delivery information based on different users for both industrial and non-industrial consumption. Industrial sugar users include of baked goods, cereals, confectionery and related products, ice cream and dairy products, beverages products, canned, bottled, and frozen foods, and all other food and nonfood products. Non-industrial sugar users include hotels, restaurants, institutions, wholesale grocers, sugar dealers, retail grocers and chain stores, and all other deliveries.

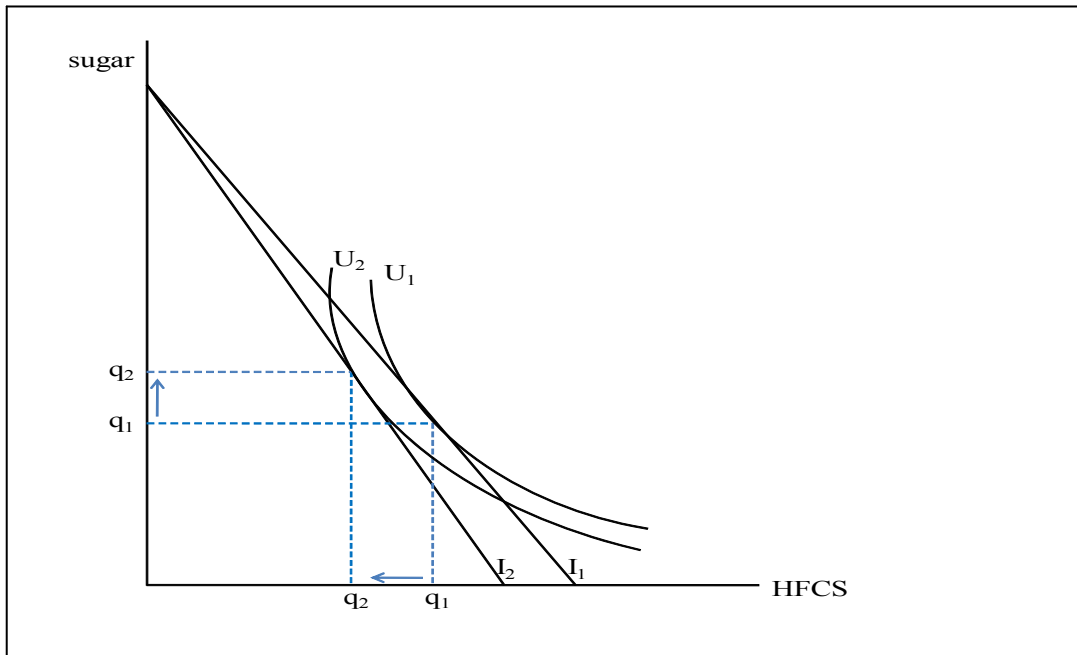


Figure 3.7. Impact of increases in HFCS price on sugar consumption

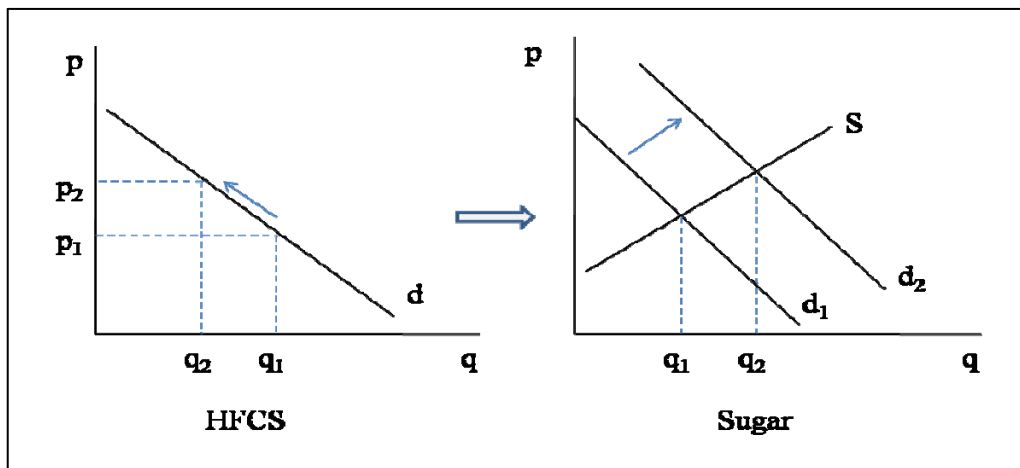


Figure 3.8. Impact of increases in HFCS price on sugar market demand

Sugar demand for industrial use is slightly different from sugar demand for non-industrial use. For instance, industrial sugar users can substitute sugar with HFCS while this kind of substitution is not common for hotels and restaurants. Therefore, the change in HFCS prices can influence industrial sugar demand more than for non-industrial sugar demand. This can be true for the impact of other variables on these two types of sugar demand as well.

In order to more precisely estimate sugar demand, we have estimated two sugar demand equations, one for industrial users and one for non-industrial users. Based on what has been said, each independent variable in the sugar demand equation can have a different impact on both industrial and non-industrial users. Therefore, even though the independent variables which are included in these two equations are structurally the same, the estimated parameters for each variable in the first equation are expected to be different than the corresponding parameters in the second equation.

Industrial and non-industrial sugar demands are formulated in two Equations (3.22) and (3.23) as follows:

$$(3.22) \quad SuInd = r_1 + r_2*DRfSuP + r_3*WSuP + r_4*QP + r_5*DHfP + r_6*GLP + r_7*DxP \\ + r_8*GDP + r_9*POP$$

Expected signs: $r_2, r_3, r_4 \leq 0$ and $r_5, r_6, r_7, r_8, r_9 \geq 0$

$$(3.23) \quad SuNoInd = s_1 + s_2*DRfSuP + s_3*WSuP + s_4*QP + s_5*DHfP + s_6*GLP + s_7*DxP \\ + s_8*GDP + s_9*POP$$

Expected signs: $s_2, s_3, s_4 \leq 0$ and $s_5, s_6, s_7, s_8, s_9 \geq 0$

In this equation, SuInd, SuNoInd, and QP indicate sugar industrial use, sugar non-industrial use, and quota premium, respectively. DRfSuP, WSuP, DHfP, GLP, DxP, BvP, and FIP are used for domestic sugar price, world sugar price, domestic HFCS price, glucose price, dextrose price, beverage price index, and flour price index, respectively.

3.6. Empirical Model

The previously specified equations can now be combined to form the entire empirical model framework. It is shown as follows:

Ethanol market equations:

- Ethanol supply equation:

$$(3.24) \quad EthPr = a_1 + a_2*EthP + a_3*DHfP + a_4*DCoP + a_5*NgP + a_6*GfP + a_7*GmP \\ + a_8*DdgP + a_9*CoOilP + a_{10}*Ir$$

- Ethanol demand equation:

$$(3.25) \quad EthCon = b_1 + b_2*Ethp + b_3*GasP + b_4*GDP + b_5*Pop + b_6*Car + b_7*GR$$

Corn market equations:

- Corn supply equation (quarterly model):

$$(3.26) \quad CoPr = c_1 + c_2*DCoPl + c_3*WCop + c_4*CoLR + c_5*CoY + c_6*FeP + c_7*FuP \\ + c_8*BaP + c_9*SoyP + c_{10}*CotP + c_{11}*RicP + c_{12}*WhP + c_{13}*WeCo + c_{14}*T$$

Corn supply equation (annual model):

$$(3.27) \quad CoSup = d_1 + d_2*DCoP + d_3*DCoPl + d_4*CoPr$$

- Demand for corn for feed:

$$(3.28) \quad CoFeed = e_1 + e_2*DCoP + e_3*MeatP + e_4*Cattl + e_5*GDP + e_6*Pop$$

- Demand for corn for HFCS production:

$$(3.29) \quad HfCo = f_1 + f_2*DHfP + f_3*DCoP + f_4*EthP + f_5*NgP + f_6*GfP + f_7*GmP \\ + f_8*CoOilP + f_9*Ir$$

- Demand for corn for other consumption:

$$(3.30) \quad CoOthCon = g_1 + g_2*DCoP + g_3*BakP + g_4*GDP + g_5*POP$$

HFCS demand equation:

- HFCS demand equation:

$$(3.31) \quad HfCon = k_1 + k_2*DHfP + k_3*DRaSuP + k_4*BvP + k_5*FlP + k_6*Qp + k_7*GDP \\ + k_8*POP$$

Sugar market equations:

- Sugarcane supply equation:

$$(3.32) \quad SuCaPr = m_1 + m_2*SuCaP + m_3*SuCaLR + m_4*SuCaY + m_5*RicP + m_6*T \\ + m_7*WeSuCa$$

- Sugar beets supply equation:

$$(3.33) \quad SuBePr = n_1 + n_2*SuBep + n_3*SuBeLR + n_4*SuBeY + n_5*Whp + n_6*BaP + n_7*T \\ + n_8*WeSuBe$$

- Industrial demand for sugar:

$$(3.34) \quad SuInd = r_1 + r_2*DRfSuP + r_3*WSuP + r_4*QP + r_5*DHfP + r_6*GlP + r_7*DxP \\ + r_8*GDP + r_9*POP$$

- Non-Industrial demand for sugar:

$$(3.35) \quad SuNoInd = s_1 + s_2*DRfSuP + s_3*WSuP + s_4*QP + s_5*DHfP + s_6*GlP + s_7*DxP \\ + s_8*GDP + s_9*POP$$

To close the model three price equations are added for the corn market, HFCS market, and sugar market along with four identity equations, one for each market. Price equations are as follows:

Price equation for HFCS market:

$$(3.36) \quad DHfP = u_1 + u_2*HfPr + u_3*HfCon + u_4*SuP + u_5*DCoP + u_6*NgP$$

Price equation for corn market:

$$(3.37) \quad DCoP = v_1 + v_2*CoPr + v_3*EthPr + v_4*HfPr + v_5*CoFeed + v_6*CoOthCon \\ + v_7*CoEx + v_8*FuP + v_9*FrP$$

Price equation for corn market:

$$(3.38) \quad SuP = w_1 + w_2*SuBePr + w_3*SuCaPr + w_4*SuIm + w_5*SuInd + w_6*SuNoInd \\ + w_7*WSuP + w_8*QP + w_9*SuWe$$

Equations (3.39) to (3.42) are identities which close and clear the markets.

Equation to close the ethanol market:

$$(3.39) \quad EthCon = EthPr + NetEthIm + EtnStCh$$

Equation to close the corn market:

$$(3.40) \quad CoFood + CoOthCo + CoHf + 2.7*EthPr = CoPr + NetCoIm + CoStCh$$

Equation to close the HFCS market:

$$(3.41) \quad HfCon = HfPr + NetHfIm + HfStCh$$

Equation to close the sugar market:

$$(3.42) \quad SuInd + SuNoInd = SuCaPr + SuBePr + NetSuIm + SuStCh$$

In these equations, NetSuIm, NetCoIm, NetHfIm, and NetEthIm, are used for net sugar imports (U.S. sugar imports minus U.S. sugar exports), net corn imports, net HFCS imports, and net ethanol imports, respectively. Also, SuStCh, CoStCh, HfStCh, and EtnStCh show net stock changes (ending stock minus beginning stocks) for sugar, corn, HFCS, and ethanol, respectively.

Therefore, in each annual and quarterly model, there are 18 equations composed of 14 behavioral equations and 4 identities. After estimating these equations using a “simultaneous equation estimation approach,” the U.S. supply and demand equations for sugar, corn, HFCS, and ethanol can be derived. From these, the U.S. government policy impacts on the U.S. ethanol and sugar markets can be analyzed. Definition of all variables used in the models is shown in Appendix C.

CHAPTER IV

EMPIRICAL RESULTS

4.1. Introduction

In this chapter, the results of the econometric models are first analyzed. These results are then used to answer the research questions. In this study, we analyze two different models: an annual data model and a quarterly data model. The reason for using two different models is that corn is a commodity that plays a critical role in the analysis and if only quarterly data is used a corn production function cannot be specified. Without a corn production function, we cannot estimate the effect that an increase in corn prices, resulting from increases in ethanol production, would have on ethanol production with any type of statistical precision. On the other hand, using a small number of observations (33 years) for a model with 14 equations may decrease the reliability of the results. Therefore, by using both models gives a greater level of confidence in the results.

4.2. Estimation Approach

The Ordinary Least Squares (OLS) estimator is consider being the blue optimal estimator when the classical linear regression model (CLR model) assumptions are met. One of the critical and basic assumptions of the CLR model is that, in a repeated sampling, the observations on the independent variable can be considered fixed. This assumption is violated when we have simultaneous equations. In this case, the CLR model assumption is violated and, thus, the OLS estimator is biased and cannot be considered a blue optimal estimator. Therefore, an alternative estimator, such as the Two or Three Stages Least Squares (2SLS or 3SLS) estimators, must be used instead of OLS. Since we have simultaneous equations in this study we cannot use the OLS estimator. Thus we have to use 2SLS or 3SLS approaches to estimates the model. A significant

difference between 2SLS and 3SLS estimators is that the 2SLS estimator does not take into account the correlation between different equations in estimation calculations. In order to consider the correlation between the equations, the 3SLS approach was used.

4.3. Data

Sixty-seven (67) data variables for the quarterly model from the first quarter of 1980 to the last quarter of 2007 were collected. Information prior to 1980 was not used because quarterly information for some of the variables before that year was not available. Although data were gathered for the years from 1980 to 2007, only data from years 1982 to 2007 were used because some of the quarterly data were missing. Seventy five (75) data variables were also collected for the annual model from years 1975 to 2007. The sources for data are as follows:

United States Department of Agriculture (USDA):

- | | |
|---------------------------------------|--------------------------|
| - barley price | - glucose price |
| - corn loan rate | - gluten meal price |
| - corn oil price | - HFCS consumption |
| - corn production | - HFCS production |
| - cotton price | - HFCS export |
| - corn yield | - HFCS import |
| - domestic corn price | - rice price |
| - world corn price | - soybeans price |
| - dried distillers grains (DDG) price | - sugarcane loan rate |
| - domestic HFCS price | - sugar beets loan rate |
| - domestic refined sugar price | - sugar beets production |
| - dextrose price | - sugarcane yield |
| - gluten feed price | - sugar beets yield |

- sugarcane production
- total sugar consumption
- total domestic corn utilization
- total corn utilization
- weather condition
- world HFCS price
- wheat price
- world raw sugar price
- world refined sugar price
- number of cattle on feed
- CCC owned corn stock
- Corn area harvested
- corn beginning stock
- corn ending stock
- imported corn
- exported corn
- corn used for ethanol production
- corn used for HFCS production
- corn used as feed
- domestic raw sugar price
- domestic refined retail sugar price
- fertilizer price, fertilizer price index
- meat price
- oat price
- soybeans meal price
- sorghum price
- sugar beginning stock
- sugar ending stock
- sugar export
- sugar import
- sugar beets area harvested
- sugarcane area harvested
- sugar industrial use
- sugar nonindustrial use
- sugar used in beverages production

Energy Information Administration (EIA):

- crude oil price
- annual gasoline price
- natural gas price
- quarterly ethanol production
- quarterly ethanol consumption
- quarterly ethanol imports

Economic Time Series Page:

- Beverage Price Index
- Flour Price Index
- bakery price index

Nebraska Ethanol Board:

- Ethanol price
- quarterly gasoline price

Federal Highway Administration (FHWA):

- Number of cars

International Financial Statistics (IFS):

- Gross Domestic Product
- Interest Rate
- Population
- world (Caribbean) sugar price

Renewable Fuels Association (RFA):

- Annual ethanol production
- annual ethanol import
- annual ethanol consumption

4.4. Results

As stated previously, in this analysis two models are employed. One model was based on annual data with the other model being based on quarterly data. There are four markets: the ethanol, the HFCS, the sugar, and the corn markets. Each of these markets has a different number of equations: two (supply and demand) for the ethanol market, two (demand and price equation) for the HFCS market, five (sugarcane and sugar beet supply, nonindustrial and industrial demand for sugar, and price equation) for the sugar market, and five (corn production or supply, corn used for HFCS, corn demand for feed, corn demand for other utilizations, and price equation) for the corn market. Altogether, there are a total of 14 equations. The main difference between these two models is that the annual data model has a corn production equation, while the quarterly data

model has a corn supply equation instead of a corn production equation. The main focus is on the quarterly data model; the annual data model is simply a supportive model, especially when using the estimated results of the corn production equation in our analysis.

Each model has 14 equations and there is also one identity for each market that equates demand to supply for that particular market. Thus we have 14 equations and 4 identities in each model. The quarterly data model has 104 observations – from the first quarter of 1982 to the last quarter of 2007 – and the annual data model has 33 observations – from 1978 to 2007. System Weighted R-square for the quarterly and annual models are 0.943 and 0.994, respectively.

4.4.1. Ethanol Market Equations

There are two equations for the ethanol market in each model. The first equation is a log-log form ethanol supply and the second equation is for ethanol inverse demand. Estimated equations for ethanol production (or ethanol supply) and ethanol demand are shown in Table 4.1.

As expected, based on estimated results, ethanol prices have a positive effect on ethanol production while corn prices have a negative effect on ethanol production. As Figure 4.1 illustrates, increases in corn price, resulting from increases in corn demand or decreases in corn supply, increases the ethanol production cost and reduces ethanol supply.

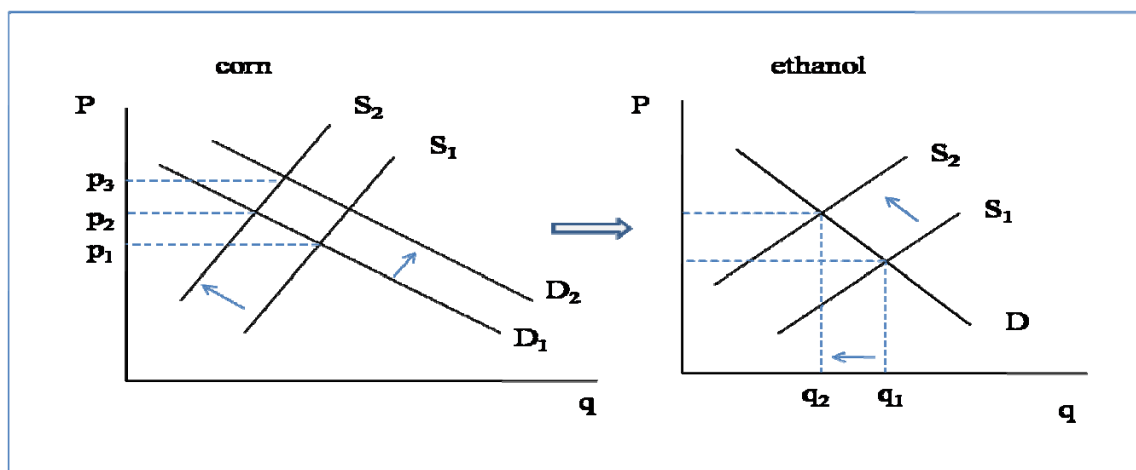


Figure 4.1. Impact of increases in corn price on ethanol supply

Note that the ethanol production equation is actually a derived demand for corn to produce ethanol. Since each bushel of corn produces approximately 2.75 gallons of ethanol, in dry mill plants, the ethanol production equation represents the amount of corn demanded for producing ethanol divided by 2.75. Thus, the ethanol production equation can be written in the form of a demand equation for corn to produce ethanol as:

$$\text{Corn demanded for ethanol}/2.75 = f(\text{corn price, ethanol price } \dots)$$

The estimated parameter for the corn price in this equation has a negative sign which shows the demand equation for corn to be used in ethanol production.

Based on the estimate derived from the quarterly model, price elasticity of ethanol supply is very small (0.10), which indicates ethanol supply is price inelastic. Even though the annual model shows a larger price elasticity of ethanol supply (0.53), the ethanol supply is inelastic in this model as well. One reason for this difference is that the ethanol industry has little unused capacity. Therefore, producers need time to establish capacity for producing more ethanol in response to price changes. Thus, the annual response to the change in price is larger than the quarterly response.

The estimation results for the inverse ethanol demand in both models show that gasoline prices have significant impacts on ethanol consumption. The estimation results show a positive sign for the gasoline price parameter. That means that ethanol consumers (mostly oil refineries) have used gasoline as a substitute product for ethanol (Figure 4.2). For instance, based on Federal Government requirement, refineries had to blend 4.7 billion gallons of ethanol with gasoline in 2007. This could be illustrated as point E_2 in Figure 4.2. But, because of increases in the gasoline price, they blended 6.48 billion gallons of ethanol with gasoline and instead of being at point E_2 they shifted to point E_3 . The difference between q_3 and q_2 is the amount of ethanol consumed resulting from the substitution of gasoline with ethanol resulting from high gasoline

Table 4.1. Ethanol supply and demand equations

Dependent variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
lethpr		Log ethanol production		
	Intercept	Intercept	0.647 (3.39)***	- 0.237 (2.93)***
	LEthP	Log ethanol price	0.102 (2.76)***	0.526 (4.68)***
	LDcoP	Log domestic corn price	- 0.085 (2.02)**	—
	Llr	Log interest rate	- 0.073 (2.03)**	- 0.350 (3.71)***
	LEthPr1	Log ethanol production with 1 lag	0.925 (43.33)***	0.173 (7.07)***
	T	Technology (time variable)	—	0.070 (9.53)***
	Du1	Dummy variable ($q_1 = 1$)	0.035 (1.64)*	—
	Du4	Dummy variable ($q_4 = 1$)	0.042 (1.89)*	—
	ddd	Dummy variable (1975 to 1979 = 0)		5.26 (15.44)***
DW			2.03	1.37
Ethp		Ethanol price		
	Intercept	Intercept	0.416 (6.38)***	- 3.253 (4.83)***
	EthCon	Ethanol consumption	- 0.0006 (7.26)***	- 0.0005 (4.35)***
	GasP	Gasoline price	0.766 (9.69)***	0.018 (5.86)***
	Mand	Dummy variable for mandatory ethanol use	0.318 (3.31)***	
	T	Time trend		0.097 (4.26)***
	EthP1	Ethanol price with 1 lag	0.572 (6.93)***	0.614 (6.61)***
	EthP2	Ethanol price with 2 lags	- 0.132 (1.84)*	
DW			1.88	2.46

- Parentheses show t-statistic values

- *** 1% significance; ** 5% significance; * 10% significance level.

prices. In fact, the increase in the ethanol demand and the use of more ethanol than the amount required by the Federal Government, shows that oil refineries have blended ethanol with gasoline at a level greater than that required by the Federal Government in order to get an advantage of the difference between gasoline and ethanol prices along with other federal and states' governmental subsidies. As Own price elasticity of demand for ethanol is 6.72 for the quarterly model and 2.67 for the annual model. The elasticity of demand for ethanol relative to the gasoline price is 3.03 for the quarterly model and 3.88 for the annual model, both of which are large and significant.

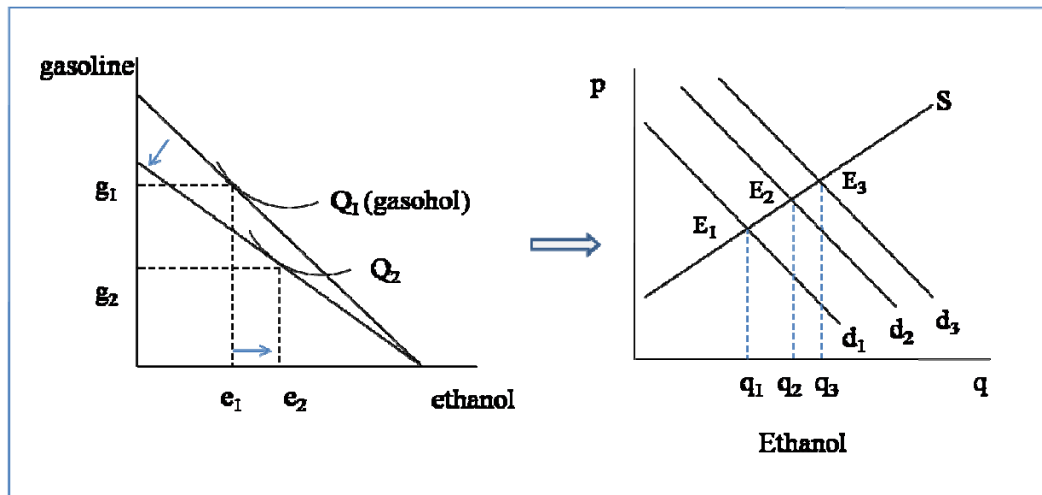


Figure 4.2. Impact of increases in gasoline price on ethanol demand

4.4.2. HFCS Market Equations

Two equations for the HFCS market were estimated, including a demand equation and a price equation. Another equation that shows corn demand for HFCS production (which is a type of HFCS supply equation) was estimated and will be subsequently discussed in the corn market section. As seen in the literature review and the theoretical model sections, the reason there is no specific equation for HFCS supply is that the HFCS industry is an oligopoly market that only contains four main producers. Since the oligopoly market does not have a supply equation, we

cannot have a supply equation for HFCS in our model. In this study there was an examination made to determine if any relationship between HFCS production and its prices could be found. However, both the annual and quarterly data showed that there was no reasonable relationship between HFCS production and prices, which supports the hypothesis that the U.S. HFCS market is an oligopoly.

The estimation results for the HFCS demand and price equation are shown in Table 4.2. As seen in this table, the quarterly data model shows that, as expected, domestic HFCS prices have a negative effect and the flour price index has a positive effect on per capita HFCS utilization. In fact, because HFCS is used as an input and its demand is a derived demand, an increase in the flour price index (as representative of an increase in the price of food products that use HFCS as an input) increases the demand for HFCS. This model does not show any relationship between the demand for HFCS and sugar prices. The estimated parameter for the HFCS price is - 0.14 indicating that if HFCS prices increased by 1.0 cent, HFCS per capita consumption would then decrease by 0.00014 short tons or 0.28 pounds. Own price elasticity of HFCS demand is 0.48. These results show that HFCS demand is price inelastic in our data range.

On the other hand, the annual data model shows that the demand for HFCS is dependent upon sugar prices (domestic refined sugar price) and the sugar quota premium so that the increase in sugar prices and quota premium increases the demand for HFCS. That means that sugar is a substitute product for HFCS in the United States. But this model does not show a statistically significant impact of HFCS prices on the HFCS quantity demanded. In this model, the estimated parameter for domestic HFCS prices has a negative sign but is not significant ($P_value = 0.81$). As Figures 2.32 and 2.33 show, since 2001, total and per capita consumption of both sugar and HFCS have been very stable. This analysis used a dummy variable dd , which

Table 4.2. HFCS demand and HFCS price equations

Dependent Variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
HfConP		Per capita HFCS Consumption		
	Intercept	Intercept	7.72 (7.66)***	- 0.989 (1.11)
	DHfP	Domestic HFCS Price	- 0.136 (6.48)***	
	FIP	Flour Price Index	0.013 (3.02)***	
	Du1	Dummy variable ($q_1 = 1$)	- 0.568 (3.56)***	
	Du2	Dummy variable ($q_2 = 1$)	0.590 (3.63)***	
	DRfSuP	Domestic Refined Sugar Price	—	0.037 (2.70)***
	QP	Quota Premium	—	0.056 (5.04)***
	dd	Dummy Variable (=1 after 2000)	—	- 1.70 (4.79)***
	T	Time	—	0.100 (2.31)**
	HfConP1	HFCS Consumption with 1 lag		0.927 (27.23)***
DW			1.53	1.55
DHfP		Domestic HFCS price		
	Intercept	Intercept	- 14.09 (2.24)**	- 3.85 (2.24)**
	DRaSuP	Domestic Raw Sugar Price	0.415 (2.43)**	0.554 (6.59)***
	DCoP	Domestic Corn Price	0.546 (1.81)*	1.14 (2.07)**
	DHfp1	Domestic HFCS price with 1 lag	0.819 (17.78)***	0.278 (5.49)***
	T	Time trend	0.072 (2.13)**	—
	Du2	Dummy variable ($q_2 = 1$)	1.24 (2.11)**	—
	Du3	Dummy variable ($q_3 = 1$)	2.51 (4.62)***	—
DW			2.09	1.52

- Parentheses show t-statistic values

- *** 1% significance; ** 5% significance; * 10% significance level.

is equal to zero for the period between 1975 and 2000 and one from 2001 and thereafter, to show this stability. Based on the annual data model, the dummy variable dd has a negative sign. That means that the reduction in the possibility of substituting for sugar with HFCS in industrial uses has had a negative impact on HFCS demand.

Both the quarterly and annual data models show that corn and sugar prices play a role in determining the domestic HFCS prices. So the increase in sugar prices and/or domestic corn prices increases the domestic HFCS price. This again confirms the idea that the HFCS industry has an oligopolistic structure in which price is determined by producers based on sugar prices.

4.4.3. Sugar Market Equations

As stated before, there are 5 equations for the sugar market. Two equations show sugarcane and sugar beets supply. U.S. sugar demand is also broken into two main parts: demand for sugar for industrial use and demand for sugar for nonindustrial use. This deviation of demand makes the estimated equations more accurate. The last equation for the sugar market is the sugar price equation. The results of estimation for both the quarterly and annual data Sugar market equations are shown in Tables 4.3 to 4.5.

4.4.3.1. Sugarcane Supply Equation

As shown in Table 4.3, the domestic refined sugar price has a positive impact on sugarcane production. A log-log model form was utilized for this equation so that the estimated parameter for the sugar price shows the own price elasticity. Based on the quarterly and annual data models, the own price elasticities of sugarcane supply are 0.65 and 0.18, respectively. That shows, based on our data, that the sugarcane supply is price inelastic. It is also important to note that in the quarterly model domestic raw sugar prices are used, as opposed to domestic retail refined sugar prices in the annual model. Results of both models show that increase in rice price has a negative impact on sugarcane supply.

Table 4.3. Sugarcane and sugar beets supply equations

Dependent Variable	Independent Variable	Variable name	Quarterly model estimation	Annual model estimation
ISuCaPr DW		Log sugarcane production		
	Intercept	Intercept	1.15 (0.89)	3.41 (3.20)***
	IDRfSuP4	Log refined sugar price with 4 lags	0.477 (3.25)***	
	ISuCaY	Log sugarcane yield	1.50 (3.65)***	
	IRicP4	Log Rice price with 4 lags	- 0.258 (3.43)***	
	du1	Dummy variable ($q_1 = 1$)	- 0.567 (7.74)***	
	du2	Dummy variable ($q_2 = 1$)	- 2.14 (27.14)***	
	du3	Dummy variable ($q_3 = 1$)	- 2.22 (29.94)***	
	IDRtRfSuP1	Log retail refined sugar price with 1 lag		0.174 (1.88)*
	IRicP1	Log Rice price with 1 lag		- 0.165 (4.24)***
	WeSuCa	Weather condition		- 0.050 (2.72)***
	ISuCaPr1	Log sugarcane production with 1 lag		0.545 (4.77)***
			1.82	1.75
ISuBePr		Log sugar beets production		
	Intercept	Intercept	- 4.66 (1.14)	5.22 (5.34)***
	IDRfSuP4	Log refined sugar price with 4 lags	0.435 (2.78)***	
	ISuBeLR	Log sugar beets loan rate	2.74 (2.57)***	
	lWhP4	Log wheat price with 4 lags	- 0.347 (3.64)***	
	du1	Dummy variable ($q_1 = 1$)	- 0.818 (5.84)***	
	du2	Dummy variable ($q_2 = 1$)	- 1.53 (16.25)***	
	du3	Dummy variable ($q_3 = 1$)	- 1.63 (34.75)***	

Table 4.3. Continued

Dependent variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
DW	T	Time (Technology)	0.023 (3.15)***	0.014 (3.59)***
	IDRaSuP1	Log raw sugar price with 1 lags		0.187 (2.17)**
	IFeP	Log fertilizer price		- 0.157 (1.92)*
	ISuBePr1	Log sugar beets production with 1 lag	0.150 (1.73)*	0.369 (3.41)***
			1.95	2.12

- Parentheses show t-statistic values

- *** 1% significance; ** 5% significance; * 10% significance level.

4.4.3.2. Sugar Beets Supply Equation

The sugar beets supply equation is estimated by using a log-log model. Both quarterly and annual models show that domestic sugar prices have a positive effect on sugar beets supply.

Quarterly and annual model's own price elasticity for sugar beets supply is 0.58 and 0.18, respectively. These values are similar to the own price elasticity for the sugarcane supply. Again, based on the data, the sugar beets supply is inelastic. As the quarterly model shows, wheat competes with sugar beets. Therefore, an increase in wheat prices decreases sugar beets supply. The quarterly model also shows that the sugar beets loan rate has a positive effect on the sugar beets supply (Table 4.3).

4.4.3.3. Demand for Sugar for Nonindustrial Use

Nonindustrial sugar users are composed of consumers such as hotels, restaurants, and individual users. Both the quarterly and annual models show that domestic refined sugar prices have a negative impact on the amount of sugar demanded by nonindustrial sugar consumers (Table 4.4). None of these models show a relationship between HFCS prices and nonindustrial uses of sugar.

While the quarterly model shows that per capita GDP has a significance influence on the sugar demand for nonindustrial use, the annual model shows that this part of sugar demand is affected by consumer habits (the amount of sugar consumed in the previous period). The own price elasticity of nonindustrial demand for sugar is equal to 0.12 based on the quarterly data and 0.03 based on the annual data. This shows the nonindustrial demand for sugar to be price inelastic.

4.4.3.4. Demand for Sugar for Industrial Use

Industrial sugar users are composed of cereal, confectionery products, ice cream, beverages, canned bottled, and frozen food producers and bakeries. In previous section, the data did not show the effect of HFCS prices on nonindustrial sugar demand. But results for industrial demand show that HFCS has a significant effect on sugar consumption. Thus, an increase in HFCS price, resulting from increases in corn price or other input costs, increases the demand for sugar for industrial use (Figure 4.3).

This implies that, based on our results, HFCS is not a substitute for sugar for nonindustrial users while it is a substitute for sugar in food industries. The annual model shows that domestic raw sugar prices have a negative impact on the amount of sugar demanded for

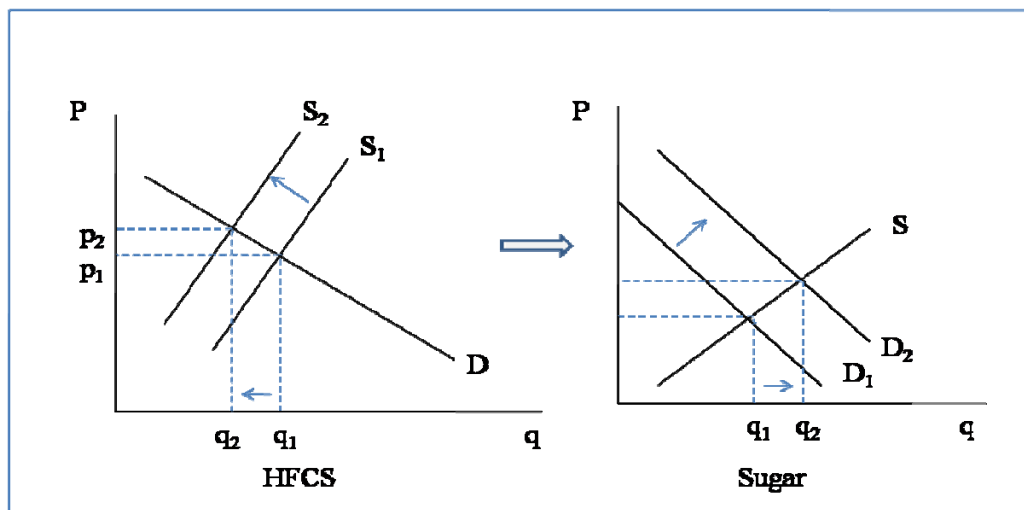


Figure 4.3. Impact of increases in HFC'S price on sugar industrial demand

Table 4.4. Nonindustrial and industrial sugar demand equations

Dependent variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
SuNoInd		Sugar nonindustrial use		
	Intercept	Intercept	605.18 (5.17)***	784.20 (2.78)***
	DRfSuP	Domestic refined sugar price	- 3.24 (2.20)**	- 4.00 (2.24)**
	GDPP	Per capita GDP	13.45 (5.42)***	
	Du1	Dummy variable ($q_1 = 1$)	- 112.98 (7.89)***	
	Du4	Dummy variable ($q_4 = 1$)	52.67 (3.78)***	
	SuNoInd1	Sugar nonindustrial use with 1 lag		0.825 (12.12)***
DW			1.98	1.85
SuInd		Sugar nonindustrial use		
	Intercept	Intercept	4.99 (0.05)	- 1459.54 (2.21)**
	DHfP	Domestic HFCS price	3.54 (1.84)*	24.19 (2.51)**
	GDP	GDP	0.027 (2.93)***	0.623 (4.02)***
	dd	Dummy variable (=1 after 2000)	- 38.99 (1.93)*	-547.28 (3.82)***
	SuInd1	Sugar nonindustrial use with 1 lag	0.789 (15.04)***	0.856 (13.26)***
	Du2	Dummy variable ($q_2 = 1$)	24.43 (2.10)**	
	Du4	Dummy variable ($q_4 = 1$)	- 132.86 (10.56)***	
	DRaSuP	Domestic raw sugar price		- 29.18 (3.37)***
	T	Time		- 122.00 (3.59)***
DW			2.31	1.85

- Parentheses show t-statistic values

- *** 1% significance; ** 5% significance; * 10% significance level.

industrial use, but the quarterly model does not show such a relationship in the estimated equation (Table 4.4). Based on the quarterly data, industrial sugar demand is a function of HFCS prices instead of sugar prices. Both models show that GDP and previous period consumption have a positive effect on industrial sugar demand.

Dummy variable dd , which is equal to zero for the period between 1975 and 2000 and one from 2001 and thereafter, was not statistically significant in the estimated demand equation for nonindustrial use of sugar, but it has a negative sign in the demand equation for industrial use of sugar. This means that substitution of sugar with HFCS had reached its limit in year 2000.

4.4.3.5. Sugar Price Equation

The last equation estimated for the sugar market is the sugar price equation. In this equation, domestic refined sugar prices are used as a dependent variable. Both the quarterly and annual models show that world sugar prices (Caribbean sugar prices) and quota premium have the most influence on the domestic sugar prices (Table 4.5).

Increases in world sugar prices also increase domestic sugar prices. The Quota premium has a positive effect on domestic sugar prices. While the annual model shows that total sugar production has a negative effect on the domestic price, the quarterly model shows that only sugar beets production puts downward pressure on domestic sugar prices.

4.4.4. Corn Market Equations

The corn market plays an important role in the analysis and discussion because the corn market is a bridge that transfers the effects of government policies from one market (e.g., the ethanol market) to other markets such as the HFCS and sugar markets. Therefore the analysis has been very sensitive to this market's equations estimation. This market has six equations including: demand for corn for producing ethanol, demand for corn for producing HFCS, demand for corn for feed, other demand for corn, corn supply (in quarterly model) , corn production (in annual

model), and corn price equation. The corn price equation is critical because it is used to discuss and answer several research questions. To estimate the corn market equations more accurately, domestic demand for corn has been broken into four parts (corn for ethanol, HFCS, feed, and other uses). The demand for corn for ethanol production was already introduced and analyzed in the ethanol market section. The remainders of the corn demand equations are discussed in this section. Tables 4.6 to 4.10 shows estimation results of corn market equations for both the quarterly and annual models.

Table 4.5. Estimation results for sugar market price equation

Dependent variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
DRfSuP		Domestic refined sugar price		
	Intercept	Intercept	- 7.00 (1.81)*	20.15 (3.68)***
	WSuP	World sugar price	0.665 (5.53)***	1.18 (20.28)***
	QP	Quota premium	0.539 (4.60)***	0.812 (8.94)***
	SuPr	Total sugar production		- 0.002 (3.49)***
	SuBePr	Sugar beets production	- 0.004 (4.19)***	
	DRfSuP1	Refined sugar price with 1 lag	0.661 (13.21)***	
	T	Time trend	0.066 (3.19)***	
	Du1	Dummy variable ($q_1 = 1$)	2.43 (3.22)***	
DW	Du4	Dummy variable ($q_4 = 1$)	6.36 (4.17)***	
			1.66	1.79

- Parentheses show t-statistic values

- *** 1% significance; ** 5% significance; * 10% significance level

4.4.4.1. Corn Demand for Feed

As can be seen in Table 4.6, there is a strong relationship between corn demanded for feed verses corn prices and the number of cattle on feed. Both the quarterly and annual models show that the increase in domestic corn prices reduces the amount of corn demanded for feed while increases in the number of cattle on feed increases the corn demand for feed. It is interesting to note that the own price elasticity of corn demand for feed in both models is equal to 0.18. This indicates that the demand for corn for feed is price inelastic.

4.4.4.2. Corn Demand for Producing HFCS

Based on the estimated results, both the quarterly and annual models show that corn prices have a negative effect on demand for corn for HFCS production (Table 4.7). This means that an

Table 4.6. Estimation results for corn demand for feed equation

Dependent variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
CoFeed		Corn used for feed		
	Intercept	Intercept	1471.59 (11.42)***	1505.68 (2.03)**
	DCoP	Domestic corn price	- 69.94 (4.20)***	- 226.46 (5.17)***
	Cattl	Number of cattle on feed	59.31 (5.64)***	0.213 (3.30)***
	Du1	Dummy variable ($q_1 = 1$)	- 416.55 (9.89)***	
	Du2	Dummy variable ($q_2 = 1$)	- 702.85 (16.96)***	
	Du3	Dummy variable ($q_3 = 1$)	- 946.39 (23.24)***	
	CoFeed1	Corn used for feed with 1 lag		0.321 (2.94)***
DW			1.80	2.22

- Parentheses show t-statistic values
- *** 1% significance; ** 5% significance; * 10% significance level.

increase in the domestic corn price decreases the amount of corn used for producing HFCS. The own price elasticity of demand for corn to produce HFCS is 0.82 and 0.24 for the quarterly and annual models, respectively.

The production capacity of HFCS plants is another variable that has a positive effect on corn demanded for producing HFCS. Since data was not available pertaining to the production capacity of HFCS plants for the entire period of study, the amount of HFCS produced in the previous quarter/year was used as a proxy for the production capacity for each quarter/year.

Table 4.7. Estimation results for corn demand for HFCS production

Dependent variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
Hfpr		HFCS Production (or corn demand for HFCS production)		
	Intercept	Intercept	640.95 (3.43)***	330.58 (1.31)
	DCoP	Domestic corn price	- 63.25 (2.20)**	- 59.23 (2.11)**
	HfPr1	HFCS Production with 1 lag	0.764 (12.47)***	0.832 (17.12)***
	DRaSuP	Domestic raw sugar price		9.42 (1.86)*
	DD	Dummy variable (=1 after 2000)		- 611.78 (6.23)***
	T	Time		60.07 (3.66)***
DW			1.86	1.67

- Parentheses show t-statistic values
- *** 1% significance; ** 5% significance; * 10% significance level.

4.4.4.3. Demand for Corn for Other Utilizations

The demand for corn for other utilizations is defined as follow:

$$\text{Demand for corn for other utilizations} = \text{Total domestic corn utilization} -$$

(corn used in ethanol + corn used for feed + corn used in HFCS)

A significant part of “demand for corn for other utilization” comes from demand for corn for human food production. Based on the quarterly and annual models, domestic corn prices and consumers’ habits (tastes) are important variables which affect this part of demand for corn, so that an increase in domestic corn prices reduces the amount of corn demanded (Table 4.8). The quarterly model also shows that the bakery price index has a positive impact on this component of corn demand, which means corn demanded for other utilization is a derived demand that comes from the demand for food. The own price elasticity of demand for this portion of corn demand is 0.06 for the quarterly model and 0.05 for the annual model, indicating an inelastic relationship.

Table 4.8. Estimation results for demand for corn for other utilization

Dependent variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
CoOthCon		Corn other consumption		
	Intercept	Intercept	63.03 (5.73)***	101.21 (2.67)***
	DCoP	Domestic corn price	- 3.41 (2.86)***	- 8.18 (2.42)**
	CoOthCon1	Corn other consumption with 1 lag	0.364 (4.99)***	0.912 (22.60)***
	BakP	Bakery prices index	0.356 (7.31)***	
	Du1	Dummy variable ($q_1 = 1$)	- 9.88 (4.49)***	
DW	Du2	Dummy variable ($q_2 = 1$)	24.17 (9.21)***	
			1.65	1.87

- Parentheses show t-statistic values

- *** 1% significance; ** 5% significance; * 10% significance level.

4.4.4.4. Corn Production and Supply Equations

As stated previously, estimation of the corn production equation is possible only for the annual model. Corn production cannot be estimated in the quarterly model because corn production data is only available for one quarter in each year (the first quarter of the corn market year) and the amount of production for other quarters (quarters 2, 3, and 4) is zero. Instead, a corn supply equation is estimated in the quarterly model to complete this model.

As the estimation results for corn production (Table 4.9) show, the domestic corn price in the previous year, corn yield, and technology are the only variables that have a statistically significant effect on corn production. Based on these results, a one dollar increase in per bushel of corn price increases the amount of corn production in the next year by as much as 459.33 million bushels.

The corn supply equation estimated for the quarterly model shows that only corn prices and corn production affect corn supply. Based on these results, an increase in domestic corn prices in each quarter increases the amount of corn supplied in the same quarter. Corn prices in each quarter have a negative impact on the amount of corn supplied in the next quarter because an increase in corn prices in one quarter increases the amount of corn supplied in that quarter and therefore reduces the accessible amount of corn for the following quarter. Corn production has a positive effect on the amount of corn supplied in each quarter because an increase in corn production provides more corn for the entire market year and, therefore, has a positive influence on multiple quarters of that market year.

4.4.4.5. Corn Price Equation

The corn price equation is one of the most important equations of the specified models. The corn price equation demonstrates how a change in ethanol supply, resulting from either governmental policies or an increase in oil prices or other sources, can impact corn prices. This impacts corn

Table 4.9. Estimation results for corn production and supply equations

Dependent variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
CoPr		Corn production		
	Intercept	Intercept		-5199.80 (8.68)***
	DCoP1	Domestic corn price with 1 lag		459.33 (7.08)***
	CoY	Corn yield		1426.84 (18.23)***
	T	Technology (Time)		64.14 (3.79)***
DW				2.05
CoSup		Corn supply		
	Intercept	Intercept	577.86 (5.54)***	
	DCoP	Domestic corn price	152.85 (5.63)***	
	CoPr	Corn production	0.126 (30.28)***	
	DCoP1	Domestic corn price with 1 lag	- 205.05 (7.37)***	
	CoSup1	Corn supply with 1 lag	0.602 (16.39)***	
DW			2.17	

- Parentheses show t-statistic values

- *** 1% significance; ** 5% significance; * 10% significance level.

production, ethanol production costs, and HFCS production costs and, therefore, affects the HFCS low price advantage over sugar, and so on.

As table 4.10 illustrates, both the quarterly and annual model estimation results show that ethanol production and corn exports have a positive effect on domestic corn prices while the effect of corn production on corn prices is negative. One important and very interesting point is

Table 4.10. Estimation results for domestic corn price equation

Dependent variable	Independent variable	Variable name	Quarterly model estimation	Annual model estimation
DCoP		Domestic Corn price		
	Intercept	Intercept	- 1.60 (4.34)***	3.48 (4.07)***
	Ethpr	Ethanol production	0.00043 (2.04)**	0.00051 (4.47)***
	CoEx	Corn export	0.0012 (4.26)***	0.0011 (4.06)***
	CoHf	Corn used in HFCS production	0.007 (2.52)***	
	CoFeed	Corn used for feed	0.00098 (6.64)***	
	WeCo	Weather condition	0.26 (3.15)***	
	CoPr	Corn production	- 0.00008 (6.00)***	- 0.00037 (5.33)***
	T	Technology (Time)	- 0.014 (3.07)***	- 0.072 (2.38)**
DW	DCoP1	Domestic corn price with 1 lag	0.944 (20.71)***	0.497 (4.96)***
			1.91	1.85

- Parentheses show t-statistic values

- *** 1% significance; ** 5% significance; * 10% significance level.

that the effect of ethanol production on domestic corn prices is almost the same for both the quarterly and annual models. Based on the results of the quarterly and annual models, each 1 billion gallons additional ethanol production increases domestic corn prices as much as 43 cents and 51 cents, respectively.

The estimated results show that every 1 billion bushel increase in corn production reduces domestic corn prices by as much as 37 cents per bushel based on the annual model and by as much as 8 cents per bushel for the quarterly model. Based on the quarterly model estimation results, in addition to ethanol production and corn exports, adverse weather conditions

and the amount of corn demanded for feed and for producing HFCS, have had positive effects on domestic corn prices.

4.5. Research Questions Discussion

In this section the results of the estimated econometrics models along with the information collected in the literature review section are used to answer the research questions. To reiterate, the research questions were:

- What will be the effect of the 2007 Energy Act required levels of ethanol production (10.5, 13.2, and 15 billion gallons) on the U.S. corn, HFCS, and sugar markets?
- What is the maximum amount of ethanol that can be produced from corn?
- In what scenario would sugar-based ethanol production be profitable in the United States? Furthermore, what policies would make sugar a profitable feedstock for producing ethanol in the United States?
- What are the impacts of an ethanol subsidy, import tariffs, and sugar import quotas on the U.S. ethanol, corn, HFCS, and sugar markets?
- What would the effect be of eliminating sugar import quotas on the U.S. sugar, HFCS, corn, and ethanol markets?

We now summarily discuss each question one by one.

4.5.1. First Question

What will be the effect of the 2007 Energy Act required levels of ethanol production (10.5, 13.2, and 15 billion gallons) on the U.S. corn, HFCS, and sugar markets?

In order to answer this question, the estimated model results for “domestic corn price equation (DCoP)” from the quarterly model and “corn production equation (CoPr)” from the annual model will be used. As shown in Tables 4.9 and 4.10, the estimated equations for corn production (CoPr) and domestic corn prices (DCoP) are as follows:

$$(4.1) \quad DCoP = -1.60 + 0.00043 \text{ EthPr} + 0.0073\text{CoHf} + 0.0012\text{CoEx} + 0.00098 \text{ CoFeed} \\ + 0.26 \text{ WeCo} - 0.00008 \text{ CoPr} - 0.014 \text{ T} + 0.944 \text{ DCoP1}$$

$$(4.2) \quad \text{CoPr} = -5199.80 + 459.33 \text{ DCoP1} + 1426.84 \text{ CoY} + 64.14 \text{ T}$$

In order to calculate the impact of the mandatory ethanol consumption policy on domestic corn prices we can write:

$$(4.3) \quad d(\text{Dcop}) = 0.00043*d(\text{EthPr}) + 0.0012*d(\text{CoHf}) + 0.00098*d(\text{CoFeed}) \\ + 0.0012d(\text{CoEx}) + 0.26*d(\text{WeCo}) - 0.00008*d(\text{CoPr}) - 0.014*d(\text{T}) \\ + 0.944*d(\text{DCoP1})$$

If we suppose that $d(\text{CoHf}) = d(\text{CoFeed}) = d(\text{WeCo}) = d(\text{DCoP1}) = d(\text{CoEx}) = 0$ then we will have:

$$(4.4) \quad d(\text{Dcop}) = 0.00043*d(\text{EthPr}) - 0.00008*d(\text{CoPr}) - 0.014*d(\text{T})$$

We use 2007 as a base point to estimate the change in domestic corn prices in the years 2009, 2012, and 2015. In 2007, about 6.485 billion gallons of ethanol were produced. Based on the Energy Independence and Security Act of 2007, renewable ethanol consumption must reach 10.5 billion gallons by 2009, therefore $d(\text{EthPr})$ is equal to 4.015 billion gallons of ethanol relative to 2007. Since $d(\text{EthPr})$ is equal to 4.015 billion gallons, $d(\text{T})$ is equal to 8 (8 quarters from the beginning of 2008 to the end of 2009) then we will have:

$$(4.5) \quad d(\text{Dcop}) = 0.00043 * 4015 - 0.00008*d(\text{CoPr}) - 0.014 * 8 \\ = 1.614 - 0.00008*d(\text{CoPr})$$

Now we will use the corn production equation to estimate the impact of the increase in corn production, resulting from increased corn prices, on corn prices. Based on equation (4.2) we can write:

$$(4.6) \quad d(\text{CoPr}) = 459.33*d(\text{DCoP1}) + 1426.84*d(\text{CoY}) + 64.14*d(\text{T})$$

If we suppose that corn yield increases by 0.10 mt/ha each year, based on the last 3 years of data, then $d(\text{Coy})$ is equal to 0.2. Since $d(\text{T})$ is equal to 2, because we have two years from 2007 to 2009, we can rewrite equation (4.6) as below:

$$\begin{aligned} (4.7) \quad d(\text{CoPr}) &= 459.33*d(\text{DCoP1}) + 1426.84*d(\text{CoY}) + 64.14*d(\text{T}) \\ &= 459.33*d(\text{DCoP1}) + 1426.84*0.2 + 64.14*2 \\ &= 459.33*d(\text{DCoP1}) + 413.65 \end{aligned}$$

Now substituting equation (4.7) in equation (4.5), we have:

$$\begin{aligned} (4.8) \quad d(\text{DCoP}) &= 1.614 - 0.00008*d(\text{CoPr}) \\ &= 1.614 - 0.00008 [459.33*d(\text{DCoP1}) + 413.65] \\ &= 1.58 - 0.037 d(\text{DCoP1}) \end{aligned}$$

For simplicity, suppose that $d(\text{DCoP}) = d(\text{DCoP1})$, then we have:

$$(4.9) \quad 1.037 d(\text{DCoP}) = 1.58 \rightarrow d(\text{DCoP}) = 1.53$$

Thus, if ethanol production reaches 10.5 billion gallons in 2009, the change in corn prices relative to 2007 will be \$1.53 per bushel of corn. If we add the calculated change in corn prices to the 2007 (our base year) corn price, then the expected corn price for 2009 is \$6.03 per Bushel for ethanol production at 10.5 billion gallons. At this price, the level of corn production will reach 14,188.66 million Bushels per year because the change in corn production caused by change in corn prices and corn yield will increase the amount of corn production in 2009 as follows:

$$(4.10) \quad d(\text{CoPr}) = 459.33*1.40 + 1426.84*.20 + 64.133*2 = 1114.86$$

$$\begin{aligned} (4.11) \quad \text{Total corn production in 2009} &= \text{corn production in 2007} + d(\text{CoPr}) \\ &= 13073.8 + 1114.86 = 14188.66 \end{aligned}$$

We can repeat the same procedure to calculate domestic corn prices and corn production for 2012 and 2015. The estimated results are shown in Table 4.11.

In order to determine if the results of the annual data model support the results of the quarterly data model, the above procedure is used to calculate corn prices and corn production levels for years 2009, 2012, and 2015 based on the annual model. Calculated results are shown in Table 4.12. Comparing Tables 4.11 and 4.12 shows that the difference between the calculated corn price from the quarterly model and the calculated corn price from the annual model is only 3 cents per bushel of corn (difference between \$6.00 and \$6.03) for the year 2009. The difference for the years 2012 and 2015 is 15 cents and 28 cents, respectively. Even though the estimated domestic corn price equation based on the quarterly data differs from the estimated domestic corn price equation based on the annual data, predicted corn prices and corn production from both models are similar.

Predicted corn prices for 2009, 2012 and 2015 along with previous information related to ethanol and HFCS production costs can be used to predict the net feedstock costs of ethanol and HFCS production in these years. As seen in Chapter 2, wet milling plants can produce 1.6 pounds of corn oil, 12.5 pounds of gluten feed, and 2.5 pounds of gluten meal along with 33 pounds of HFCS or 2.65 gallons of ethanol from per bushel of corn. Dry milling plants can produce 17 pounds of dry distillers' grains with soluble (DDGs) along with 2.75 gallons of ethanol from each bushel of corn. Using this information and the estimated corn prices for the years 2009, 2012, and 2015 we can calculate the net corn cost of producing each gallon of ethanol and one pound of HFCS in these years as follow:

$$(4.12) \quad \text{Net corn cost of per pound of HFCS} = \{ \text{corn price} - [\text{corn oil price} * 1.6 \\ + \text{gluten feed price} * 12.5 + \text{Gluten meal price} * 2.5] \} / 33$$

$$(4.13) \quad \text{Net corn cost of per gallon of ethanol} = (\text{Corn price} - \text{DDGs price} * 17) / 2.75$$

Calculated results are shown in Tables 4.11 and 4.12. The calculation is based on the year 2007 prices for dry distillers' grains, corn oil, gluten feed, and gluten meal. For the calculation,

we assume that the credit for CO₂ produced in ethanol and HFCS production process is zero and all new ethanol plants are dry milling plants.

The processing cost of HFCS was 6.57 cents per pound in 1994/95 (Haley, 1998b). Using the CPI, the adjusted processing cost of HFCS would be 8.94 cents per pound in 2007. If the processing cost of HFCS is added to the net corn cost of HFCS, the cost of producing HFCS would be 18.21 cents in 2007 and 27.22 cents in 2015 (Table 4.11).

The U.S. domestic raw and refined sugar prices were 21.0 cents and 25.1 cents per pound in 2007, respectively (USDA, 2008). If we compare these prices with the estimated HFCS production cost, HFCS cannot compete with raw sugar after 2009 and cannot compete with refined sugar after 2012 because HFCS production cost will be higher than sugar prices (assuming the sugar prices and HFCS processing costs will not increase). In fact, the break even corn price for producing HFCS that equates HFCS production costs and refined sugar prices, based on 25.1 cents per pound of refined sugar, is \$6.74 per bushel of corn. Therefore:

$$(4.14) \text{ If corn price } > \$6.74 \rightarrow \text{HFCS production cost} > \text{Domestic refined sugar price} > \text{Domestic raw sugar price}$$

This means that if corn prices reach \$6.74 per bushel, HFCS cannot compete with sugar. Therefore the demand for sugar will increase which will, in turn, raise sugar prices and imports. The increase in imported sugar depends on the strength of sugar users' reaction to the increase in HFCS prices. The amount of HFCS utilization was 8.8 million tons in 2007. Thus sugar imports can increase by 8.8 million tons of sugar, if industries replace their HFCS utilization with sugar.

4.5.2. Second Question

What is the maximum amount of ethanol that can be produced from corn?

In order to answer this question, we have to consider the corn-based ethanol production limitation from various prospective.

Table 4.11. Effect of the 2007 Energy Act on U.S. corn, ethanol, and HFCS (based on quarterly data model results)

Variable name \ Year	2007 (Base)	2009	2012	2015
Ethanol production (billion gallons)	6.485	10.50	13.20	15.00
Domestic corn price (\$/bu)	4.50	6.03	6.94	7.48
Corn production (mill bu)	13073.80	14188.66	15227.61	16094.99
Ethanol production feedstock net costs (\$/gallon)	1.18	1.74	2.07	2.26
HFCS production net corn costs (cents/lb)	9.41	14.05	16.80	18.44
HFCS net corn cost + processing cost (cents/lb)	18.35	22.99	25.74	27.38

Table 4.12. Effect of the 2007 Energy Act on U.S. corn, ethanol, and HFCS (based on annual data model results)

Variable name \ Year	2007 (Base)	2009	2012	2015
Ethanol production (billion gallons)	6.485	10.50	13.20	15.00
Domestic corn price (\$/bu)	4.50	6.00	6.79	7.20
Corn production (mill bu)	13073.80	14174.76	15160.81	15966.63
Ethanol production net feedstock costs (\$/gallon)	1.18	1.72	2.01	2.16
HFCS production net corn costs (cents/lb)	9.27	13.80	16.21	17.44
HFCS net corn cost + processing cost (cents/lb)	18.21	22.74	25.15	26.38

The maximum possible amount of corn-based ethanol production depends upon the ethanol supply and demand. The demand for ethanol depends upon the prices of ethanol and gasoline, and those governmental policies related to mandatory ethanol consumption and excise tax credit. Ethanol supply depends upon ethanol production costs, especially upon the prices for corn and other feedstocks, and ethanol prices. If other factors are held constant, then the federal government mandated ethanol consumption requirement and corn and gasoline prices determine the equilibrium of ethanol quantity and price.

First, suppose that the federal mandates regarding ethanol consumption do not exist (Figure 4.4). Then ethanol demand and supply together determine ethanol quantity and price. Assume that the gasoline price is P_{g0} and ethanol demand is D_0 , then the ethanol quantity and price are q_0 and p_0 at the ethanol market equilibrium point E_0 . If the gasoline price increases to P_{g1} , then ethanol demand shifts to the right (D_1). If the gasoline price decreases to P_{g2} , then ethanol demand shifts to the left (D_2) and we have a new ethanol market equilibrium quantity and price. As the graph shows, for each given gasoline price, ethanol supply and demand determine the maximum ethanol that has to be produced so that the market is in equilibrium.

Now suppose that we impose the condition of federally mandated ethanol consumption into the model. In this scenario, ethanol will exhibit a kinked demand curve (DD_0) as shown in Figure 4.5. Assume that this figure shows the 2008 ethanol market of 9 billion gallons of ethanol produced. Therefore, the ethanol demand curve is kinked where $q_0 = 9$. Suppose that the gasoline price is less than the net ethanol price (ethanol price minus excise tax). Without federally mandated consumption, ethanol demand and supply determine the equilibrium point at E_0 . At this point, the quantity of ethanol demanded is less than 9 billion gallons. However, the ethanol consumption requirement forces gasoline producers to use 9 billion gallons of ethanol. Therefore, the equilibrium will be at E_1 . In the case where the gasoline price is less than P_{g1} , the

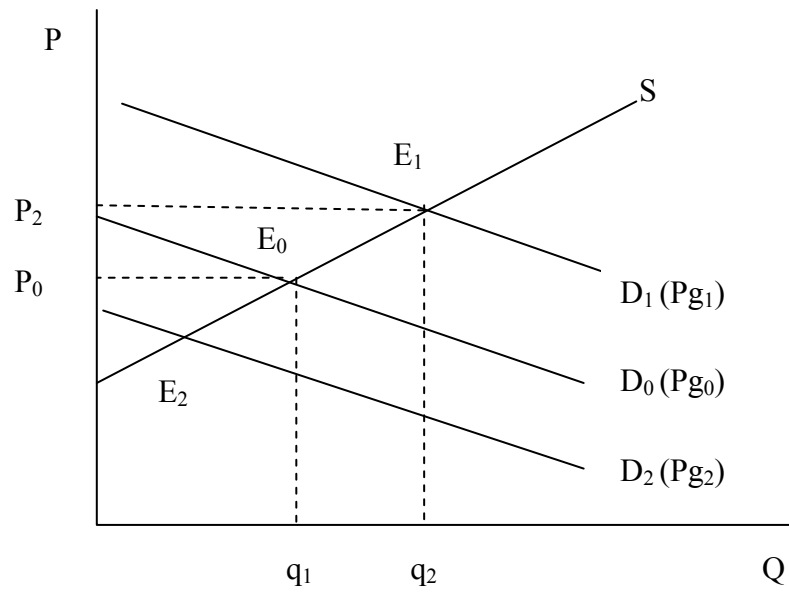


Figure 4.4. Ethanol market without mandatory law

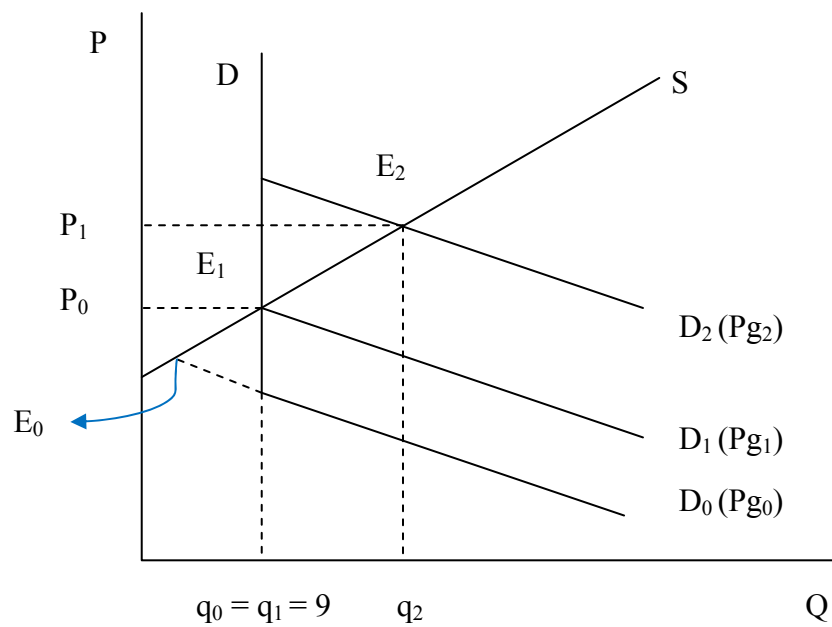


Figure 4.5. Ethanol market with mandatory law

2007 Energy Act determines the minimum amount of ethanol that must be used, the maximum amount of ethanol production, and we have q_0 and p_0 . Therefore, for each unit price of gasoline less than P_{g1} , ethanol demand determines the equilibrium quantity (at 9 billion gallons) and ethanol supply determines equilibrium price. Where gasoline price equals P_{g1} , both the ethanol supply (S) and demand determine p and q . At this gasoline price, the ethanol equilibrium quantity is exactly equal to the federally mandated amount of ethanol that is to be produced.

Now assume that the gasoline price increases to P_{g2} . The increase in the gasoline price shifts the downward sloping portion of the ethanol demand curve to the right. If the increase in gasoline price is large enough so that the gasoline price is significantly higher than the subtotal of ethanol production and blending costs, then ethanol demand shifts to DD_2 . The new equilibrium quantity of ethanol will be q_2 which is higher than the mandatory level of 9 billion gallons. The reason for having an ethanol quantity more than the required amount of ethanol in P_{g2} is that when gasoline prices are significantly high then gasoline blenders use more gasoline in order to get benefits of margin between gasoline price and ethanol costs and this increases their demand for ethanol. The increase in ethanol demand continues until the increase in ethanol production costs, and thus the increase in ethanol prices, removes the margin. So for any gasoline price equal to or higher than P_{g1} , ethanol supply and demand together determine ethanol equilibrium price and quantity, as in Figure 4.4, and the quantity of ethanol demanded is more than the federally mandated amount.

To estimate the practical maximum amount of ethanol production, the mandatory level of ethanol consumption requirement must be considered, along with corn and gasoline prices. Based on the 2007 Energy Act, the mandatory level of corn-based ethanol consumption will be 15 billion gallons for 2015 and will maintain this level till 2025. As seen in the discussion for the

first question, at this level of corn-based ethanol production, corn prices will reach somewhere between \$7.20 and \$7.48 per bushel.

For estimating the equilibrium level of ethanol production, we use the equilibrium condition where marginal revenue equals marginal cost ($MR = MC$). We assume that the ethanol market is a competitive market and therefore we have marginal revenue equal to price ($MR = P$). That changes the equilibrium condition to $P = MC$. Since there is sufficient time to construct new ethanol factories, we assume long-run condition, so that investment costs are included in the marginal cost.

Traditionally, the following relationship has existed between ethanol and gasoline prices:

$$(4.15) \quad EthP = GasP + (10 * FETC) + (10 * SC) - MI$$

In this equation, EthP, GasP, FETC, SC and MI denote ethanol price, gasoline price, the Federal Excise Tax Credit, the state credit, and the margin of improvement, respectively. The ethanol production cost per gallon is:

$$(4.16) \quad MC = \text{net corn cost of ethanol} + \text{operation cost} + \text{capital cost}$$

And net corn cost of ethanol can be calculated as follow:

$$(4.17) \quad \text{net corn cost} = (\text{domestic corn price (DCoP)} - \text{byproduct credits}) / 2.75$$

From Equations (4.16) and (4.17) we can have:

$$(4.18) \quad MC = [(\text{DCoP} - \text{byproduct credits}) / 2.75] + \text{operation cost} + \text{capital cost}$$

If we substitute Equations (4.15) and (4.18) into the ethanol market equilibrium condition ($P = MC$) then we have:

$$(4.19) \quad EthP = MC \rightarrow GasP + (10 * FETC) + (10 * SC) - MI = [(\text{DCoP} - \text{byproduct credits}) / 2.75] + \text{operation cost} + \text{capital cost}$$

For simplicity, we assume that SC and MI are equal to zero. Based on 2007 data, DDGs was \$147.38 per ton. Thus, byproduct credit is equal to \$1.253 per bushel of corn or 46 cents per

gallon of ethanol. FETC is equal to 51 cents per gallon of ethanol blended with gasoline or 5.1 cents for every gallon of gasoline blended with ethanol. The operation cost and capital cost are \$0.52 and \$0.14 per gallon of ethanol, respectively (Salassi et al., 2006).

The above information can now be used, along with our estimated model, to find the maximum amount of ethanol that can be produced from corn under the scenario of varying gasoline prices in 2015. Based on Equation (4.19), equilibrium condition for ethanol market is:

$$(4.19) \text{ GasP} + (10 * \text{FETC}) + (10 * \text{SC}) - \text{MI} = \\ [(\text{DCoP} - \text{byproduct credits}) / 2.75] + \text{operation cost} + \text{capital cost}$$

If we substitute the operation cost (\$0.52 per gallon) and capital cost (\$0.14 per gallon) in the Equation (4-19) we have:

$$(4.20) \text{ GasP} + (10 * \text{FETC}) + (10 * \text{SC}) - \text{MI} = (\text{DCoP} - \text{byproduct credits}) / 2.75 + 0.52 + 0.14$$

With substituting for other variables we have:

$$(4.21) \text{ GasP} + 0.51 = [(\text{DCoP} - 1.25) / 2.75] + 0.52 + 0.14 = (\text{DCoP} / 2.75) - 0.46 + 0.66$$

$$(4.22) \text{ GasP} + 0.31 = \text{DCoP} / 2.75$$

$$(4.23) \text{ DCoP} = 2.75 \text{ GasP} + 0.85$$

For example, we assume that the gasoline price will be equal to \$3.50 per gallon in 2015. Under the assumed price of \$3.50/gallon for gasoline we then calculate domestic corn price according to the following equation:

$$\text{DCoP} = 2.75 \text{ GasP} + 0.85 = 2.75 * 3.50 + 0.85 \rightarrow \text{DCoP} = \$10.48$$

This means that at \$3.50 per gallon of gasoline, the increase in ethanol production in 2015 can continue until the corn price per bushel reaches \$10.48. Now we can use our model estimation results to determine the levels of ethanol production where corn prices reach \$10.48 per bushel. Based on our quarterly model results, at \$3.5 per gallon gasoline and a Federal Excise Tax Credit of \$0.51 per gallon of ethanol, corn-based ethanol production can reach 22.24

billion gallons. That raises corn prices to \$10.48 per bushel. But such a corn price can make other feedstocks, like raw sugar, more competitive with corn to produce ethanol. As considered the next question, when corn-based ethanol production reaches 19.61 billion gallons annually and corn prices increase to \$9.39 per bushel, ethanol from raw sugar will be profitable and, therefore, ethanol producers may use raw sugar to produce ethanol. From this point, additional use of corn for producing ethanol depends on raw sugar and corn price changes. Therefore, based on 2007 data and our estimated quarterly model, the maximum amount of ethanol that can be produced from corn will be 19.61 billion gallons in 2015. At this production level, corn prices will reach \$9.39 per bushel and, relative to 2007, an additional 4.77 billion bushels of corn goes to ethanol production with 3.9 billion bushels of the total 4.77 billion bushes coming from increases in corn production. If corn prices reach \$9.39 per bushel, the net corn cost of HFCS increases to 24 cents and HFCS ceases to compete with sugar. This decreases HFCS production and frees up corn previously dedicated to HFCS production for ethanol production. Therefore, a portion of needed corn to produce additional ethanol will come from the HFCS industry.

This example shows that in addition to gasoline prices, the relative prices of corn and other feedstocks play a significant role in determining the maximum amount of ethanol that can be produced from corn. The maximum amount of corn-based ethanol production in 2015 for different scenarios is shown in Table 4.13.

4.5.3. Third Question

In what scenario would sugar-based ethanol production be profitable in the United States? Furthermore, what policies would make sugar a profitable feedstock for producing ethanol in the United States?

Based on Salassi et al., the ethanol production cost from different feedstocks is shown in Table 4.14 (based on 2003-2005 average prices). As this table shows, the U.S. molasses feedstock cost

Table 4.13. Maximum amount of ethanol production in 2015 for different scenarios

Gasoline Price (\$/gal)	Tax credit (\$/gal)	margin improvement (\$/gal)	without requirement		with requirement		limit level from other feedstocks
			Corn Price (\$/bu)	Ethanol Production (mill gal)	Corn Price (\$/bu)	Ethanol Production (mill gal)	
1	0.51	0.1	3.31	4969.09	7.48	15000.00	
	0	0.1	1.91	1589.58	7.48	15000.00	
1.25	0.51	0.1	4.00	6625.72	7.48	15000.00	
	0	0.1	2.60	3246.20	7.48	15000.00	
1.5	0.51	0.1	4.69	8282.35	7.48	15000.00	
	0	0.1	3.29	4902.83	7.48	15000.00	
1.75	0.51	0.1	5.38	9938.97	7.48	15000.00	
	0	0.1	3.97	6559.46	7.48	15000.00	
2	0.51	0.1	6.06	11595.60	7.48	15000.00	
	0	0.1	4.66	8216.08	7.48	15000.00	
2.25	0.51	0.1	6.75	13252.23	7.48	15000.00	
	0	0.1	5.35	9872.71	7.48	15000.00	
2.5	0.51	0.1	7.44	14908.85	7.48	15000.00	
	0	0.1	6.04	11529.34	7.48	15000.00	
2.75	0.51	0.1	8.13	16565.48	7.48	16565.48	
	0	0.1	6.72	13185.96	7.48	15000.00	
3	0.51	0.1	8.81	18222.11	8.81	18222.11	
	0	0.1	7.41	14842.59	7.48	15000.00	
3.25	0.51	0.1	9.39	19613.67	9.39	19613.67	raw sugar
	0	0.1	8.10	16499.21	8.10	16499.21	
3.5	0.51	0.1	9.39	19613.67	9.39	19613.67	raw sugar
	0	0.1	8.79	18155.84	8.79	18155.84	
3.75	0.51	0.1	9.39	19613.67	9.39	19613.67	raw sugar
	0	0.1	9.39	19613.67	9.39	19613.67	raw sugar

is 72% more expensive than corn feedstock cost in dry mill plants. The net feedstock cost of sugarcane and sugar beets are three times as much as that of corn. The net feedstock cost of U.S. raw sugar and U.S. refined sugar are more than six times that of corn. Based on this information, we can determine corn prices that make molasses, sugarcane, sugar beets, raw sugar, and refined sugar competitive with corn as a feedstock for ethanol production in Table 4.9, given the current sugar import quota regime.

Table 4.14. U.S. ethanol production costs excluding capital costs (\$/per gallon)

	Corn Dry mill	molasses	Sugar cane	Sugar beets	Raw sugar	Refined sugar
Net feedstock cost	0.53	0.91	1.48	1.58	3.12	3.61
Processing cost	0.52	0.36	0.92	0.77	0.36	0.36
Total cost	1.05	1.27	2.40	2.35	3.48	3.97

Source: Salassi et al. 2006.

Based on the results in Tables 4.11 and 4.12 and corn prices more than \$4 per bushel, even with the sugar import quota, molasses can currently compete with corn. This is theoretically true, but it is not practical because producing ethanol from molasses necessitates collecting molasses from different sugar refinery plants which is not economical. Its bulky physical consistency limits its ability to be transported in an efficient manner. Therefore, we do not refer to molasses as a potential feedstock.

After 2012, both sugarcane and sugar beets would be able to compete with corn as a feedstock for producing ethanol. Because of their high prices, raw sugar and refined sugar cannot compete with corn in producing ethanol under the mandatory level of 15 billion gallons of ethanol per year. Table 4.15 shows how the increase in corn prices, resulting from an increase in

corn demand for ethanol, makes other feedstocks competitive with corn in the production of ethanol. For instance, if the corn price reaches \$10.74 per bushel, then the corn-based ethanol production cost would be as much as the cost of producing ethanol from refined sugar.

Table 4.15. Impact of increase in corn price on other ethanol feedstocks competitiveness

corn price (\$/bu)	Corn-based ethanol Production cost (\$/gal)	Competitor feedstock with sugar TRQ	Competitor feedstock without sugar TRQ
6.28	2.35	Sugar beets	Raw sugar
6.42	2.40	sugarcane	Raw sugar
9.39	3.48	Raw sugar	Raw sugar
10.74	3.97	Refined sugar	Raw sugar

However, if the sugar import quota is removed, the outcome could be different. Suppose that the U.S. allows ethanol producers the ability to import raw sugar directly from other countries at world sugar prices. In this case, raw sugar prices for U.S. ethanol producers will be equal to world sugar prices plus transportation costs. In 2007, the world (Caribbean) raw sugar price was 10 cents per pound (IFS data). Based on the Sweetener Users Association's report, the average transportation cost of raw sugar to New York is 1.5 cents per pound; that would increase the world raw sugar price to 11.5 cents per pound for ethanol producers. Each 1 million metric ton increase in U.S. sugar imports would increase world raw sugar prices by as much as 0.08 cents per pound (Kennedy et al, 2003). For simplicity we do not include this in our calculations.

To produce 1 gallon of ethanol, 14.77 pounds of raw sugar are required. Therefore, the feedstock cost of per gallon of ethanol produced from imported raw sugar would be 169.86 cents

or \$1.70. This is just 54% of the current feedstock cost per gallon of ethanol produced from U.S. raw sugar (\$3.12). If we add the processing cost of producing ethanol from raw sugar, 0.36 cents per gallon of ethanol (USDA), to the feedstock cost, the total production cost for one gallon of ethanol using imported raw sugar would be \$2.06. In this case, imported raw sugar for ethanol production at world sugar prices can compete with corn at \$5.49 per bushel. Based on the simultaneous estimates, the corn price reaches \$5.49 when the ethanol production level reaches approaches 9.3 billion gallons annually. Therefore we can say that, when importing raw sugar at world sugar prices, ethanol producers will use corn until ethanol production reaches 9.3 billion gallons per year. After that, depending on the effect of U.S. imports on the world sugar price, ethanol producers will use both imported raw sugar and corn to produce ethanol to reach to the mandatory level of 15 billion gallons per year.

Based on Tables 4.11 and 4.12, corn prices reach \$6.0 per bushel in 2009 when ethanol production reaches 10.5 billion gallons per year. Thus, allowing ethanol producers to import raw sugar is an alternative that will make sugar a profitable feedstock for producing ethanol in the United States after 2009.

4.5.4. Fourth Question

What are the impacts of an ethanol subsidy, import tariffs, and sugar import quota on the U.S. ethanol, corn, HFCS, and sugar markets?

4.5.4.1. Ethanol Subsidy

The ethanol subsidy plays a significant role in ethanol production, especially when ethanol prices are higher than gasoline prices. Table 4.13 shows impact of the ethanol subsidy (51 cents per gallon) on the ethanol production and corn price. The ethanol subsidy can increase ethanol production and, therefore, increases the demand for corn as a feedstock to produce ethanol.

Increases in the demand for corn raise corn prices and as previously demonstrated, this increases

the production cost of HFCS. Increases in the HFCS production cost decreases HFCS production and increases HFCS prices. These changes reduce the demand for HFCS, which is displaced with sugar. Increases in the demand for sugar increase sugar prices, production, and imports.

4.5.4.2. Ethanol Import Tariff

The U.S. government has imposed an ethanol import tariff to prevent foreign countries from gaining benefits of U.S. ethanol production subsidies (51 cents per gallon of ethanol). The ethanol import tariff decreases foreign ethanol producers' access to the U.S. ethanol market and, therefore, increases ethanol prices. Without federally mandated ethanol consumption, the ethanol import tariff decreases ethanol consumption. However, under the 2007 Energy Act and mandatory ethanol consumption requirement, the ethanol import tariff increases domestic ethanol production. Again, the increase in ethanol production increases corn and HFCS prices, reduces HFC production, and increases the demand for sugar.

4.5.4.3. Sugar Import Quota

The sugar import quota has increased sugar prices and caused sugar consumers to replace sugar with HFCS. HFCS is produced from corn and, as a result, every year a portion of the corn crop, 500 million bushels in 2007, goes to HFCS production. This has several impacts on both the corn and ethanol markets:

- First, it increases the demand for corn (as much as 500 million bushels in 2007) and, therefore, increases corn prices. An increase in corn prices imposes additional costs on a variety of corn consumers including corn-based ethanol producers. It also increases ethanol production costs and the ethanol prices.
- Second, the sugar import quota has raised sugar prices so that sugar cannot be profitably considered as a feedstock for producing ethanol since sugar cannot compete with corn when its price is at these elevated levels.

- Third, the sugar quota shifts a portion of produced corn, 500 million bushels in 2007, toward the production of HFCS which could otherwise be used to produce an additional 1.375 billion gallons of ethanol per year.

4.5.5. Fifth Question

What would be the effect of eliminating sugar import quotas on the U.S. sugar, HFCS, corn, and ethanol markets?

The elimination of the sugar import quota has a direct effect on the U.S. sugar and HFCS markets and an indirect effect on the corn and ethanol markets. Removing the sugar import quota decreases U.S. domestic sugar prices and brings the U.S. sugar price closer to the world sugar price. This increases U.S. sugar consumption and import and decreases domestic sugar production. It also has a significant impact on the HFCS market. Using corn for producing ethanol along with the resulting increase in corn prices, HFCS production costs will increase significantly. The cost of producing HFCS has been more than 18 cents per pound in 2007 (see Table 4.11). It cannot compete with sugar at the world sugar price level, which was 10 cents per pound in 2007. Thus, eliminating or relaxing the sugar import quota encourages HFCS consumers to replace HFCS consumption with sugar, thus minimizing the importance of the HFCS market if not eliminating it.

On the other hand, as seen in the discussion of Question 3, sugar imported at world prices for producing ethanol allows raw sugar to compete with corn at \$5.49 per bushel of corn. But removing the sugar import quota on all imported sugar will have different effects on ethanol production. By reducing HFCS consumption and, therefore, HFCS production, there will be more corn available to produce ethanol. In 2007, 500 million bushels of corn was used to produce HFCS (USDA). If this quantity of corn were used to produce ethanol, it would result in an additional 1.375 billion gallons of ethanol production without displacing any other corn for

use as a feedstock. At the same time, importing more sugar from abroad will raise world sugar prices and, therefore, increases the cost of producing ethanol from imported raw sugar. These two combined effects determine the share of corn and raw sugar in ethanol production.

CHAPTER V

CONCLUSION

Renewable energy has garnered much attention in recent years. Factors such as environmental concerns, air pollution, global warming, energy security, and high oil prices have raised renewable energy's profile in the public consciousness. Bioenergy, especially ethanol, is one source of renewable energy which has enjoyed tremendous growth in production and in consumption in recent years. The United States and Brazil are the largest ethanol producers in the world. However, producing ethanol in the United States differs from producing ethanol in Brazil because, while the United States uses corn to produce ethanol, Brazil primarily uses sugarcane.

Ethanol production in the United States has grown rapidly since 2000. U.S. ethanol production capacity has increased from an annual rate of 1.7 billion gallons in 2000 to an annual capacity of 10.25 billion gallons in September 2008. The United States is the largest corn producer in the world. This has brought about a unique situation of using cheap corn to produce ethanol. Boosts in ethanol production have increased corn demand, thereby increasing U.S. corn prices. An increase in the corn price can have a negative impact on other corn users such as HFCS producers.

The United States is the largest HFCS producer in the world. In 2008, more than 37 percent of U.S. sweetener consumption came from HFCS. Replacing sugar with HFCS has had a significant impact on U.S. sugar consumption and has decreased U.S. sugar imports significantly. Thus, an increase in corn prices, resulting from an increase in ethanol production, impacts HFCS production and, in turn, the U.S. sweeteners market (including sugar). Using corn

as the primary input in ethanol and HFCS production in the United States, along with the high degree of substitutability between sugar and HFCS, has linked the U.S. ethanol market to the U.S. HFCS, sugar, and corn markets. Therefore, any governmental policy related to either the ethanol or the sugar market impacts other markets as well.

Even though ethanol can be used alone in specially equipped vehicles, in the United States it is normally blended with gasoline up to 10% (known in the United States as *E10*). E10 can be used in motor vehicles, and use of E10 does not warrant any special modifications to the vehicle. The primary input material, or “feedstock”, is the most critical input in ethanol production. Feedstock costs constitute more than half of total ethanol production cost. There are a vast variety of different feedstocks, such as sugar cane, sugar beets, sorghum, switchgrass, barley, potatoes, fruit, molasses, corn and/or corn cobs, grain, wheat, wood, paper, straw, cotton, grain sorghum, barley, as well as many various types of cellulosic waste that can be used to produce ethanol. Depending upon feedstock costs, feedstock used for ethanol production is different from one country to the next. For instance, in Brazil sugarcane is the cheapest feedstock with which to produce ethanol, while in the United States it is corn. Energy cost, including electricity and natural gas, ranks next to feedstock cost as a major component of ethanol production cost.

There are two types of corn-based ethanol plants, dry mill and wet mill plants. These use different production processes and produce different byproducts. Wet mill plants produce ethanol along with gluten feed, gluten meal, and corn oil. Dry mill plants produce ethanol along with dry distillers’ grains (DDGs) and CO₂. Ethanol byproducts reduce ethanol production cost and, therefore, impact ethanol production profitability. Most U.S. ethanol plants are dry mill plants which utilize more efficient technology.

The Energy Policy Act of 2005 and the 2007 Energy Independence and Security Act (EISA) have played a critical role in ethanol market development and, therefore, in ethanol consumption and production growth. Based on these Acts, gasoline used in the United States must be blended with a certain amount of ethanol. The share of ethanol in blended fuel increases annually and must reach 36 billion gallons by 2022 from its 9 billion gallon level in 2008. Based on the 2007 Energy Independence and Security Act, corn-based ethanol production must reach an annual produced capacity of 15 billion gallons by 2015 and stay at this level thereafter. This Act forces refiners to blend ethanol with gasoline, no matter ethanol's price.

The United States is the largest corn producer and exporter in the world. U.S. corn is used for feed, food, HFCS production, and ethanol production. Traditionally, approximately half of U.S. corn is used as feed and about 5% of that is used to produce HFCS (USDA). Emphasis on bioenergy in recent years has changed the U.S. corn market. The share of ethanol in corn demand has risen from about 5% in 2000 to 23% in 2007 (USDA). In 2007, for the first time the amount of U.S. corn used for ethanol surpassed the amount of corn exported. The increase in corn-based ethanol production has significantly inflated corn prices in recent years.

Since each bushel of corn produces approximately 2.75 gallons of ethanol, producing 15 billion gallons ethanol goal (as mandated in the 2007 EISA) would require 5.45 billion bushels of corn. Given total U.S. corn production of 13.1 billion gallons in 2007, we can see what an impact 15 billion gallons ethanol would have on the world corn market. Using this volume of corn in producing ethanol will reduce the share of other areas of corn consumption and increase the corn price. However, it is expected that a part of this increase in corn demand will be met by an increase in corn production resulting from gains in both corn yield and area planted.

Corn can also be used to produce High Fructose Corn Syrup (HFCS). The use of corn as the common input for the production of ethanol and HFCS in the United States links the HFCS

and ethanol markets. Therefore, government policies regarding ethanol consumption and production impact the HFCS market as well. HFCS is a liquid sweetener which is similar to sugar. The sugar support program has focused much attention to HFCS so that industries which primarily use sugar, such as the soft drink industry, have switched from sugar to HFCS. In 2007, U.S. HFCS consumption was nearly that of U.S. sugar consumption. Only wet mill plants are capable of producing HFCS. HFCS byproducts are corn oil, gluten feed, and gluten meal. An increase in the corn price resulting from increases in ethanol production will raise HFCS production costs and, thereby, potentially reduce HFCS consumption. In this case, demand for sugar will increase the sugar price and, therefore, sugar imports. Thus, even though corn is the main feedstock for ethanol production in the United States, government policies regarding ethanol production impact the sugar market through HFCS.

In the United States, ethanol is related to sugar in two ways. First, as previously mentioned, the ethanol market impacts sugar market through HFCS. Second, sugar is a potential feedstock for producing ethanol in the United States. Therefore, ethanol policies impact the sugar market as well.

Sugar is an important crop in U.S. agriculture. Slightly more than half of total U.S. sugar production comes from sugar beets with the rest coming from sugarcane. The U.S. government supports sugar producers using different tools which include: a loan program for producers; an import quota system on foreign sugar; and marketing allotments for domestic sugar. Domestic sugar production alone is not able to supply domestic U.S. sugar demand, thus, the United States imports sugar in an effort to regulate the domestic sugar price. The United States ranks as one of the largest sugar importers in the world.

Currently, because of its sugar program, U.S. domestic sugar prices are sufficiently high so that sugar cannot compete with corn in ethanol production. However, an increase in corn

prices resulting from an increase in ethanol production, along with the possibility of trade liberalization regarding agricultural product import barriers, could change this situation and remove any advantage that corn currently has over sugar.

Government policies have a significant impact on ethanol production and consumption in the United States. The phasing out of MTBA as a fuel octane enhancer, fuel tax reductions, and federal and state producer subsidies, along with the 2005 and 2007 Energy Acts have stimulated ethanol consumption and production in the United States.

This study attempted to determine the impact of U.S. government policies on the U.S. ethanol market and its consequences for the U.S. corn, sugar, and HFCS markets. Specifically, this study sought to answer the following questions:

- What will be the effect of the 2007 Energy Act required levels of ethanol production (10.5, 13.2, and 15 billion gallons) on the U.S. corn, HFCS, and sugar markets?
- What is the maximum amount of ethanol that can be produced from corn?
- In what scenario would sugar-based ethanol production be profitable in the United States? Furthermore, what policies would make sugar a profitable feedstock for producing ethanol in the United States?
- What are the impacts of an ethanol subsidy, import tariffs, and sugar import quotas on the U.S. ethanol, corn, HFCS, and sugar markets?
- What effect would eliminating sugar import quotas have on the U.S. HFCS, corn, and ethanol markets?

To answer these questions, data was collected and a simultaneous econometric model was constructed. Two sets of data, quarterly and annual data, are used in the estimation procedure in an effort to increase the reliability of the estimation results. The annual data set covers 75 variables and has 33 observations from 1978 to 2007. The quarterly data set covers 67 variables

and has 104 observations from 1982 to 2007. Each model has 18 equations including 14 behavioral equations and 4 identity equations. The fourteen behavioral equations consist of two (supply and demand) equations for the ethanol market, two (demand and price) equations for the HFCS market, five equations (sugarcane and sugar beet supply, nonindustrial and industrial demand for sugar, and price equation) for the sugar market, and five equations (corn production or supply, corn used for HFCS, corn demand for feed, corn demand for other utilizations, and price equation) for the corn market. Even though equations used in both the annual and quarterly models are not unique, the estimated results from the annual model are very similar to those obtained for the quarterly model, suggesting some degree of reliability in the results.

Based on the estimated results for the model's ethanol market equations, the ethanol price has a positive impact on ethanol production and a negative impact on ethanol consumption. Estimated ethanol demand and supply equations indicate that ethanol demand is price elastic while ethanol supply is price inelastic. Both annual and quarterly models show that the gasoline price has a significant impact on ethanol consumption so that an increase in gasoline prices increases ethanol consumption. Therefore, based on our data, ethanol is a gasoline substitute. Domestic corn prices and interest rates have a negative impact on ethanol production because they increase ethanol production costs and, therefore, decrease the profitability of ethanol production.

Two equations are estimated for the HFCS market. The HFCS market is an oligopoly. Thus, there is no supply equation for this market. Instead of a supply equation, a price equation was estimated along with a demand equation for this market. Based on the estimated demand equation, the domestic HFCS price has a negative impact on HFCS consumption while an increase in the sugar price and the flour price index (as a representative for food prices) increases HFCS consumption. Also, a sugar quota premium has a positive impact on HFCS consumption.

This means that imposing sugar import quota, and the corresponding decrease in sugar imports, increases HFCS consumption. On the other hand, sugar and domestic corn prices have a positive impact on the HFCS price. An increase in the domestic corn price increases HFCS production costs and, therefore, increases the HFCS price.

The sugar market model is composed of five equations including sugarcane and sugar beets supply equations, industrial and non-industrial sugar demand equations, and the sugar price equation. Estimated results show that sugarcane supply is a function of the sugar price, sugarcane yield, and rice prices. Sugar beet supply is a function of the sugar price, loan rates, and wheat prices. Both sugarcane and sugar beets supply are price inelastic. An interesting point on the sugar demand side is that the HFCS price has a positive impact on industrial demand for sugar while it does not affect non-industrial sugar demand. The sugar price has a negative impact on the quantity of sugar demanded by nonindustrial users. Regarding industrial demand for sugar, only the annual model shows that the sugar price has a negative impact on the quantity of sugar demanded.

There are five equations for the corn market. Corn demand equations are comprised of corn demand for feed, corn demand for HFCS production, and corn demand for other consumption (besides feed, HFCS, and ethanol). In fact, our ethanol supply equation, which was discussed previously in the discussion on the ethanol market, can be viewed as corn demand for ethanol production. Based on our estimation results, the domestic corn price has a negative impact on corn demand for feed while Cattle on Feed has a positive impact on corn demand. Also, the domestic corn price has a negative impact on corn demand for HFCS production while the sugar price and HFCS production capacity have a positive impact on this portion of corn demand. An increase in the domestic corn price decreases corn demand for “other consumption” but increases in the prices of bakery commodities results in increased corn demand. Corn

production (used in the annual model) is a positive function of the domestic corn price and corn production yield; corn supply (used in the quarterly model) is a positive function of the domestic corn price and quantity of corn production. However, estimation results indicate that corn prices are influenced by ethanol production, quantity of exported corn, quantity of corn used for HFCS production, quantity of corn used for feed, quantity of corn production, and weather condition.

Estimation results along with other collected information were used to answer the specific research questions mentioned earlier in this section. With regards to the first question, estimated results show that the “2007 Energy Independence and Security Act” will increase the domestic corn price through an increase in corn demand via increased ethanol production. An increase in corn demand, in turn, increases ethanol and HFCS production costs. An increase in HFCS production costs decreases the comparative advantage of HFCS over sugar and will encourage HFCS users to replace HFCS with sugar. Based on estimation results, HFCS will lose its comparative advantage over domestic raw sugar after 2009 and over domestic refined sugar after 2012. If corn prices were to reach \$6.76 per bushel, the HFCS production cost would be higher than the domestic refined sugar price. This will increase sugar prices and imports. In turn, increased corn prices will increase corn production. However, this increase in corn supply would not be sufficient, on its own, to bring corn prices back to their original level.

The second question concerns the “determination of the maximum quantity of corn-based ethanol production that is economically possible.” The market equilibrium quantity of corn-based ethanol is determined by ethanol supply and demand. Based on the estimation results, ethanol supply is dependent on corn and ethanol prices, while ethanol demand depends on ethanol and gasoline prices and governmental policies. Therefore, these factors determine the ethanol market equilibrium quantity and, therefore, the maximum quantity of corn-based ethanol production that is economically possible. *Ceteris paribus*, government policies, gasoline prices,

and corn prices are the most significant factors determining ethanol supply and demand and, by virtue of this, corn-based ethanol production.

Without government policies that mandate consumption levels for ethanol, ethanol supply and demand determine the optimum corn-based ethanol production levels based on gasoline and corn prices. In this case, depending on gasoline and corn prices, maximum corn-based ethanol production would be between 1.5 and 19.6 billion gallons per year in year 2015 (Table 4.13). For annual ethanol production greater than 19.6 billion gallons, the increase in corn prices would be so great that any advantages corn would have had over sugar for producing ethanol would be negated.

In the case of having “mandatory ethanol consumption,” the outcome will be different. In this case there will be a minimum quantity of ethanol consumption and production, equal to 15 billion gallons per year in 2015. Depending on the relative levels of corn and gasoline prices, annual corn-based ethanol production will be between 15 and 19.6 billion gallons in 2015.

With regards to the third question related to the “profitability of sugar-based ethanol production”, the U.S. sugar support program plays a critical role. Using raw sugar, at world sugar price levels, for producing ethanol, sugar can compete with corn when corn prices reach \$5.49 per bushel. Based on the estimation results, the corn price reaches \$5.49 per bushel when the ethanol production level approaches 9.3 billion gallons annually. Therefore, when importing raw sugar at world sugar prices, ethanol producers will use corn until ethanol production reaches 9.3 billion gallons per year. After that, depending on the effect of U.S. imports on the world sugar price, ethanol producers will use both imported raw sugar and corn to produce ethanol to reach to the mandatory level of 15 billion gallons per year.

With the sugar support program in force, raw and refined sugar cannot compete with corn in the near future. However, results show that costs of producing ethanol from sugarcane and

sugar beets will be comparable with corn-based ethanol production costs after 2012. As a result, importing raw sugar at the world sugar price is an alternative to reduce corn demand from ethanol production and therefore control the corn price.

The fourth question concerns “the impact of an ethanol subsidy, import tariffs, and the sugar import quota on the U.S. ethanol, corn, HFCS, and sugar markets.” The ethanol subsidy has had an important role in promoting the production of ethanol, especially in those times when the ethanol price was lower than the gasoline price. The ethanol subsidy increases ethanol production and increases corn demand for producing ethanol. This has a positive impact on corn prices and increases HFCS production costs.

The ethanol import tariff was primarily imposed to prevent foreign ethanol producers from gaining access to the domestic ethanol production tax credit. However, as estimation results show, among these different types of subsidies and import barriers, sugar import barriers have the most significant impact on the ethanol, corn and sweetener markets. The sugar support program regulates sugar prices in the United States and induces sugar users to replace sugar with HFCS. This increases corn prices through increased demand for corn and also reduces available corn for other uses, including ethanol production. In addition, high domestic sugar prices, resulting from the domestic sugar support program, increases the cost of sugar-based ethanol production and eliminates sugar as a viable feedstock for the production of ethanol. This forces ethanol producers to use corn, as the cheapest feedstock, to produce ethanol.

The last research question considers “the impact of the elimination of sugar import quotas on the U.S. HFCS, corn, and ethanol markets.” Removal of the sugar import quota changes the U.S. sugar market significantly so that sugar production and price decrease while sugar imports and consumption increase. Consequently, U.S. HFCS consumption decreases and available corn for ethanol production increases. Additionally, as mentioned previously, eliminating or

expanding the sugar import quota reduces domestic sugar prices and allows sugar to be considered as a viable feedstock for the production of ethanol. Using sugar for ethanol production reduces the amount of corn needed for ethanol production, suppresses the corn price, and stabilizes the corn market. From this point of view, removing the sugar import quota changes the situation for both the corn and ethanol markets. Note that importing sugar in a large volume for producing ethanol and replacing HFCS would serve to increase world sugar price. Therefore, in the case of eliminating or relaxing sugar import barriers, the final share of corn and sugar in the production of ethanol depends on the relative domestic corn and world sugar prices.

5.1. Future Research Recommendations

One shortcoming of this study involves the linkages between the world corn, sugar and ethanol markets. The United States is the largest ethanol producer and consumer in the world. The United States is also the world's largest corn producer and exporter and a major player in the world sugar market. Consequently, because of the closely intertwined relationship between the ethanol, corn, and sugar markets, U.S. ethanol production policies impact both corn and sugar at both the domestic and world market levels. This calls for the modeling of the linkages between the domestic markets for both corn and sugar to their respective world markets to better refine the results.

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APPENDIX A. ETHANOL HISTORY TIMELINE

1975: U.S. begins to phase out lead in gasoline. MTBE eventually replaced lead. (Between 2004 and 2006, MTBE banned in almost all states, due to groundwater contamination and health risks).

1980's: Oxygenates added to gasoline included MTBE and ETBE.

1988: Denver, Colorado, mandated ethanol oxygenates fuels for winter use to control carbon monoxide emissions. Other cities followed.

June 1989: Phase 1 Summer Volatility (RVP) Regulation.

1990: Clean Air Act Amendments mandated the winter use of oxygenated fuels in 39 major carbon monoxide non-attainment areas (based on EPA emissions standards for carbon dioxide not being met) and required year-round use of oxygenates in 9 severe ozone non-attainment areas in 1995.

1992: The Energy Policy Act of 1992 (EP Act) was passed by Congress to reduce our nation's dependence on imported petroleum by requiring certain fleets to acquire alternative fuel vehicles, which are capable of operating on nonpetroleum fuels. The Clean Air Act (1990) and Alternative Motor Fuels Act (1998 & 1992) contain provisions for mandating oxygenated fuel (RFG =Ethanol and MTBE). Requirements set for 2 types of clean-burning gasoline, RFG Federal Reformulated Gasoline and Wintertime Oxygenated Fuel.

May 1992: Phase 2 Summer Volatility (RVP) Regulation.

Nov 1992: Oxygenated Gasoline.

Dec 1994: Reformulated Gasoline Phase 1.

1995: The EPA began requiring the use of reformulated gasoline year round in metropolitan areas with the most smog.

1999: Some states began to pass bans on MTBE because traces of it were showing up in drinking water sources.

Late 1990's to Present: Major U.S. auto manufacturers begin selling Flexible Fuel Vehicles (FFV's) that can run on up to 85% ethanol.

Jan 2000: Reformulated Gasoline Phase 2

2003: California began switching from MTBE to ethanol to make reformulated gasoline.

(California was the first state to completely ban MTBE, effective January 1, 2004).

2003 to Present: Almost all states have followed California's lead, banning MTBE, (a few states still have lawsuits pending with the EPA for exemption from MTBE ban), resulting in MTBE being replaced by ethanol nationwide.

2005: The Energy Policy Act of 2005, written by the EPA contains regulations to ensure that gasoline sold in the United States contains a minimum volume of renewable fuel (ethanol is a renewable fuel).

Apr 2005: Bombardier Recreational Products (BRP - OMC) is the first marine manufacturer to receive the EPA "Clean Air Excellence Award", for their newly re-designed outboard engine called the Evinrude ETec, specifically designed to run on E10 ethanol gas (Almost all marine engines manufactured prior to 2000 prohibit use of alcohol fuel).

2006-Present: Many marine and auto engine owners report marine damage and severe engine failure caused by ethanol blend fuels - Investigations reveal gas sold contained over the legal limit of 10% for E10 or was used in an engine not designed for gasohol and all types of alcohol-blends of gas.

Sep 7, 2006: The Renewable Fuel Standard Program (RFS) is signed. This national renewable fuel program is designed to encourage the blending of renewable fuels (ethanol) into our nation's motor vehicle fuel.

Dec 2007: Energy Independence and Security Act signed by Congress and the President, which requires the use of 15 billion gallons of renewable (ethanol) fuel by 2015. In 2007 about 6.5 billion gallons were produced.

2007-2008: Surge in individual states mandating the use of 10% ethanol E10 gasoline.

Source: FUEL-TESTERS. Ethanol Alcohol Fuel Test Kits

APPENDIX B. COMPARING THE 2005 AND 2007 ENERGY ACTS

- The average annual volume of renewable fuel that must be contained in transportation fuel sold in the United States was increased from 5.4 billion gallons (as required under prior law) to 9 billion gallons (under EISA) in 2008 and from 7.5 to 15.2 billion gallons by 2012.
- The timeframe of the annual national mandate was extended, culminating in a total requirement of 36 billion gallons of renewable fuel by 2022.
- Beginning in 2009 the annual required volume of renewable fuel must include escalating volumes of advanced biofuel, cellulosic biofuel and biomass-based diesel (pursuant to the definitions discussed above). The EPA must ensure that transportation fuel sold in the United States contains at least the volumes specified by the EISA and, as noted, with respect to any renewable fuel produced from new facilities that commence construction after December 19, 2007. The EPA must ensure that a 20% reduction in lifecycle GHG emissions is achieved compared to baseline lifecycle GHG emissions
- The 2007 Energy Act requires studies and reports related to the impacts of the RFS, including a report that must be submitted to Congress in 2010, and every three years thereafter, assessing the future impacts of the RFS requirements on:
 - Environmental issues (including air quality, effects on hypoxia, pesticides, sediment, nutrient and pathogen levels in waters, acreage and function of waters, and soil environmental quality);

- Resource conservation issues (including soil conservation, water availability, and ecosystem health and biodiversity); and
- The growth and use of cultivated invasive or noxious plants and their impacts on the environment and agriculture.

Source: <http://www.beveridgediamond.com/news-270.html>

APPENDIX C. VARIABLES DEFINITION

BakP = Bakery Price Index

BaP = Barley Price

Car = Number Of Cars

CoEth = Corn Used in Ethanol

CoFeed = Corn Used for feed

CoLR = Corn Loan Rate

CoOthCon = Corn other consumption

CoStCh = Corn Stock change

CoY = Corn Yield

DdgP = Dried Distillers Grains (DDG) Price

DRaSuP = Domestic Raw Sugar Price

DxP = Dextrose Price Consumption

EthCon = Ethanol Consumption

EthP = Ethanol Price

FeP = Fertilizer Price

GasP = Gasoline Price

GfP = Gluten Feed Price

GmP = Gluten Meal Price

HfCon = HFCS Consumption

Ir = Interest Rate

NgP = Natural Gas Price

POP = Population

BaP = Barley Price

BvP = Beverage Price Index

Cattl = number of cattle on feed

CoEx = Corn Export

CoHf = Corn Used for HFCS

CoOilP = Corn Oil Price

CoPr = Corn Production

CotP = Cotton Price

DCoP = Domestic Corn Price

DHfP = Domestic HFCS Price

DRfSuP = Domestic Refined Sugar Price

EthIm = Ethanol Import

EthPr = Ethanol Production

FuP = Fuel Price

GDP = Gross Domestic Product

GLP = Glucose Price

GR = Governmental policies

HfPr = HFCS Production

HFStCh = HFCS Stock change

MeatP = Meat price

OatP = Oat Price

QP = Quota Premium

RicP = Rice Price

SuBeLR = Sugar Beets Loan Rate

SuBePr = Sugar Beets Production

SuCaLR = Sugarcane Loan Rate

SuCaPr = Sugarcane Supply

SuInd = Industrial Sugar demand

SuNoInd = Non-Industrial sugar Demand

T = Technology

WeCo = Weather Condition Variable

WHfP = World HFCS Price

WSuP = World Sugar Price

SoyP = Soybeans Price

SuBeP = Sugar Beets Price

SuBeY = Sugar Beets Yield

SuCaP = Sugarcane Price

SuCaY = Sugarcane Yield

SuNetIm = Sugar Net Import

SuStCh = Sugar Stock Change

WCoP = World Corn Price

WeSuCa = Weather Condition

WhP = Wheat Price

APPENDIX D. QUARTERLY DATA

T	Y	GDP ⁶	GDPDef ⁶	POP ⁶	CPI ⁶	HfPr ¹	HfCon ¹	DD
1	1980	5221.25	52.20	229.23	45.84	536	517	0
2	1980	5115.92	53.35	229.79	47.50	537	518	0
3	1980	5107.38	54.56	230.36	48.40	538	519	0
4	1980	5202.11	56.07	230.92	49.66	569	549	0
5	1981	5307.54	57.52	231.50	50.98	558	540	0
6	1981	5266.12	58.60	232.08	52.16	729	706	0
7	1981	5329.83	59.64	232.66	53.65	840	814	0
8	1981	5263.37	60.73	233.24	54.42	547	529	0
9	1982	5177.08	61.56	233.84	54.87	660	654	0
10	1982	5204.86	62.30	234.44	55.71	855	848	0
11	1982	5185.22	63.18	235.03	56.76	917	909	0
12	1982	5189.84	63.86	235.63	56.88	705	698	0
13	1983	5253.85	64.39	236.24	56.85	737	745	0
14	1983	5372.34	64.85	236.85	57.56	959	970	0
15	1983	5478.36	65.52	237.46	58.25	1103	1116	0
16	1983	5590.47	66.01	238.07	58.76	844	853	0
17	1984	5699.83	66.84	238.69	59.40	906	924	0
18	1984	5797.90	67.41	239.31	60.05	1168	1192	0
19	1984	5854.25	67.95	239.93	60.70	1230	1256	0
20	1984	5902.35	68.39	240.55	61.14	1034	1055	0
21	1985	5956.94	69.16	241.18	61.54	1117	1134	0
22	1985	6007.79	69.55	241.81	62.28	1418	1441	0
23	1985	6101.74	69.84	242.43	62.74	1538	1563	0
24	1985	6148.56	70.29	243.06	63.30	1197	1216	0
25	1986	6207.37	70.65	243.70	63.46	1148	1177	0
26	1986	6232.01	71.02	244.33	63.30	1522	1561	0
27	1986	6291.69	71.43	244.97	63.77	1480	1517	0
28	1986	6323.40	71.89	245.60	64.13	1198	1228	0
29	1987	6365.03	72.49	246.24	64.84	1239	1241	0
30	1987	6435.02	72.88	246.88	65.69	1588	1590	0
31	1987	6493.43	73.43	247.52	66.43	1587	1591	0
32	1987	6606.82	73.96	248.16	67.00	1272	1275	0
33	1988	6639.12	74.59	248.81	67.40	1310	1309	0
34	1988	6723.54	75.30	249.46	68.25	1653	1652	0
35	1988	6759.38	76.14	250.11	69.16	1670	1668	0
36	1988	6848.61	76.71	250.76	69.88	1317	1316	0
37	1989	6918.12	77.58	251.42	70.65	1360	1392	0
38	1989	6963.47	78.32	252.08	71.82	1725	1765	0
39	1989	7013.14	78.88	252.74	72.40	1542	1578	0
40	1989	7030.91	79.43	253.40	73.09	1341	1372	0
41	1990	7112.10	80.38	254.08	74.35	1460	1461	0

T	Y	GDP	GDPDef	POP	CPI	HfPr	HfCon	DD
42	1990	7130.26	81.31	254.75	75.11	1727	1728	0
43	1990	7130.75	82.03	255.43	76.40	1676	1677	0
44	1990	7076.86	82.65	256.10	77.64	1418	1419	0
45	1991	7040.83	83.63	256.79	78.28	1513	1514	0
46	1991	7086.48	84.17	257.48	78.75	1776	1777	0
47	1991	7120.74	84.76	258.16	79.37	1731	1732	0
48	1991	7154.12	85.21	258.85	79.97	1465	1466	0
49	1992	7228.23	85.72	259.55	80.53	1584	1611	0
50	1992	7297.93	86.19	260.25	81.18	1845	1866	0
51	1992	7369.50	86.58	260.95	81.82	1699	1723	0
52	1992	7450.69	87.03	261.65	82.40	1506	1527	0
53	1993	7459.72	87.71	262.36	83.10	1592	1616	0
54	1993	7497.51	88.19	263.07	83.74	1915	1939	0
55	1993	7536.00	88.57	263.78	84.07	1929	1955	0
56	1993	7637.41	89.04	264.49	84.65	1661	1663	0
57	1994	7715.06	89.58	265.21	85.19	1634	1648	0
58	1994	7815.68	89.95	265.93	85.73	2073	2083	0
59	1994	7859.47	90.53	266.64	86.49	2067	2065	0
60	1994	7951.65	90.95	267.36	86.90	1693	1685	0
61	1995	7973.73	91.53	268.08	87.61	1760	1762	0
62	1995	7987.97	91.86	268.81	88.39	2136	2126	0
63	1995	8053.06	92.29	269.53	88.77	2111	2097	0
64	1995	8111.96	92.73	270.25	89.20	1752	1748	0
65	1996	8169.19	93.33	270.97	90.01	1830	1833	0
66	1996	8303.09	93.66	271.70	90.90	2267	2241	0
67	1996	8372.70	93.95	272.42	91.39	2163	2141	0
68	1996	8470.57	94.45	273.14	92.04	1897	1841	0
69	1997	8536.05	95.05	273.87	92.66	1946	1920	0
70	1997	8665.83	95.21	274.59	93.03	2352	2311	0
71	1997	8773.72	95.53	275.32	93.40	2348	2286	0
72	1997	8838.41	95.85	276.04	93.77	2031	2000	0
73	1998	8936.19	96.09	276.77	94.02	2012	1975	0
74	1998	8995.29	96.25	277.50	94.52	2540	2439	0
75	1998	9098.86	96.60	278.23	94.89	2476	2399	0
76	1998	9237.08	96.93	278.96	95.22	2123	2066	0
77	1999	9315.52	97.33	279.70	95.59	2122	2072	0
78	1999	9392.58	97.67	280.43	96.52	2547	2482	0
79	1999	9502.24	98.01	281.17	97.12	2503	2440	0
80	1999	9671.09	98.43	281.90	97.72	2240	2188	0
81	2000	9695.63	99.32	282.64	98.68	2169	2129	0
82	2000	9847.89	99.75	283.38	99.73	2553	2482	0
83	2000	9836.60	100.26	284.12	100.52	2438	2400	0
84	2000	9887.75	100.67	284.86	101.07	2155	2103	1
85	2001	9875.58	101.48	285.61	102.03	2193	2165	1
86	2001	9905.91	102.25	286.35	103.10	2400	2370	1

T	Y	GDP	GDPDef	POP	CPI	HfPr	HfCon	DD
87	2001	9871.06	102.68	287.10	103.23	2442	2433	1
88	2001	9910.03	103.19	287.84	102.94	2201	2181	1
89	2002	9977.28	103.57	288.59	103.31	2105	2114	1
90	2002	10031.60	103.94	289.34	104.43	2541	2527	1
91	2002	10090.70	104.33	290.08	104.88	2498	2491	1
92	2002	10095.80	104.91	290.83	105.21	2158	2161	1
93	2003	10126.00	105.72	291.58	106.27	2119	2122	1
94	2003	10212.70	106.06	292.34	106.66	2484	2469	1
95	2003	10398.70	106.61	293.09	107.18	2412	2408	1
96	2003	10467.00	107.19	293.84	107.20	2135	2136	1
97	2004	10543.60	108.18	294.59	108.17	2183	2185	1
98	2004	10634.20	109.18	295.34	109.72	2446	2438	1
99	2004	10728.70	109.79	296.09	110.11	2359	2361	1
100	2004	10796.40	110.67	296.84	110.76	2076	2076	1
101	2005	10878.40	111.73	297.59	111.46	2143	2128	1
102	2005	10954.10	112.45	298.35	112.95	2446	2408	1
103	2005	11074.30	113.41	299.10	114.32	2454	2392	1
104	2005	11107.20	114.39	299.85	114.91	2185	2130	1
105	2006	11238.70	115.36	300.60	115.53	2256	2195	1
106	2006	11306.70	116.35	301.35	117.48	2519	2431	1
107	2006	11336.70	117.03	302.09	118.14	2454	2356	1
108	2006	11395.50	117.52	302.84	117.13	2147	2073	1
109	2007	11412.60	118.70	303.57	118.30	2179	2087	1
110	2007	11520.10	119.50	304.33	120.60	2485	2363	1
111	2007	11658.90	119.80	305.08	120.90	2392	2266	1
112	2007	11675.70	120.50	305.84	121.80	2226	2073	1

DHfP ¹	WRaSuP ¹	WRfSuP ¹	WSuP ⁶	DRaSuP ¹	QP	DRfSuP ¹	DRtRfSuP ¹	GIP ¹
17.27	20.13	23.26	19.89	21.84	4.25	28.71	30.97	9.83
21.93	28.18	31.76	27.66	28.89	2.58	36.30	39.27	13.24
26.69	31.74	35.26	31.40	32.64	2.55	41.17	46.80	16.93
28.66	36.01	38.91	35.72	37.09	2.76	47.00	53.93	17.40
23.00	24.69	30.14	24.56	26.50	3.80	35.50	51.73	16.52
22.00	16.44	20.16	16.43	18.76	4.47	27.47	40.33	15.92
21.15	14.25	16.92	14.25	17.33	5.75	25.43	35.07	16.63
19.72	12.35	14.81	12.33	16.34	7.36	24.63	32.90	14.84
14.08	12.43	14.44	12.41	17.69	9.61	27.50	33.63	14.03
14.46	8.17	11.79	8.18	19.50	20.32	26.77	33.80	14.03
15.85	6.84	9.70	6.78	21.83	26.51	28.20	34.30	13.43
12.80	6.23	9.51	6.25	20.69	25.38	28.00	35.40	12.75
15.16	6.19	9.71	6.22	21.62	27.08	24.53	35.73	11.63
17.56	8.93	12.11	8.90	22.52	23.67	26.33	35.73	11.77
20.92	10.17	12.78	10.17	22.28	20.78	26.96	36.50	14.76
20.92	8.67	10.99	8.57	21.75	22.43	26.56	36.73	13.29
19.45	6.65	8.88	6.68	21.80	25.47	26.62	36.47	12.98
19.49	5.67	7.64	5.71	22.03	27.18	26.42	36.60	13.36
21.99	4.21	7.10	4.23	21.77	28.90	25.35	36.00	13.81
18.84	4.19	7.22	4.19	21.35	28.07	24.24	36.23	11.39
17.96	3.68	6.24	3.71	20.67	27.56	23.31	35.90	10.69
18.08	2.96	5.97	3.01	21.11	29.07	23.26	35.20	11.31
18.81	4.21	7.10	4.23	20.44	25.84	23.40	35.33	11.13
16.14	5.30	7.86	5.27	19.15	21.93	22.75	34.93	11.33
16.90	5.83	8.18	5.81	20.88	23.74	23.34	35.30	11.43
17.22	7.45	9.34	7.45	20.91	21.26	23.27	35.40	10.62
19.08	5.25	8.22	5.27	20.90	24.52	23.85	34.83	10.16
19.08	5.67	8.16	5.68	21.12	24.08	23.06	34.80	10.16
16.93	7.10	9.11	7.14	21.67	22.41	23.43	35.00	10.16
14.73	6.58	8.51	6.61	21.96	23.37	23.99	34.97	10.16
17.61	5.80	8.18	5.85	21.94	24.23	24.33	35.43	10.16
16.72	7.38	9.18	7.43	21.73	21.35	22.63	35.73	9.93
11.34	8.84	10.86	8.87	22.03	19.52	22.75	35.73	9.85
16.30	9.29	11.50	9.34	22.28	18.96	24.30	35.60	9.85
21.31	11.77	12.98	11.79	22.37	15.30	27.45	36.90	13.41
16.92	10.80	12.70	10.78	21.81	15.78	27.27	38.17	13.54
16.56	10.57	13.52	10.61	22.02	16.15	29.08	39.33	13.05
20.37	12.23	16.26	12.25	22.58	14.38	29.43	39.87	13.65
22.50	14.03	21.14	14.06	23.54	13.09	28.67	40.33	14.89
17.55	14.32	17.69	14.30	23.07	12.01	29.04	40.57	13.03
17.55	14.80	19.53	14.72	23.21	11.41	30.50	42.13	13.94

DHfP	WRaSuP	WRfSuP	WSuP	DRaSuP	QP	DRfSuP	DRtRfSuP	GlP
20.25	14.28	19.67	14.28	23.57	12.38	30.50	42.83	14.68
22.95	11.28	16.12	11.32	23.31	15.69	30.50	43.13	15.38
18.00	9.83	13.95	9.73	22.97	17.05	28.37	43.00	13.00
18.00	8.89	13.55	8.82	21.58	16.30	26.63	43.27	13.38
20.70	8.60	13.28	8.43	21.31	16.36	25.96	43.20	15.85
24.30	9.70	14.07	9.74	21.71	15.09	25.33	42.83	15.90
20.70	8.97	12.73	8.92	21.67	15.94	24.68	41.90	16.48
20.70	8.24	12.10	8.17	21.43	16.47	26.13	42.27	16.48
20.70	9.89	12.95	9.81	21.11	13.93	26.30	41.63	16.48
23.39	9.79	12.89	9.83	21.33	14.06	25.00	41.20	16.48
18.00	8.45	11.63	8.47	21.37	15.65	24.31	41.00	11.33
17.81	9.21	12.21	9.14	21.16	14.46	23.08	40.93	11.11
17.19	11.17	13.14	11.13	21.51	12.40	23.50	40.63	12.71
21.15	9.47	12.72	9.52	21.90	14.73	26.92	40.40	14.83
19.18	10.28	13.12	10.29	21.89	13.70	27.08	40.20	14.28
18.81	10.93	14.24	10.95	21.97	12.93	25.58	40.43	14.89
22.32	11.64	15.58	11.55	22.23	12.46	24.83	39.90	15.32
22.03	12.13	15.53	12.15	22.11	11.52	24.90	40.00	15.95
17.50	13.80	17.29	13.79	21.83	9.26	25.29	39.63	14.88
16.53	14.63	18.12	14.60	22.60	9.13	25.50	39.80	14.28
16.62	13.70	17.51	13.72	22.98	10.48	25.24	39.53	14.26
16.62	13.31	18.95	12.75	23.62	12.24	25.00	39.70	14.20
18.38	12.10	17.38	12.04	22.63	11.87	27.58	40.30	15.23
14.53	12.87	17.80	12.75	22.55	10.88	29.06	40.47	16.38
14.44	12.30	17.94	11.84	22.60	11.84	29.57	41.23	16.38
14.44	12.34	16.51	12.37	22.23	10.79	29.17	42.60	16.38
14.44	11.44	14.30	10.86	22.21	12.33	29.00	42.87	16.38
11.10	11.12	13.97	10.88	21.92	11.91	28.71	43.13	11.75
10.56	11.69	14.58	11.29	21.70	11.20	27.83	43.50	10.59
10.56	12.44	15.08	11.53	22.18	11.40	26.68	43.50	10.59
10.56	12.98	13.68	11.91	22.03	10.80	25.13	42.90	10.59
11.53	11.14	12.84	10.69	21.79	11.81	25.50	43.07	13.57
10.18	9.92	11.81	9.00	22.29	14.06	25.83	43.00	12.33
9.90	9.14	11.11	8.11	22.26	14.91	26.17	43.33	12.33
10.71	8.52	10.58	7.87	21.90	14.73	26.97	42.50	12.41
11.33	7.19	10.45	6.99	22.45	16.17	27.11	43.43	11.98
11.62	5.98	9.28	5.74	22.61	17.48	27.00	43.30	12.45
11.62	6.49	8.93	5.92	21.32	15.85	27.00	43.33	12.45
12.27	6.48	7.73	6.41	18.27	12.14	25.73	43.00	13.39
13.03	5.56	7.73	5.36	17.80	12.60	22.38	43.27	12.87
13.03	7.51	9.45	7.04	19.29	12.28	19.92	42.20	12.76

DHfP	WRaSuP	WRfSuP	WSuP	DRaSuP	QP	DRfSuP	DRtRfSuP	GlP
13.03	10.56	11.47	10.03	18.24	8.17	19.57	42.43	12.76
11.96	10.40	11.24	9.88	21.03	11.04	21.35	41.73	12.93
13.38	10.18	10.73	9.38	21.13	11.52	22.63	43.33	14.20
13.38	9.68	11.67	8.58	21.25	12.28	21.26	43.40	14.20
13.38	8.95	11.78	7.87	20.87	12.60	23.21	43.93	14.20
14.48	7.66	10.99	7.10	21.17	13.67	26.15	43.00	14.40
15.21	7.35	11.16	6.30	20.55	13.79	26.23	43.47	14.63
15.21	7.17	10.13	5.35	19.73	13.77	24.38	43.37	14.63
15.91	8.14	10.08	6.02	21.14	14.42	25.22	43.43	15.05
16.72	8.84	10.04	7.28	22.06	14.05	27.34	42.13	15.88
16.20	8.73	10.75	8.03	21.89	13.05	27.14	42.80	15.88
16.20	7.39	9.92	6.89	21.76	13.94	27.88	42.90	15.88
16.20	7.06	9.51	6.57	21.31	13.75	25.71	43.07	15.88
16.93	6.84	8.76	6.21	20.73	13.55	24.09	41.93	16.27
17.91	7.22	9.76	6.13	20.66	13.43	23.57	42.70	16.81
17.96	8.23	10.90	7.00	20.53	12.34	23.50	42.57	16.81
17.96	9.09	11.58	8.24	20.24	10.90	23.50	42.70	16.81
18.10	9.89	11.24	8.81	20.42	10.48	23.36	42.60	16.94
19.01	10.47	11.91	9.05	20.49	10.27	23.42	43.50	17.75
19.01	10.29	12.04	8.69	21.69	11.51	24.81	43.03	17.75
18.87	11.19	14.70	10.10	21.18	9.69	30.95	43.10	17.64
17.61	13.45	14.09	12.45	21.76	8.10	38.97	44.53	16.81
18.31	18.07	19.12	17.11	23.59	5.61	36.03	46.67	17.43
18.31	17.41	21.36	16.68	23.45	5.76	35.46	49.43	17.43
18.54	14.20	18.81	13.72	21.70	6.75	33.57	51.20	17.64
22.23	12.31	16.73	11.65	19.82	6.98	27.35	51.03	20.89
24.51	11.64	15.21	10.60	20.49	8.36	25.13	51.70	21.01
24.51	10.89	14.50	9.30	21.17	9.84	25.00	51.40	21.01
24.51	11.82	13.18	9.80	21.98	10.07	25.45	51.93	21.01
28.41	12.05	13.11	10.10	20.31	8.38	24.67	50.87	24.75

DxP ¹	SuBegSt ¹	SuEndSt ¹	SuNetIm ¹	SuBePr ¹	SuCaPr ¹	SuCon ¹	SuBv ¹	SuInd ¹
22.28	3701	3408	762	717	722	2494	508	1512
28.50	3408	2529	987	417	349	2632	567	1549
31.65	2529	1691	1261	226	385	2710	602	1561
34.16	1691	3082	815	1692	1229	2345	444	1344
32.29	3082	3292	824	777	817	2208	440	1340
30.05	3292	2349	728	467	394	2532	504	1507
28.59	2349	1576	1260	298	394	2725	502	1585
27.17	1576	3461	1113	1640	1437	2305	382	1261
49.52	3461	3666	813	894	581	2083	373	1274
48.77	3666	2723	701	462	312	2418	430	1378
47.87	2723	1649	643	322	361	2400	433	1435
47.04	1649	3068	667	1482	1522	2252	347	1218
44.84	3068	3123	567	635	931	2078	329	1249
45.79	3123	2312	639	356	389	2195	344	1291
45.25	2312	1408	853	219	373	2349	325	1371
44.86	1408	2570	475	1378	1499	2190	250	1212
44.24	2570	2928	868	715	804	2029	251	1231
43.75	2928	2319	689	447	376	2121	259	1235
43.43	2319	1611	836	297	397	2238	236	1264
43.74	1611	3005	606	1600	1254	2066	162	1080
40.19	3005	3417	750	627	944	1909	102	1079
38.39	3417	2686	516	387	338	1972	96	1109
38.11	2686	1760	543	301	380	2150	78	1139
37.77	1760	3126	380	1554	1436	2004	64	1022
37.68	3126	3384	457	728	892	1819	67	1010
37.77	3384	2540	326	393	344	1907	73	1051
36.93	2540	1652	500	313	368	2069	70	1088
35.60	1652	3222	332	1767	1462	1991	56	1016
35.06	3222	3497	158	933	1092	1908	55	1066
33.09	3497	2476	214	457	309	2001	57	1109
33.75	2476	1497	302	496	369	2146	51	1164
35.69	1497	3195	157	2013	1640	2112	50	1061
36.29	3195	3567	244	1038	1041	1951	70	1048
35.84	3567	2467	111	465	307	1983	64	1064
37.59	2467	1316	354	306	336	2147	52	1132
38.11	1316	3132	329	1849	1745	2107	51	1056
37.74	3132	3402	368	851	974	1923	55	1053
34.81	3402	2364	338	396	281	2053	67	1153
34.53	2364	1224	424	300	317	2181	53	1152
33.52	1224	2833	70	1943	1779	2183	47	1114
32.95	2833	3079	547	893	782	1976	60	1120

DxP	SuBegSt	SuEndSt	SuNetIm	SuBePr	SuCaPr	SuCon	SuBv	SuInd
32.62	3079	2113	518	283	289	2056	61	1139
32.07	2113	1148	699	347	305	2316	53	1213
31.55	1148	2730	465	1961	1471	2315	55	1177
31.30	2730	3488	713	963	1063	1981	49	1111
31.11	3488	2431	372	372	316	2117	53	1142
30.87	2431	1381	577	422	304	2353	54	1244
30.64	1381	3039	86	2088	1778	2295	48	1097
30.42	3039	3624	393	1010	1167	1985	39	1110
30.18	3624	2759	571	464	279	2178	43	1141
29.94	2759	1450	351	496	235	2390	43	1243
29.73	1450	3225	129	2164	1756	2273	39	1096
29.48	3225	3904	330	1237	1151	2039	38	1162
29.26	3904	3014	459	527	296	2172	41	1194
29.14	3014	1704	415	464	243	2432	42	1301
28.94	1704	3512	172	2021	1892	2277	37	1147
30.23	3512	4019	393	1109	1126	2121	34	1208
30.33	4019	2666	273	363	275	2265	40	1255
30.06	2666	1337	333	597	272	2532	46	1397
29.68	1337	3139	136	2115	1812	2260	36	1117
29.11	3139	3929	462	1204	1229	2105	41	1215
28.85	3929	2575	82	679	196	2311	49	1274
28.73	2575	1241	514	496	198	2542	41	1402
28.59	1241	2909	70	1988	1989	2379	38	1212
28.33	2909	3285	438	1010	1119	2191	47	1254
28.05	3285	2285	661	522	173	2355	59	1329
27.90	2285	1390	1054	397	174	2519	48	1369
27.70	1390	3195	361	1981	1894	2430	42	1250
27.52	3195	3901	774	1082	993	2143	43	1251
27.41	3901	2734	555	544	135	2401	49	1360
27.30	2734	1487	767	405	171	2591	35	1410
27.20	1487	3377	246	1945	2143	2443	31	1252
28.95	3377	3918	398	1252	1124	2233	38	1318
32.43	3918	2881	567	618	205	2428	50	1409
32.30	2881	1679	633	574	159	2568	40	1436
32.19	1679	3421	251	1883	2066	2458	38	1393
30.77	3421	4219	363	1253	1391	2208	46	1308
16.32	4219	3183	490	741	285	2553	52	1483
16.22	3183	1639	363	544	204	2655	43	1486
16.12	1639	3855	114	2134	2549	2580	38	1355
15.96	3855	4553	332	1487	1197	2318	38	1358
15.79	4553	3497.794	518	734	177	2484	44	1377

DxP	SuBegSt	SuEndSt	SuNetIm	SuBePr	SuCaPr	SuCon	SuBv	SuInd
15.67	3497.794	2216.12	557	620	153	2611	40	1444
15.58	2216.12	4336.536	96	2081	2507	2564	45	1312
15.44	4336.536	5174.624	507	1430	1271	2370	39	1366
15.28	5174.624	3705.686	189	669	158	2486	39	1439
15.26	3705.686	2179.678	402	499	153	2580	38	1377
16.76	2179.678	4525.131	359	1971	2490	2474	41	1232
17.18	4525.131	5109.084	351	1228	1232	2227	40	1232
17.00	5109.084	3405.95	235	379	122	2439	50	1316
16.92	3405.95	1527.783	289	338	140	2645	51	1369
17.35	1527.783	3431.663	335	1960	2106	2497	48	1219
18.58	3431.663	4034.964	110	1227	1449	2183	49	1227
18.52	4034.964	3017.064	467	640	235	2360	55	1261
18.43	3017.064	1670.041	355	589	173	2464	57	1353
19.11	1670.041	4087.942	306	2248	2368	2504	54	1193
19.28	4087.942	4849.411	265	1511	1272	2286	58	1246
19.00	4849.411	3465.471	229	578	177	2368	64	1324
18.94	3465.471	1897.331	456	355	140	2520	58	1377
19.48	1897.331	4029.174	347	2229	2104	2547	63	1308
19.83	4029.174	4437.789	318	1463	962	2335	59	1268
19.57	4437.789	2925.875	300	543	116	2471	58	1357
19.33	2925.875	1331.649	613	375	83	2666	60	1362
19.23	1331.649	3357.043	662	2043	1892	2571	60	1298
19.71	3357.043	4150.407	948	1437	843	2436	57	1229
19.66	4150.407	3072.384	865	409	135	2487	58	1262
19.74	3072.384	1697.526	675	554	86	2690	57	1328
22.99	1697.526	4038.985	440	2199	2092	2389	57	1237
23.12	4038.985	4774.192	363	1626	1054	2307	67	1296
22.68	4774.192	3372.058	295	662	175	2535	82	1402
22.85	3372.058	1798.5	471	521	117	2682	78	1441
24.92	1798.5	4007.967	415	2105	2204	2514	85	1321

SuNoInd ¹	SuCaY ¹	SuBeY ¹	SuCaLR ¹	SuBeLR ¹	WeSuCa ¹	WeSuBe ¹	OatP ¹	RicP ¹
745.05	37.42	19.75	13.00	15.15	0	0	1.37	10.86
778.53	37.42	19.75	13.00	15.15	0	0	1.43	11.03
931.15	37.42	19.75	13.00	15.15	0	0	1.55	10.53
838.83	37.42	19.75	13.00	15.15	0	0	1.80	11.87
701.91	36.56	22.43	0.00	0.00	0	0	2.02	13.20
850.58	36.56	22.43	0.00	0.00	0	0	2.03	13.00
952.19	36.56	22.43	0.00	0.00	0	0	1.77	11.77
883.91	36.56	22.43	0.00	0.00	0	0	1.87	9.80
665.50	40.62	20.34	16.75	19.70	0	1	3.63	9.26
873.04	40.62	20.34	16.75	19.70	0	1	3.51	8.54
797.60	40.62	20.34	16.75	19.70	0	1	2.53	7.77
877.92	40.62	20.34	16.75	19.70	0	1	2.44	7.86
684.47	37.09	19.88	17.00	20.15	1	0	2.60	8.10
751.57	37.09	19.88	17.00	20.15	1	0	2.66	8.11
815.18	37.09	19.88	17.00	20.15	1	0	2.55	8.28
824.79	37.09	19.88	17.00	20.15	1	0	2.85	8.75
656.45	37.12	20.20	17.50	20.86	1	0	3.09	8.68
737.79	37.12	20.20	17.50	20.86	1	0	3.03	8.31
816.90	37.12	20.20	17.50	20.86	1	0	2.69	8.19
842.08	37.12	20.20	17.50	20.86	1	0	2.75	8.10
696.79	37.18	20.44	17.75	20.76	0	0	2.77	7.99
725.20	37.18	20.44	17.75	20.76	0	0	2.61	7.98
860.78	37.18	20.44	17.75	20.76	0	0	1.90	7.65
840.62	37.18	20.44	17.75	20.76	0	0	1.82	7.76
681.26	38.55	21.13	18.00	21.06	0	0	1.83	7.79
721.90	38.55	21.13	18.00	21.06	0	0	1.81	4.63
836.31	38.55	21.13	18.00	21.06	0	0	1.44	3.91
835.59	38.55	21.13	18.00	21.06	0	0	2.01	3.82
708.38	36.01	22.42	18.00	21.09	0	0	2.25	3.67
752.33	36.01	22.42	18.00	21.09	0	0	2.33	3.65
831.08	36.01	22.42	18.00	21.09	0	0	2.10	3.88
907.00	36.01	22.42	18.00	21.09	0	0	2.48	7.14
765.83	35.89	19.07	18.00	21.16	0	0	2.68	8.84
779.76	35.89	19.07	18.00	21.16	0	0	3.07	8.19
862.89	35.89	19.07	18.00	21.16	0	0	3.84	7.47
906.82	35.89	19.07	18.00	21.16	0	0	3.55	6.78
715.34	34.94	19.41	18.00	21.37	0	0	3.49	6.62
762.06	34.94	19.41	18.00	21.37	0	0	2.87	6.86
859.66	34.94	19.41	18.00	21.37	0	0	2.02	7.48
921.58	34.94	19.41	18.00	21.37	0	0	2.04	7.16
709.17	36.45	19.98	18.00	21.54	0	0	1.92	7.52

SuNoInd	SuCaY	SuBeY	SuCaLR	SuBeLR	WeSuCa	WeSuBe	OatP	RicP
764.75	36.45	19.98	18.00	21.54	0	0	1.87	7.29
932.64	36.45	19.98	18.00	21.54	0	0	1.44	6.64
967.27	36.45	19.98	18.00	21.54	0	0	1.49	6.15
788.35	34.09	20.34	18.00	21.93	0	0	1.46	6.74
756.67	34.09	20.34	18.00	21.93	0	0	1.44	7.43
968.64	34.09	20.34	18.00	21.93	0	0	1.38	7.35
955.33	34.09	20.34	18.00	21.93	0	0	1.55	7.82
833.58	33.17	20.65	18.00	22.85	0	0	1.73	7.86
800.08	33.17	20.65	18.00	22.85	0	0	1.75	7.20
1024.21	33.17	20.65	18.00	22.85	0	0	1.56	6.67
1010.14	33.17	20.65	18.00	22.85	0	0	1.57	6.62
815.62	33.17	18.62	18.00	23.33	0	1	1.71	6.01
782.85	33.17	18.62	18.00	23.33	0	1	1.75	5.25
1002.15	33.17	18.62	18.00	23.33	0	1	1.58	5.07
988.38	33.17	18.62	18.00	23.33	0	1	1.63	7.58
763.00	33.35	22.07	18.00	23.62	0	0	1.66	9.67
670.00	33.35	22.07	18.00	23.62	0	0	1.60	9.49
980.00	33.35	22.07	18.00	23.62	0	0	1.36	7.13
955.00	33.35	22.07	18.00	23.62	0	0	1.37	6.58
764.00	33.31	19.76	18.00	22.90	0	1	1.43	6.75
902.00	33.31	19.76	18.00	22.90	0	1	1.57	6.89
1009.00	33.31	19.76	18.00	22.90	0	1	1.66	7.66
1026.00	33.31	19.76	18.00	22.90	0	1	1.91	9.17
816.00	33.38	20.16	18.00	22.90	0	0	2.20	9.25
903.00	33.38	20.16	18.00	22.90	0	0	2.49	9.62
1001.00	33.38	20.16	18.00	22.90	0	0	2.17	9.97
1039.00	33.38	20.16	18.00	22.90	0	0	1.96	9.63
819.00	34.88	20.92	18.00	22.90	0	0	2.00	10.08
907.00	34.88	20.92	18.00	22.90	0	0	1.98	10.13
1059.00	34.88	20.92	18.00	22.90	0	0	1.68	9.95
1044.00	34.88	20.92	18.00	22.90	0	0	1.72	9.86
815.00	36.86	22.40	18.00	22.90	0	0	1.72	9.66
894.00	36.86	22.40	18.00	22.90	0	0	1.60	9.45
1007.00	36.86	22.40	18.00	22.90	0	0	1.15	9.34
1046.00	36.86	22.40	18.00	22.90	0	0	1.18	9.14
812.00	35.67	21.88	18.00	22.90	0	0	1.26	9.01
916.00	35.67	21.88	18.00	22.90	0	0	1.28	8.32
1022.00	35.67	21.88	18.00	22.90	0	0	1.08	7.11
1054.00	35.67	21.88	18.00	22.90	0	0	1.15	5.96
831.16	35.11	23.70	18.00	22.90	0	0	1.27	5.81
955.34	35.11	23.70	18.00	22.90	0	0	1.30	5.69

SuNoInd	SuCaY	SuBeY	SuCaLR	SuBeLR	WeSuCa	WeSuBe	OatP	RicP
1025.07	35.11	23.70	18.00	22.90	0	0	0.98	5.61
1080.93	35.11	23.70	18.00	22.90	0	0	1.13	5.66
859.30	33.78	20.72	18.00	22.90	0	1	1.22	5.75
914.16	33.78	20.72	18.00	22.90	0	1	1.27	5.41
1041.52	33.78	20.72	18.00	22.90	0	1	1.28	5.00
1111.77	33.78	20.72	18.00	22.90	0	1	1.73	4.31
883.97	34.88	20.36	18.00	22.90	0	0	1.88	4.15
983.51	34.88	20.36	18.00	22.90	0	0	1.89	3.95
1130.80	34.88	20.36	18.00	22.90	0	0	1.64	3.95
1110.01	34.88	20.36	18.00	22.90	0	0	1.79	4.24
869.33	34.32	22.79	18.00	22.90	0	0	1.95	4.40
1010.08	34.32	22.79	18.00	22.90	0	0	1.80	4.96
1004.96	34.32	22.79	18.00	22.90	0	0	1.32	5.93
1154.33	34.32	22.79	18.00	22.90	0	0	1.34	7.83
922.31	30.98	22.97	18.00	22.90	1	0	1.44	8.42
948.44	30.98	22.97	18.00	22.90	1	0	1.50	8.92
1011.58	30.98	22.97	18.00	22.90	1	0	1.24	8.92
1073.83	30.98	22.97	18.00	22.90	1	0	1.37	7.45
921.64	28.81	22.07	18.00	22.90	1	0	1.51	7.09
967.01	28.81	22.07	18.00	22.90	1	0	1.49	6.97
1099.14	28.81	22.07	18.00	22.90	1	0	1.35	6.73
1038.21	28.81	22.07	18.00	22.90	1	0	1.44	7.37
880.99	33.03	26.13	18.00	22.90	0	0	1.55	7.96
976.46	33.03	26.13	18.00	22.90	0	0	1.56	8.10
1028.36	33.03	26.13	18.00	22.90	0	0	1.45	8.70
970.66	33.03	26.13	18.00	22.90	0	0	1.66	10.15
860.58	34.20	25.60	18.00	22.90	0	0	1.96	10.17
979.94	34.20	25.60	18.00	22.90	0	0	2.07	10.07
1052.65	34.20	25.60	18.00	22.90	0	0	1.94	10.17
983.81	34.20	25.60	18.00	22.90	0	0	2.13	11.00

BaP ¹	SorgP ¹	WhP ¹	CotP ⁶	SoyP ¹	SoyMeP ¹	BakP ³	FIP ³	BVP ³
NA	5.23	3.72	93.15	6.18	NA	80.80	88.60	88.53
NA	5.30	3.65	87.70	5.77	NA	83.13	90.90	90.73
NA	6.32	3.91	95.45	7.17	NA	84.37	93.67	92.70
NA	6.66	4.24	98.63	7.89	NA	86.87	93.60	93.57
NA	6.50	4.16	95.69	7.63	NA	89.80	96.53	94.97
NA	6.16	3.91	87.51	7.35	NA	91.50	97.23	95.40
NA	5.30	3.63	81.08	6.68	202.00	92.37	98.10	95.20
NA	5.03	3.81	71.59	6.03	194.22	93.67	97.37	95.47
2.46	5.17	3.72	70.13	6.05	200.53	94.97	97.83	97.53
2.44	5.17	3.57	74.49	6.19	200.75	95.80	99.27	98.10
2.46	4.52	3.33	75.90	5.60	182.57	96.60	99.93	97.80
2.44	4.83	3.47	69.50	5.29	181.63	97.23	98.10	98.37
2.21	5.44	3.60	75.10	5.68	191.33	98.53	98.30	99.73
2.09	5.94	3.66	82.73	6.02	198.67	99.30	99.30	99.57
2.13	6.00	3.53	89.70	7.37	232.67	99.93	100.70	99.33
2.23	5.98	3.54	88.86	7.84	237.67	100.87	98.97	100.47
2.30	5.83	3.46	87.89	7.60	209.00	102.57	101.00	101.93
2.51	5.90	3.58	87.20	7.98	200.33	103.40	101.87	102.17
2.53	4.89	3.38	75.89	6.51	166.00	104.83	103.53	102.20
2.62	4.83	3.42	72.76	5.97	152.67	105.93	101.37	102.83
2.35	5.20	3.38	69.09	5.85	140.67	107.07	104.00	104.37
2.26	5.12	3.27	64.78	5.73	123.00	107.77	105.43	104.60
2.22	4.08	2.94	57.43	5.17	130.00	108.50	107.10	103.93
2.19	4.28	3.19	48.38	4.93	150.67	109.33	104.93	104.23
2.02	4.34	3.21	52.86	5.19	166.33	109.83	106.23	110.30
1.95	4.40	2.95	44.98	5.22	169.00	110.40	107.23	111.53
2.04	3.01	2.26	39.32	4.98	178.38	111.63	108.03	110.10
1.81	3.19	2.41	54.58	4.62	165.70	112.37	105.07	109.63
1.57	3.16	2.56	64.87	4.71	162.82	113.60	106.53	110.83
1.56	3.44	2.58	74.02	5.15	188.47	114.73	107.90	107.77
1.62	3.16	2.40	84.48	5.10	190.67	115.43	109.20	105.87
1.71	3.47	2.67	75.70	5.34	219.67	116.50	106.53	105.50
1.88	3.77	2.76	68.67	5.91	206.67	118.60	107.23	107.43
1.83	4.14	3.04	66.70	7.18	254.00	120.10	108.00	107.47
1.78	5.08	3.62	59.53	8.25	277.67	122.87	113.83	107.20
1.71	4.83	3.89	59.17	7.50	271.97	125.50	113.53	108.03
2.80	5.00	4.04	64.04	7.54	258.73	127.97	115.83	110.73
2.92	4.90	3.96	76.65	7.18	238.85	130.53	119.10	111.63
2.72	4.41	3.75	82.48	6.20	240.07	132.77	123.87	111.50
2.71	4.67	3.75	80.62	5.62	198.20	134.80	121.90	111.33
2.49	4.64	3.58	76.69	5.62	177.70	136.80	123.43	112.93

BaP	SorgP	WhP	CotP	SoyP	SoyMeP	BakP	FlP	BVP
2.45	4.96	3.32	86.22	5.89	183.13	138.67	124.43	112.80
2.38	4.73	2.61	84.78	5.99	186.88	140.13	128.20	114.17
2.25	4.49	2.41	82.55	5.79	178.52	141.27	124.53	114.27
2.14	4.85	2.46	84.27	5.71	173.03	143.30	125.83	115.63
2.10	4.68	2.60	83.81	5.67	182.62	144.03	126.70	114.77
1.96	4.69	2.64	74.94	5.55	191.33	145.20	126.63	112.93
2.12	4.85	3.25	64.60	5.47	189.88	146.37	123.43	113.13
2.21	5.26	3.68	57.08	5.60	185.10	148.10	130.30	115.40
2.15	4.87	3.57	60.82	5.82	195.45	149.93	133.07	114.63
2.17	4.26	3.12	60.56	5.45	186.42	151.57	135.67	114.07
1.92	4.22	3.16	53.27	5.41	183.37	152.03	131.23	112.93
2.01	4.31	3.33	59.76	5.60	184.08	153.23	132.97	114.47
2.02	4.18	3.07	59.91	5.81	191.25	155.03	132.57	114.60
1.98	4.40	2.97	56.22	6.44	216.30	156.67	133.67	114.10
1.90	5.04	3.45	56.19	6.32	203.37	157.77	130.57	115.20
2.08	5.38	3.63	76.56	6.72	197.37	159.30	134.13	116.03
2.02	4.85	3.40	85.16	6.69	192.72	161.33	134.80	115.63
2.00	4.24	3.29	78.08	5.66	178.07	163.30	137.07	128.73
1.98	4.40	3.75	79.06	5.36	162.23	163.53	133.13	132.27
2.05	4.64	3.61	101.74	5.46	154.87	164.77	138.63	133.30
2.16	4.44	3.66	111.14	5.60	160.47	166.67	139.57	132.03
2.53	5.52	4.30	90.58	5.90	172.65	168.43	143.50	131.27
2.81	6.51	4.80	89.75	6.44	207.20	169.53	141.50	130.30
3.18	7.27	4.96	85.31	6.93	228.97	172.37	146.90	129.87
3.30	8.28	5.44	83.01	7.51	244.13	175.10	148.97	129.20
3.11	6.72	4.56	77.30	7.74	263.37	177.63	157.83	127.97
2.74	4.96	4.11	76.54	6.92	250.20	179.17	152.70	127.23
2.55	5.08	3.95	80.27	7.49	264.03	180.20	156.77	128.77
2.33	5.10	3.90	79.53	8.26	294.30	180.73	157.43	133.37
2.31	4.59	3.48	80.68	7.16	275.05	181.53	159.03	136.57
2.45	5.09	3.52	76.44	6.69	232.37	182.10	151.83	134.80
2.42	5.04	3.31	69.80	6.55	189.92	183.60	157.47	134.37
2.26	4.53	3.00	66.33	6.23	163.70	184.97	160.20	133.20
2.04	4.10	2.44	68.14	5.61	155.15	186.27	162.40	132.17
1.99	4.09	2.86	57.85	5.31	142.20	186.83	156.17	132.33
1.94	4.13	2.74	56.23	4.91	134.70	188.20	160.37	134.17
1.90	3.95	2.54	58.71	4.52	135.60	189.37	162.07	134.27
2.18	3.62	2.44	51.62	4.38	141.68	189.67	166.57	134.33
2.04	3.60	2.58	45.95	4.45	154.10	190.50	154.73	134.40
2.14	4.08	2.55	52.72	4.77	169.92	191.50	159.17	138.00
2.19	3.99	2.55	59.58	5.04	181.44	193.00	161.10	137.47

BaP	SorgP	WhP	CotP	SoyP	SoyMeP	BakP	FlP	BVP
2.28	3.52	2.38	60.31	4.52	166.92	195.30	165.23	138.23
1.95	4.32	2.79	63.58	4.59	182.37	196.63	155.13	137.33
2.10	4.44	2.85	59.73	4.51	168.53	199.37	163.40	139.60
2.08	4.03	2.86	49.53	4.34	165.41	200.77	162.83	138.53
2.24	4.28	2.74	43.38	4.72	178.08	202.43	168.97	139.37
2.27	4.33	2.87	39.35	4.15	161.91	202.70	161.87	139.30
2.16	4.24	2.86	42.76	4.27	157.20	204.70	168.33	139.87
2.16	4.11	2.85	41.58	4.66	165.39	206.07	171.97	138.50
2.48	5.03	3.68	48.33	5.42	186.38	206.87	176.50	138.70
2.68	5.16	4.23	52.37	5.37	165.00	206.87	167.00	139.80
2.88	4.91	3.71	58.76	5.55	173.20	209.57	177.67	140.57
2.85	4.78	3.26	59.03	5.99	189.80	211.30	180.57	140.37
2.89	4.75	3.23	61.62	5.85	198.32	213.07	183.37	139.10
2.83	4.61	3.58	74.36	6.94	232.91	212.67	172.10	139.23
2.81	5.84	3.76	74.15	8.30	273.06	213.67	180.10	140.97
2.77	5.66	3.75	68.04	9.42	294.84	216.67	179.07	139.80
2.68	4.47	3.33	55.72	7.04	224.86	217.20	182.20	140.37
2.40	4.07	3.43	50.12	5.46	157.93	217.43	169.93	140.27
2.41	4.22	3.40	53.22	5.65	173.67	218.70	180.93	142.77
2.41	4.46	3.30	55.59	6.27	204.40	220.93	182.40	144.37
2.47	4.99	3.27	54.66	6.19	197.23	220.97	181.93	144.77
2.45	4.48	3.47	57.20	5.69	176.02	221.50	173.03	145.53
2.48	4.93	3.66	59.46	5.70	178.47	224.10	181.43	147.50
2.77	5.45	3.96	56.34	5.61	176.02	224.63	181.90	146.50
2.72	5.74	3.95	58.47	5.36	165.89	228.00	185.67	146.90
2.74	7.45	4.57	57.95	5.93	183.03	228.70	179.70	148.57
3.00	7.95	4.66	58.50	6.73	201.54	232.27	189.36	152.25
3.10	7.28	4.93	57.70	7.17	205.91	235.45	191.18	152.59
3.48	7.64	5.85	67.50	7.82	231.36	237.90	194.94	154.39
4.26	8.19	7.58	69.40	9.26	285.36	240.91	190.86	154.50

Ir ⁶	WCoP ¹	DCoP ¹	CoLR ¹	TCoCon ¹	CoOthCon ¹	CoProd ¹	CoPr ¹	CoSup ¹
16.40	2.79	2.60	2.25	1439.53	107.8	7928.14	0	1439.53
16.32	2.81	2.67	2.25	1325.13	143.0	7928.14	0	1325.13
11.61	3.52	3.29	2.25	1015.41	137.6	7928.14	0	1015.41
16.73	3.67	3.47	2.25	1390.22	120.7	6639.40	6639.4	1390.22
19.21	3.68	3.51	2.40	1287.53	93.2	6639.40	0	1287.53
18.93	3.58	3.47	2.40	1274.99	124.3	6639.40	0	1274.99
20.32	3.22	3.07	2.40	938.60	136.8	6639.40	0	938.60
17.01	2.80	2.58	2.40	1390.68	125.8	8118.65	8118.7	1390.68
16.27	2.90	2.64	2.55	1364.64	93.7	8118.65	0	1364.64
16.50	2.98	2.71	2.55	1290.50	125.6	8118.65	0	1290.50
14.72	2.65	2.38	2.55	932.13	130.4	8118.65	0	932.13
11.96	2.54	2.30	2.55	1422.51	142.5	8235.10	8235.1	1422.51
10.88	2.97	2.75	2.65	1497.59	97.7	8235.10	0	1497.59
10.50	3.41	3.17	2.65	1500.07	124.0	8235.10	0	1500.07
10.80	3.73	3.48	2.65	1007.57	138.3	8235.10	0	1007.57
11.00	3.71	3.45	2.65	1552.68	135.1	4174.25	4174.3	1552.68
11.07	3.61	3.37	2.55	1281.12	96.2	4174.25	0	1281.12
12.31	3.73	3.61	2.55	1206.99	132.6	4174.25	0	1206.99
12.99	3.48	3.21	2.55	765.58	129.4	4174.25	0	765.58
11.80	2.99	2.77	2.55	1544.81	130.6	7672.13	7672.1	1544.81
10.54	3.04	2.81	2.55	1427.57	95.8	7672.13	0	1427.57
10.20	2.99	2.86	2.55	1313.82	146.2	7672.13	0	1313.82
9.50	2.73	2.52	2.55	895.52	164.5	7672.13	0	895.52
9.50	2.65	2.41	2.55	1495.01	151.2	8875.45	8875.5	1495.01
9.37	2.64	2.48	1.92	1568.35	107.5	8875.45	0	1568.35
8.61	2.63	2.51	1.92	1397.84	154.2	8875.45	0	1397.84
7.85	1.88	1.72	1.92	805.50	169.8	8875.45	0	805.50
7.50	1.77	1.62	1.92	1642.29	150.1	8225.76	8225.8	1642.29
7.50	1.75	1.56	1.82	1744.64	137.9	8225.76	0	1744.64
8.05	2.00	1.82	1.82	1420.30	166.3	8225.76	0	1420.30
8.40	1.87	1.61	1.82	1085.65	151.0	8225.76	0	1085.65
8.87	2.06	1.83	1.82	1846.99	149.9	7131.30	7131.3	1846.99
8.59	2.24	2.00	1.77	1731.37	142.9	7131.30	0	1731.37
8.78	2.54	2.29	1.77	1288.07	168.5	7131.30	0	1288.07
9.71	3.11	2.84	1.77	1174.46	153.2	7131.30	0	1174.46
10.18	2.98	2.72	1.77	1646.05	150.0	4928.68	4928.7	1646.05
10.98	3.01	2.75	1.65	1365.61	147.7	4928.68	0	1365.61
11.36	2.93	2.72	1.65	1194.22	182.4	4928.68	0	1194.22
10.66	2.63	2.37	1.65	1025.79	169.3	4928.68	0	1025.79
10.50	2.63	2.37	1.65	1798.66	166.9	7531.95	7532.0	1798.66
10.04	2.70	2.42	1.57	1588.47	153.4	7531.95	0	1588.47

Ir	WCoP	DCoP	CoLR	TCoCon	CoOthCon	CoProd	CoPr	CoSup
10.00	3.05	2.80	1.57	1369.07	187.0	7531.95	0	1369.07
10.00	2.77	2.56	1.57	996.32	173.3	7531.95	0	996.32
10.00	2.56	2.29	1.57	1956.28	176.9	7934.03	7934.1	1956.28
9.19	2.72	2.45	1.62	1680.92	161.0	7934.03	0	1680.92
8.67	2.71	2.48	1.62	1344.06	190.7	7934.03	0	1344.06
8.40	2.74	2.47	1.62	1052.77	168.4	7934.03	0	1052.77
7.60	2.73	2.49	1.62	2034.10	175.2	7474.77	7474.8	2034.10
6.50	2.85	2.66	1.72	1629.05	175.0	7474.77	0	1629.05
6.50	2.78	2.59	1.72	1456.38	207.0	7474.77	0	1456.38
6.01	2.53	2.26	1.72	1211.89	186.2	7474.77	0	1211.89
6.00	2.40	2.12	1.72	2184.39	174.6	9476.70	9476.7	2184.39
6.00	2.42	2.18	1.72	1766.15	170.1	9476.70	0	1766.15
6.00	2.47	2.27	1.72	1559.48	191.2	9476.70	0	1559.48
6.00	2.57	2.36	1.72	1297.83	179.5	9476.70	0	1297.83
6.00	2.90	2.72	1.72	2083.96	174.4	6337.73	6337.7	2083.96
6.02	3.14	2.97	1.89	1618.79	166.2	6337.73	0	1618.79
6.90	2.85	2.75	1.89	1372.26	192.3	6337.73	0	1372.26
7.50	2.48	2.24	1.89	1218.05	181.0	6337.73	0	1218.05
8.13	2.49	2.14	1.89	2372.94	174.4	10050.5	10050.5	2372.94
8.83	2.74	2.38	1.89	1902.09	171.1	10050.5	0	1902.09
9.00	2.89	2.60	1.89	1611.64	191.2	10050.5	0	1611.64
8.77	3.25	2.85	1.89	1288.23	187.2	10050.5	0	1288.23
8.72	3.65	3.30	1.89	2195.34	188.1	7400.1	7400.1	2195.34
8.33	4.17	3.79	1.89	1749.01	181.6	7400.1	0	1749.01
8.25	4.99	4.81	1.89	1476.95	212.4	7400.1	0	1476.95
8.25	4.50	4.11	1.89	899.31	177.5	7400.1	0	899.31
8.25	3.07	2.77	1.89	2272.43	186.0	9232.6	9232.6	2272.43
8.27	3.12	2.86	1.89	1886.48	186.1	9232.6	0	1886.48
8.50	3.01	2.86	1.89	1568.44	219.6	9232.6	0	1568.44
8.50	2.81	2.64	1.89	1263.88	201.4	9232.6	0	1263.88
8.50	2.97	2.74	1.89	2465.36	200.7	9206.8	9206.8	2465.36
8.50	2.89	2.72	1.89	1927.94	190.1	9206.8	0	1927.94
8.50	2.68	2.49	1.89	1553.43	217.3	9206.8	0	1553.43
8.50	2.32	2.05	1.89	1339.85	202.7	9206.8	0	1339.85
7.92	2.44	2.11	1.89	2568.45	194.4	9758.7	9758.7	2568.45
7.75	2.44	2.17	1.89	1894.05	184.3	9758.7	0	1894.05
7.75	2.37	2.13	1.89	1592.09	215.7	9758.7	0	1592.09
8.10	2.18	1.86	1.89	1259.54	195.6	9758.7	0	1259.54
8.37	2.18	1.91	1.89	2646.68	198.2	9430.6	9430.6	2646.68
8.69	2.40	2.10	1.89	1975.85	189.0	9430.6	0	1975.85
9.25	2.33	2.13	1.89	1570.32	222.2	9430.6	0	1570.32

Ir	WCoP	DCoP	CoLR	TCoCon	CoOthCon	CoProd	CoPr	CoSup
9.50	1.95	1.64	1.89	1385.37	198.6	9430.6	0	1385.37
9.50	2.29	2.01	1.89	2597.58	197.4	9915.1	9915.1	2597.58
8.62	2.36	2.03	1.89	2072.26	188.5	9915.1	0	2072.26
7.34	2.09	1.96	1.89	1666.98	215.4	9915.1	0	1666.98
6.57	2.31	2.10	1.89	1462.15	198.3	9915.1	0	1462.15
5.16	2.27	2.01	1.89	2691.54	196.6	9502.6	9502.6	2691.54
4.75	2.31	2.06	1.98	2022.76	187.4	9502.6	0	2022.76
4.75	2.29	2.09	1.98	1705.64	216.4	9502.6	0	1705.64
4.75	2.74	2.55	1.98	1490.70	199.5	9502.6	0	1490.70
4.45	2.76	2.49	1.98	2535.25	196.5	8966.8	8966.8	2535.25
4.25	2.68	2.42	1.98	2119.97	192.9	8966.8	0	2119.97
4.24	2.71	2.50	1.98	1758.69	221.1	8966.8	0	1758.69
4.00	2.56	2.30	1.98	1489.19	202.4	8966.8	0	1489.19
4.00	2.75	2.37	1.98	2755.03	200.3	10089.2	10089.2	2755.03
4.00	3.11	2.83	1.95	2179.95	197.9	10089.2	0	2179.95
4.00	3.27	3.05	1.95	1841.55	230.9	10089.2	0	1841.55
4.42	2.60	2.34	1.95	1555.54	210.4	10089.2	0	1555.54
4.94	2.40	1.94	1.95	2815.43	207.1	11807.1	11807.1	2815.43
5.44	2.46	2.04	1.95	2258.65	197.2	11807.1	0	2258.65
5.92	2.45	2.13	1.95	2011.11	230.6	11807.1	0	2011.11
6.43	2.58	2.13	1.95	1758.78	208.2	11807.1	0	1758.78
6.97	2.54	1.91	1.95	2937.88	206.1	11114.1	11114.1	2937.88
7.43	2.67	2.07	1.95	2354.62	201.0	11114.1	0	2354.62
7.90	2.78	2.28	1.95	2067.39	230.1	11114.1	0	2067.39
8.25	2.96	2.23	1.95	1775.99	212.6	11114.1	0	1775.99
8.25	4.02	3.35	1.95	2974.54	210.2	10534.9	10534.9	2974.54
8.25	4.17	3.89	1.95	2353.31	200.5	10534.9	0	2353.31
8.25	4.05	3.71	1.95	2061.98	237.2	10534.9	0	2061.98
8.18	3.87	3.33	1.95	1695.85	212.7	10534.9	0	1695.85
7.52	4.36	3.80	1.95	3405.51	206.9	13073.9	13073.9	3405.51

TCoUt ¹	CoEx ¹	CoBeSt ¹	CoEndSt ¹	CoFeed ¹	CoEth ¹	CoHf ¹	CCC ¹	Cattl ¹
2037.27	597.74	7594.10	5557.00	1299.23	0.00	32.55	100.10	8.20
1912.90	587.77	5557.00	3644.30	1149.53	0.00	32.61	213.50	7.13
1610.14	594.73	3644.30	2034.30	843.31	0.00	34.48	260.10	6.82
2078.09	687.87	2034.30	6595.90	1235.72	0.00	33.82	256.70	7.33
1933.50	645.97	6595.90	4662.40	1142.83	7.32	44.18	252.30	7.77
1888.95	613.95	4662.40	2773.50	1092.39	7.40	50.91	251.60	6.98
1381.91	443.31	2773.50	1392.10	761.20	7.48	33.15	241.80	6.74
1909.76	519.08	1392.10	7601.10	1217.38	7.48	40.00	243.60	6.60
1834.86	470.22	7601.10	5766.40	1199.24	19.86	51.82	259.30	7.19
1886.34	595.84	5766.40	3880.10	1089.20	20.08	55.58	269.70	6.95
1343.75	411.62	3880.10	2536.60	738.73	20.30	42.73	280.10	7.05
1865.65	443.14	2536.60	8906.30	1215.01	20.30	44.67	372.00	7.33
2007.16	509.57	8906.30	6899.20	1305.19	36.58	58.12	470.80	8.40
1975.39	475.31	6899.20	4923.90	1272.27	36.99	66.85	491.70	7.37
1400.90	393.33	4923.90	3523.10	780.77	37.39	51.15	1142.70	7.15
2046.05	493.37	3523.10	5651.70	1325.28	37.39	54.91	1227.00	7.10
1787.01	505.89	5651.70	3865.00	1068.82	45.31	70.79	1214.00	7.90
1720.39	513.40	3865.00	2145.10	954.49	45.31	74.55	195.00	7.47
1139.31	373.73	2145.10	1006.30	527.68	45.81	62.67	201.50	7.10
2048.05	503.25	1006.30	6631.10	1300.71	45.81	67.70	206.70	7.44
2007.98	580.42	6631.10	4623.20	1191.47	54.35	85.94	209.70	8.45
1788.55	474.73	4623.20	2835.50	1019.42	54.95	93.21	221.70	7.74
1187.38	291.86	2835.50	1648.20	602.92	55.55	72.55	224.90	6.96
1909.82	414.80	1648.20	8614.70	1218.71	55.55	69.58	388.60	6.71
2028.55	460.21	8614.70	6587.10	1305.95	62.71	92.24	509.40	7.83
1599.27	201.43	6587.10	4990.04	1090.54	63.40	89.70	550.90	7.25
956.39	150.90	4990.04	4039.52	499.00	64.10	72.61	545.70	6.65
1960.50	318.21	4039.52	10305.50	1347.81	67.94	76.40	968.20	6.95
2057.47	312.83	10305.50	8248.19	1463.15	71.51	72.04	1362.20	7.58
1916.40	496.10	8248.19	6332.24	1087.69	77.43	88.86	1491.50	7.28
1450.98	365.33	6332.24	4881.69	760.81	73.10	100.69	1443.20	7.29
2242.55	395.56	4881.69	9771.01	1550.86	67.25	78.94	1683.40	7.74
2136.12	404.75	9771.01	7635.59	1443.79	69.09	75.62	1767.70	8.35
1797.74	509.67	7635.59	5839.22	951.23	72.96	95.43	1304.90	7.93
1580.91	406.45	5839.22	4259.09	843.37	69.85	108.01	835.00	7.70
2116.83	470.77	4259.09	7071.57	1343.77	70.85	81.46	611.00	7.55
1868.23	502.62	7071.57	5203.93	1064.26	76.47	77.20	465.00	8.08
1785.84	591.62	5203.93	3419.30	841.29	72.52	98.03	417.70	8.09
1489.22	463.44	3419.30	1930.43	684.59	67.61	104.31	362.50	7.25
2380.95	582.29	1930.43	7082.08	1486.72	63.65	81.35	628.20	7.15
2270.09	681.62	7082.08	4812.42	1275.56	80.47	79.07	537.20	8.42

TCoUt	CoEx	CoBeSt	CoEndSt	CoFeed	CoEth	CoHf	CCC	Cattl
1969.83	600.76	4812.42	2843.21	993.06	89.47	99.56	299.30	8.33
1498.95	502.63	2843.21	1344.46	627.13	87.86	108.03	233.00	7.37
2339.08	382.81	1344.46	6940.29	1618.74	76.17	84.47	205.90	7.31
2151.59	470.67	6940.29	4788.97	1351.05	86.99	81.86	195.60	9.03
1797.80	453.74	4788.97	2991.96	960.03	90.88	102.46	435.90	8.80
1472.18	419.42	2991.96	1521.25	679.09	95.04	110.21	371.10	7.94
2455.18	421.07	1521.25	6547.32	1673.65	97.73	87.51	249.70	7.44
1990.74	361.69	6547.32	4560.99	1266.83	100.22	87.04	199.20	8.37
1827.84	371.46	4560.99	2738.55	1041.85	100.88	106.62	147.20	7.98
1641.59	429.70	2738.55	1100.31	815.59	99.43	110.65	112.50	7.38
2671.90	487.51	1100.31	7906.36	1814.32	103.06	92.42	87.40	7.68
2229.19	463.04	7906.36	5678.22	1401.10	106.33	88.61	86.80	9.01
1970.77	411.29	5678.22	3709.44	1145.76	112.00	110.48	64.40	8.60
1599.26	301.43	3709.44	2112.98	890.91	104.12	123.28	55.50	7.96
2519.37	435.41	2112.98	5936.55	1701.18	110.45	97.94	52.60	8.35
1948.79	330.00	5936.55	3995.71	1239.92	117.92	94.73	49.80	9.32
1642.11	269.85	3995.71	2359.88	949.51	113.10	117.32	47.80	8.89
1511.12	293.07	2359.88	850.14	789.25	116.79	130.97	44.80	7.80
2822.24	449.30	850.14	8080.48	1962.55	132.75	103.27	44.20	7.99
2492.53	590.44	8080.48	5591.69	1491.63	140.18	99.23	44.20	8.89
2179.80	568.16	5591.69	3414.90	1159.08	139.11	122.29	42.30	8.90
1857.81	569.58	3414.90	1557.84	846.41	120.75	133.85	42.30	8.00
2855.77	660.42	1557.84	6105.77	1778.12	121.20	107.95	42.10	8.03
2311.20	562.18	6105.77	3799.54	1343.51	120.80	103.14	42.00	8.68
2086.67	609.72	3799.54	1717.89	1044.01	92.20	128.31	41.10	8.07
1294.81	395.50	1717.89	425.94	526.85	61.50	133.44	30.40	6.72
2758.96	486.53	425.94	6902.97	1884.51	91.92	109.96	30.30	7.54
2411.20	524.72	6902.97	4494.13	1486.18	106.16	108.08	30.30	8.91
2001.30	432.86	4494.13	2496.55	1097.41	119.24	132.15	10.40	8.72
1617.14	353.26	2496.55	883.16	808.96	111.40	142.09	2.10	7.82
2845.44	380.09	883.16	7246.76	2030.15	116.07	118.44	2.10	8.60
2307.84	379.90	7246.76	4939.90	1503.19	122.19	112.50	2.00	9.45
1903.75	350.32	4939.90	3039.76	1083.59	118.30	134.23	2.00	8.41
1733.97	394.12	3039.76	1307.80	864.82	124.56	147.76	4.30	7.84
3018.67	450.22	1307.80	8051.85	2118.50	132.39	123.14	13.30	8.44
2359.13	465.08	8051.85	5698.43	1460.28	132.86	116.61	14.60	10.18
2089.44	497.35	5698.43	3616.23	1097.11	138.76	140.53	14.60	10.28
1831.08	571.54	3616.23	1786.98	791.98	121.80	150.19	11.60	9.59
3181.69	535.02	1786.98	8039.44	2187.51	131.73	129.26	19.30	10.42
2440.95	465.10	8039.44	5601.90	1529.27	138.26	119.37	15.10	11.61
2021.47	451.15	5601.90	3585.94	1058.46	147.95	141.73	15.50	11.17

TCoUt	CoEx	CoBeSt	CoEndSt	CoFeed	CoEth	CoHf	CCC	Cattl
1870.67	485.30	3585.94	1717.55	889.75	147.83	149.16	14.70	10.52
3104.26	506.68	1717.55	8529.63	2131.37	142.85	126.00	22.30	11.07
2487.55	415.29	8529.63	6043.00	1607.32	158.08	118.40	22.20	11.89
2122.16	455.19	6043.00	3923.96	1152.65	161.29	137.59	8.80	11.44
2026.35	564.20	3923.96	1899.11	950.75	165.37	147.76	7.70	11.04
3139.42	447.88	1899.11	8264.72	2199.46	168.29	127.20	8.50	11.28
2471.14	448.38	8264.72	5795.26	1540.32	175.17	119.87	8.70	11.68
2202.53	496.89	5795.26	3596.89	1166.13	179.85	143.25	8.00	11.36
2002.32	511.62	3596.89	1596.43	958.32	182.64	150.25	6.40	10.54
2928.67	393.43	1596.43	7637.97	1986.27	225.86	126.62	5.90	10.42
2510.16	390.19	7637.97	5131.87	1556.62	249.30	121.14	5.40	10.77
2152.11	393.41	5131.87	2984.92	1141.39	256.52	139.68	4.30	10.62
1900.05	410.86	2984.92	1086.67	878.57	263.82	144.40	4.20	10.02
3224.58	469.55	1086.67	7953.78	2165.99	262.48	126.31	4.40	10.37
2685.84	505.89	7953.78	5271.46	1571.39	290.31	120.38	3.80	11.32
2306.44	464.89	5271.46	2970.14	1165.86	304.64	140.19	0.30	10.68
2015.02	459.48	2970.14	958.09	891.73	310.12	143.31	0.01	10.18
3314.32	498.89	958.09	9452.49	2172.87	311.64	123.83	0.30	10.60
2697.86	439.21	9452.49	6756.33	1621.67	323.82	115.93	0.00	11.33
2439.53	428.41	6756.33	4320.81	1311.02	332.01	137.46	0.00	10.89
2210.33	451.55	4320.81	2113.97	1051.56	355.61	143.45	0.20	10.43
3415.21	477.33	2113.97	9814.96	2240.54	364.31	126.98	2.50	10.67
2828.86	474.24	9814.96	6987.33	1646.86	386.64	120.09	1.80	11.90
2629.77	562.38	6987.33	4361.70	1293.45	406.53	137.32	2.20	11.63
2395.86	619.86	4361.70	1967.16	973.86	445.29	144.22	1.50	10.98
3570.48	595.94	1967.16	8932.71	2175.58	465.91	122.81	1.30	11.47
2866.13	512.82	8932.71	6068.25	1532.73	506.19	113.88	1.00	11.90
2540.30	478.31	6068.25	3533.44	1144.03	545.85	134.89		11.52
2233.46	537.61	3533.44	1303.65	745.50	599.13	138.53		10.81
4101.64	696.12	1303.65	10278.09	2444.10	634.60	119.87		11.02

MeatP ¹	DdgP ¹	GfP ¹	Gmp ¹	WeCo ¹	CoY ¹	RFS	Mand	EthP ⁴	GasP ⁴
1.42	NA	NA	NA	0	0	0	0	NA	NA
1.33	NA	NA	NA	0	0	0	0	NA	NA
1.53	NA	NA	NA	0	0	0	0	NA	NA
1.63	NA	NA	NA	0	5.71	0	0	NA	NA
1.57	NA	NA	NA	0	0	0	0	NA	NA
1.53	NA	NA	NA	0	0	0	0	NA	NA
1.67	150.00	108.50	260.00	0	0	0	0	NA	NA
1.68	151.00	111.27	250.05	0	6.84	0	0	NA	NA
1.69	144.42	115.33	263.08	0	0	0	0	1.70	1.00
1.79	141.83	112.00	226.00	0	0	0	0	1.70	0.96
1.96	145.28	113.22	229.42	0	0	0	0	1.70	1.05
1.98	136.75	113.57	222.92	0	7.11	0	0	1.72	0.99
1.94	138.57	118.43	261.17	1	0	0	0	1.67	0.89
1.81	147.23	111.92	228.92	1	0	0	0	1.70	0.93
1.75	158.07	127.33	289.58	1	0	0	0	1.74	0.94
1.69	182.67	137.62	288.92	1	5.09	0	0	1.61	0.89
1.71	183.00	121.67	262.58	0	0	0	0	1.54	0.86
1.69	166.67	101.17	264.50	0	0	0	0	1.54	0.88
1.73	148.00	75.95	223.10	0	0	0	0	1.55	0.84
1.73	103.33	78.90	222.30	0	6.7	0	0	1.57	0.81
1.75	94.67	71.77	217.12	0	0	0	0	1.57	0.76
1.68	85.00	63.82	177.57	0	0	0	0	1.64	0.91
1.68	93.33	77.78	194.62	0	0	0	0	1.59	0.89
1.72	105.33	89.13	212.32	0	7.41	0	0	1.58	0.83
1.77	113.00	86.30	208.75	0	0	0	0	1.38	0.60
1.73	111.33	80.17	206.80	0	0	0	0	1.13	0.54
2.00	77.83	89.07	208.58	0	0	0	0	0.99	0.46
2.04	127.47	104.82	231.53	0	7.49	0	0	0.79	0.46
1.96	109.48	98.43	215.65	0	0	0	0	1.01	0.53
1.94	109.25	96.37	235.77	0	0	0	0	1.31	0.59
2.07	78.67	93.38	256.28	0	0	0	0	1.38	0.61
2.01	123.00	104.83	299.28	0	7.52	0	0	1.12	0.55
1.95	138.33	119.23	293.38	1	0	0	0	1.07	0.49
1.96	129.33	121.50	303.28	1	0	0	0	1.14	0.56
1.97	164.33	124.80	333.13	1	0	0	0	1.18	0.58
1.89	143.20	122.50	294.75	1	5.31	0	0	1.15	0.53
1.90	138.67	122.30	283.23	0	0	0	0	1.17	0.54
1.89	143.17	113.63	272.74	0	0	0	0	1.38	0.66
1.95	91.92	107.03	265.08	0	0	0	0	1.24	0.64
2.00	130.67	110.05	297.25	0	7.3	0	0	1.13	0.59
2.08	119.17	109.27	193.55	0	0	0	0	1.23	0.63

MeatP	DdgP	GfP	Gmp	WeCo	CoY	RFS	Mand	EthP	GasP
2.20	119.20	92.78	231.40	0	0	0	0	1.28	0.68
2.36	80.42	83.05	225.05	0	0	0	0	1.45	0.80
2.36	129.07	95.08	234.83	0	7.44	0	0	1.45	0.87
2.28	136.35	110.73	244.63	0	0	0	0	1.26	0.70
2.26	128.33	97.31	231.20	0	0	0	0	1.29	0.72
2.27	69.57	92.70	253.40	0	0	0	0	1.24	0.68
2.16	122.20	105.90	292.08	0	6.82	0	0	1.28	0.64
2.10	126.57	105.80	271.70	0	0	0	0	1.25	0.57
2.07	118.48	95.10	247.42	0	0	0	0	1.37	0.68
2.12	85.33	103.07	250.83	0	0	0	0	1.37	0.66
2.08	126.42	109.93	274.43	0	8.25	0	0	1.32	0.63
2.06	133.67	101.37	291.00	1	0	0	0	1.19	0.61
2.05	111.67	81.60	279.27	1	0	0	0	1.18	0.64
2.12	75.33	82.63	306.90	1	0	0	0	1.11	0.58
2.13	126.08	85.57	306.07	1	6.32	0	0	1.14	0.54
2.12	129.00	89.53	298.05	0	0	0	0	1.14	0.50
2.10	118.80	90.72	268.45	0	0	0	0	1.14	0.57
2.11	80.00	91.30	250.55	0	0	0	0	1.28	0.63
2.05	122.00	86.80	232.93	0	8.7	0	0	1.20	0.53
2.03	98.78	81.77	222.45	0	0	0	0	1.24	0.55
2.01	96.80	78.60	203.62	0	0	0	0	1.12	0.64
2.07	71.00	80.97	233.58	0	0	0	0	1.10	0.57
2.14	136.93	112.03	316.43	0	7.12	0	0	1.13	0.61
2.18	144.60	123.70	344.92	0	0	0	0	1.23	0.69
2.27	177.70	129.30	331.53	0	0	0	0	1.35	0.77
2.44	113.13	112.22	310.97	0	0	0	0	1.50	0.66
2.45	149.63	99.77	342.17	0	7.98	0	0	1.32	0.65
2.44	147.17	101.30	337.28	0	0	0	0	1.13	0.60
2.43	130.73	83.92	349.22	0	0	0	0	1.13	0.54
2.48	85.00	75.67	345.87	0	0	0	0	1.14	0.53
2.44	129.18	75.07	348.50	0	7.95	0	0	1.19	0.53
2.46	116.77	74.23	295.80	0	0	0	0	1.11	0.47
2.40	84.50	63.50	233.32	0	0	0	0	0.97	0.46
2.45	86.00	55.92	235.83	0	0	0	0	1.09	0.39
2.40	75.67	65.80	277.37	0	8.44	0	0	1.03	0.40
2.36	92.00	64.80	226.00	0	0	0	0	0.97	0.43
2.38	84.67	56.35	201.08	0	0	0	0	0.94	0.55
2.46	89.84	53.85	250.63	0	0	0	0	0.95	0.66
2.45	88.00	60.07	249.67	0	8.4	0	0	1.07	0.72
2.50	80.42	52.55	242.63	0	0	0	0	1.13	0.86
2.57	73.20	50.58	236.67	0	0	0	0	1.26	1.02

MeatP	DdgP	GfP	Gmp	WeCo	CoY	RFS	Mand	EthP	GasP
2.64	77.00	44.94	218.25	0	0	0	0	1.38	0.93
2.61	69.20	58.25	261.29	0	8.59	0	0	1.62	0.91
2.63	102.93	66.63	268.58	0	0	0	0	1.66	0.90
2.67	88.13	53.66	232.42	0	0	0	0	1.62	1.06
2.75	53.00	63.64	245.79	0	0	0	0	1.48	0.93
2.73	91.58	65.88	258.54	0	8.67	0	0	1.16	0.62
2.71	82.08	57.17	225.75	0	0	1	0	1.00	0.67
2.68	73.10	54.08	221.46	0	0	1	0	1.01	0.84
2.64	61.60	61.41	267.17	0	0	1	0	1.26	0.87
2.60	96.10	68.50	260.22	0	8.12	1	0	1.22	0.87
2.61	83.75	67.00	234.72	0	0	1	0	1.30	1.03
2.62	86.77	63.40	230.53	0	0	1	0	1.21	0.95
2.70	61.60	62.07	232.43	0	0	1	0	1.31	1.01
2.70	108.00	95.47	299.62	0	8.93	1	0	1.58	0.93
2.69	121.33	94.78	371.63	0	0	1	0	1.49	1.10
2.77	124.67	79.32	355.66	0	0	1	0	1.80	1.32
2.88	104.00	61.66	285.63	0	0	1	0	1.61	1.30
2.83	79.00	52.30	244.29	0	10.06	1	0	1.88	1.30
2.83	71.67	52.30	239.54	0	0	1	0	1.53	1.43
2.87	74.50	51.73	280.99	0	0	1	0	1.27	1.58
2.83	78.67	49.80	318.90	0	0	1	0	2.20	1.95
2.78	78.00	51.49	312.92	0	9.29	1	0	2.18	1.67
2.77	91.53	58.38	275.63	0	0	1	1	2.36	1.78
2.79	91.33	58.84	250.78	0	0	1	1	3.02	2.21
2.86	81.50	56.01	235.58	0	0	1	1	2.73	2.13
2.81	91.67	66.24	297.59	0	9.36	1	1	2.19	1.65
2.81	125.96	87.44	347.13	0	0	1	1	2.23	1.75
2.87	113.67	64.86	353.36	0	0	1	1	2.42	2.44
2.92	105.00	75.63	405.75	0	0	1	1	2.29	2.37
2.88	124.00	122.85	502.97	0	9.48	1	1	2.04	2.37

EthPr ²	EthCon ²	EthIm ²	Car ⁵	DCroidP ²	NGP ²
NA	NA	NA	119222	18.68	NA
NA	NA	NA	120015	20.95	NA
NA	NA	NA	120808	22.51	NA
NA	NA	NA	121601	24.35	NA
20.49	20.49	0	121975	32.57	3.14
20.71	20.71	0	122350	32.78	3.14
20.94	20.94	0	122724	31.10	3.14
20.94	20.94	0	123098	30.92	3.14
55.60	55.60	0	123249	29.64	3.87
56.22	56.22	0	123400	27.81	3.87
56.84	56.84	0	123551	28.16	3.87
56.84	56.84	0	123702	28.49	3.87
102.42	102.42	0	124388	26.57	4.18
103.56	103.56	0	125073	25.97	4.18
104.70	104.70	0	125759	25.99	4.18
104.70	104.70	0	126444	26.00	4.18
126.88	126.88	0	126873	26.01	4.30
126.88	126.88	0	127301	26.01	4.17
128.28	128.28	0	127730	26.03	4.18
128.28	128.28	0	128158	25.47	4.21
152.17	152.17	0	128090	23.93	4.21
153.86	153.86	0	128022	24.15	3.89
155.55	155.55	0	127953	24.00	3.90
155.55	155.55	0	127885	24.29	3.77
175.58	175.58	0	128415	17.80	3.69
177.53	177.53	0	128945	10.70	3.17
179.48	179.48	0	129474	10.04	2.87
179.48	179.48	0	130004	11.26	2.98
201.91	201.91	0	130374	14.28	3.19
204.16	204.16	0	130743	15.40	2.85
206.40	206.40	0	131113	16.73	2.77
206.40	206.40	0	131482	15.23	2.89
206.55	206.55	0	132071	13.34	3.18
206.55	206.55	0	132659	13.88	2.80
208.82	208.82	0	133248	12.08	2.63
208.82	208.82	0	133836	10.97	3.04
207.77	207.77	0	134017	14.56	3.26
210.08	210.08	0	134198	16.74	2.78
212.38	212.38	0	134378	15.64	2.68
212.38	212.38	0	134559	16.52	3.00
184.36	184.36	0	134344	17.74	3.34

EthPr	EthCon	EthIm	Car	DCroidP	NGP
186.41	186.41	0	134130	13.71	2.70
188.45	188.45	0	133915	21.45	2.54
188.45	188.45	0	133700	27.01	2.99
213.62	213.62	0	132350	17.00	2.99
215.99	215.99	0	131000	16.06	2.47
218.37	218.37	0	129650	16.56	2.31
218.37	218.37	0	128300	16.51	2.87
244.91	244.91	0	127870	14.05	2.80
244.91	244.91	0	127441	16.57	2.50
247.60	247.60	0	127011	17.36	2.69
247.60	247.60	0	126581	16.03	3.28
287.11	285.22	0.002214	126768	15.39	3.05
290.77	263.42	0.001119	126954	15.75	3.01
267.04	261.32	0.001	127141	13.66	2.78
309.41	341.04	0.001476	127327	12.18	3.02
312.44	334.57	0.002024	127466	10.71	3.46
292.11	290.85	0	127605	13.75	2.87
325.58	287.99	0.002167	127744	14.49	2.66
358.81	375.52	0.002452	127883	13.80	2.78
366.58	344.15	0.002143	128009	14.46	2.85
351.25	340.70	0.002833	128135	15.57	2.52
309.58	274.18	0.001952	128261	14.21	2.34
330.25	423.57	0.002286	128387	14.24	2.73
296.60	336.42	0.002429	128722	16.20	3.58
191.39	209.12	0.001429	129058	18.15	3.23
181.44	172.83	0.002476	129393	18.62	3.00
304.04	273.34	0.001119	129728	20.88	3.55
306.85	297.23	0.001119	129733	19.66	4.04
315.29	280.31	0.0005	129739	16.58	3.11
308.45	298.49	0	129744	16.16	3.14
357.71	379.72	0.000405	129749	16.51	3.82
338.90	355.07	0.000929	130272	12.26	3.55
334.82	297.65	4.76E-05	130794	10.80	3.13
341.21	333.14	0.000286	131317	10.64	2.81
390.10	401.73	0.00031	131839	9.66	2.87
363.26	345.03	0.000452	131987	9.31	3.06
353.56	324.58	0.000548	132136	13.71	2.89
342.34	324.95	0.000548	132284	17.91	3.08
405.85	448.14	0.000524	132432	21.20	3.29
397.32	395.89	0.000571	132729	25.07	3.54
401.02	369.10	0.000643	133027	25.47	3.83

EthPr	EthCon	EthIm	Car	DCroidP	NGP
391.78	406.94	0.00081	133324	28.15	4.59
432.22	481.49	0.000738	133621	28.16	5.84
433.57	468.47	0.002905	134624	24.30	7.45
414.75	356.37	0.00169	135627	23.63	5.43
439.19	430.71	0.002	136630	22.76	3.86
477.67	485.14	0.000905	137633	16.89	3.58
486.61	432.52	0.0025	137205	17.70	3.84
483.00	463.60	0.000833	136777	22.87	3.86
525.63	514.75	0.000905	136349	24.78	3.77
644.91	662.26	0.003048	135921	24.65	4.61
657.76	646.09	0.00169	135858	30.12	6.77
682.50	677.00	0.001738	135796	25.75	6.11
705.73	685.99	0.000786	135733	26.90	5.43
758.44	816.94	0.002738	135670	27.42	5.34
812.87	846.85	0.009738	135860	31.47	6.40
841.26	895.69	0.02531	136051	34.49	6.41
860.66	873.31	0.038024	136241	39.07	6.15
889.64	936.35	0.011262	136431	42.40	7.07
917.20	917.53	0.014548	136465	43.31	7.11
922.11	957.10	0.006952	136500	47.04	7.27
1003.72	1049.71	0.008286	136534	57.30	8.52
1061.34	1134.29	0.047214	136568	54.48	11.78
1122.70	1062.77	0.038952	136276	56.39	9.47
1145.76	1359.46	0.07469	135984	63.86	7.48
1264.79	1472.98	0.190643	135692	64.76	7.11
1351.10	1586.00	0.11019	135400	53.57	7.20
1440.94	1569.41	0.067643		52.40	7.99
1547.36	1620.86	0.054476		59.82	8.07
1668.70	1719.69	0.087048		70.06	6.74
1828.47	1936.12	0.037214		83.92	7.48

Source:

- 1- United States Department of Agriculture (USDA). Different Tables. 2008.
- 2- United States Department of Energy. Energy Information Administration (EIA). 2008.
- 3- Economagic.com: Economic Time Series Page. <http://www.economagic.com>.
- 4- Nebraska Ethanol Board, Lincoln, NE. Nebraska Energy Office, Lincoln, NE. Ethanol and Unleaded Gasoline Average Rack Prices F.O.B. Omaha, Nebraska, 1982-2008
- 5- U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 2005*. Washington, DC, 2006. www.fhwa.dot.gov.
- 6- International Monetary Fund. International Financial Statistics (IFS). 2008.
- 7- Renewable Fuels Association (RFA). *Changing the Climate, Ethanol Industry Outlook 2008*. February 2008 (RFA)

APPENDIX E. ANNUAL DATA

T	Y	GDP ⁶	POP ⁶	GDPP ⁶	HfPr ¹	HfCon ¹	HfConP ¹	DD
1.0	1975	4311.2	220.2	19.6	532.0	534.0	4.9	0.0
2.0	1976	4540.9	222.2	20.4	787.0	774.0	7.0	0.0
3.0	1977	4750.6	224.3	21.2	1064.0	1014.0	9.0	0.0
4.0	1978	5015.0	226.5	22.1	1208.0	1244.0	11.0	0.0
5.0	1979	5173.5	228.7	22.6	1674.0	1642.0	14.4	0.0
6.0	1980	5161.7	230.9	22.4	2181.0	2116.0	18.3	0.0
7.0	1981	5291.7	233.2	22.7	2674.0	2631.0	22.6	0.0
8.0	1982	5189.3	235.6	22.0	3137.0	3155.0	26.8	0.0
9.0	1983	5423.8	238.1	22.8	3643.0	3737.0	31.4	0.0
10.0	1984	5813.6	240.6	24.2	4338.0	4473.0	37.2	0.0
11.0	1985	6053.8	243.1	24.9	5271.0	5395.0	44.4	0.0
12.0	1986	6263.6	245.6	25.5	5348.0	5528.0	45.0	0.0
13.0	1987	6475.1	248.2	26.1	5687.0	5752.0	46.4	0.0
14.0	1988	6742.7	250.8	26.9	5951.0	6025.0	48.1	0.0
15.0	1989	6981.4	253.4	27.6	5967.0	6168.0	48.7	0.0
16.0	1990	7112.5	256.1	27.8	6281.0	6342.0	49.5	0.0
17.0	1991	7100.5	258.9	27.4	6484.0	6534.0	50.5	0.0
18.0	1992	7336.6	261.7	28.0	6634.0	6727.3	51.4	0.0
19.0	1993	7532.7	264.5	28.5	7096.9	7173.1	54.2	0.0
20.0	1994	7835.5	267.4	29.3	7467.2	7481.5	56.0	0.0
21.0	1995	8031.7	270.2	29.7	7759.2	7733.3	57.2	0.0
22.0	1996	8328.9	273.1	30.5	8157.2	8056.6	59.0	0.0
23.0	1997	8703.5	276.0	31.5	8676.5	8516.8	61.7	0.0
24.0	1998	9066.9	279.0	32.5	9150.4	8879.0	63.7	0.0
25.0	1999	9470.4	281.9	33.6	9411.6	9182.8	65.1	0.0
26.0	2000	9817.0	284.9	34.5	9315.0	9114.0	64.0	1.0
27.0	2001	9890.7	287.8	34.4	9236.0	9149.0	63.6	1.0
28.0	2002	10048.8	290.8	34.6	9302.0	9294.0	63.9	1.0
29.0	2003	10301.1	293.8	35.1	9150.0	9135.0	62.2	1.0
30.0	2004	10675.7	296.8	36.0	9063.0	9060.0	61.0	1.0
31.0	2005	11003.5	299.8	36.7	9227.0	9058.0	60.4	1.0
32.0	2006	11319.4	302.8	37.4	9375.0	9045.0	59.7	1.0
33.0	2007	11566.8	305.8	37.8	9283.0	8788.0	57.5	1.0

HfIm ¹	HfEx ¹	WeSuCa ¹	WeSuBe ¹	SuCaAr ¹	SuCaYi ¹	SuCaY ¹	SuCaPr ¹	SuBePr ¹
0.0	0.0	0.0	0.0	734.7	37.2	4.0	2934.0	4019.0
0.0	1.0	0.0	0.0	704.0	38.2	3.8	2724.0	3895.0
0.0	2.0	1.0	0.0	719.3	35.8	3.7	2684.0	3108.0
0.0	4.0	0.0	0.0	699.8	35.5	3.7	2611.0	3289.0
0.0	3.0	0.0	0.0	689.7	36.8	3.9	2700.0	2879.0
0.0	9.0	0.0	0.0	683.6	37.4	4.0	2987.0	3234.0
1.0	8.0	0.0	0.0	715.6	36.6	4.0	2804.0	3318.0
5.0	5.0	0.0	1.0	700.4	40.6	4.4	3263.0	2692.0
79.0	11.0	0.0	1.0	733.4	37.1	4.0	3073.0	2837.0
132.0	16.0	0.0	0.0	700.7	37.1	4.3	3025.0	2915.0
187.0	19.0	0.0	0.0	722.8	37.2	4.2	3136.0	2988.0
228.0	19.0	0.0	0.0	750.7	38.5	4.4	3506.0	3653.0
202.0	28.0	1.0	0.0	778.3	36.0	4.2	3425.0	3822.0
183.0	36.0	1.0	1.0	793.6	35.9	4.3	3408.0	3396.0
185.0	87.0	1.0	0.0	803.3	34.9	4.0	3225.0	3466.0
178.0	164.0	0.0	0.0	726.4	36.4	4.3	3124.0	3854.0
158.0	122.0	1.0	0.0	849.6	34.1	4.0	3461.0	3845.0
193.4	100.1	1.0	0.0	870.4	33.2	3.9	3446.0	4392.0
189.3	113.1	0.0	1.0	893.3	33.2	3.9	3565.0	4090.0
137.3	123.1	0.0	0.0	881.7	33.3	4.0	3434.0	4493.0
78.6	104.5	0.0	1.0	874.7	33.3	3.9	3454.0	3916.0
123.0	223.6	0.0	0.0	829.5	33.4	3.9	3191.0	4013.0
116.4	276.1	0.0	0.0	860.3	34.9	4.2	3632.0	4389.0
116.7	388.2	0.0	0.0	888.3	36.9	4.4	3951.0	4423.0
120.9	349.7	0.0	0.0	941.4	35.7	4.4	4076.0	4956.0
121.0	321.0	0.0	0.0	976.7	35.1	4.2	4089.3	4680.0
148.0	235.0	1.0	1.0	970.3	33.8	4.1	3984.6	3915.5
136.0	145.0	0.0	0.0	971.9	34.9	4.1	3963.6	4462.0
144.0	159.0	0.0	0.0	930.6	34.3	4.3	3957.0	4692.2
156.0	160.0	1.0	0.0	879.5	31.0	3.7	3265.2	4610.8
157.0	325.0	1.0	0.0	858.2	28.8	3.5	2954.8	4444.0
165.0	496.0	0.0	0.0	846.6	33.0	4.1	3438.0	5008.0
158.0	652.0	0.0	0.0	827.9	34.2	4.2	3522.0	4807.0

SuPr ¹	SuBeAr ¹	SuBeY ¹	SuEx ¹	SuIm ¹	SuCon ¹	WeCo ¹	CoAr ¹	CoY ¹
6953.0	1517.0	2.7	311.3	4375.8	9254.0	0.0	27367.0	5.4
6619.0	1479.0	2.6	46.2	5118.3	10043.0	0.0	28938.0	5.5
5792.0	1216.0	2.6	132.0	5285.5	10352.0	0.0	28981.0	5.7
5900.0	1269.0	2.6	195.8	4838.9	10027.0	0.0	29109.0	6.3
5579.0	1120.0	2.6	371.8	4745.4	9934.0	0.0	29299.0	6.9
6221.0	1190.0	2.7	1228.7	4863.1	9477.0	1.0	29526.0	5.7
6122.0	1228.0	2.7	249.7	3513.4	9095.0	0.0	30159.0	6.8
5955.0	1027.0	2.6	249.7	2971.1	8518.7	0.0	29428.0	7.1
5910.0	1056.0	2.7	411.4	3372.6	8199.0	1.0	20833.0	5.1
5940.0	1096.0	2.7	410.3	2821.5	7863.0	0.0	29096.0	6.7
6124.0	1102.0	2.7	592.9	2251.7	7472.3	0.0	30436.0	7.4
7159.0	1191.0	3.1	650.1	1653.3	7238.6	0.0	27886.0	7.5
7247.0	1252.0	3.1	389.4	1254.0	7598.9	0.0	24081.0	7.5
6804.0	1301.0	2.6	509.3	1928.3	7598.1	1.0	23573.0	5.3
6691.0	1295.0	2.7	642.4	2586.1	7723.0	0.0	26217.0	7.3
6978.0	1377.2	2.8	675.4	2880.9	8051.0	0.0	27095.0	7.4
7306.0	1386.7	2.8	614.9	2278.1	8063.0	1.0	27851.0	6.8
7838.0	1411.5	3.1	427.9	2009.7	8259.0	0.0	29169.0	8.3
7655.0	1409.4	2.9	456.5	1764.4	8394.0	1.0	25468.0	6.3
7927.0	1443.0	3.1	519.2	1830.4	8575.0	0.0	29345.0	8.7
7370.0	1420.1	2.8	359.7	2789.6	8804.1	1.0	26390.0	7.1
7204.0	1323.3	3.0	210.1	2768.7	8961.0	0.0	29398.0	8.0
8021.0	1428.3	3.1	178.2	2158.2	9100.5	0.0	29409.0	8.0
8374.0	1450.7	3.0	229.9	1820.5	9316.1	0.0	29376.0	8.4
9032.0	1527.3	3.2	123.2	1632.4	9433.7	0.0	28525.0	8.4
8769.3	1373.0	3.4	140.8	1587.3	9383.3	0.0	29316.0	8.6
7900.1	1243.4	3.1	136.4	1532.3	9341.0	0.0	27830.0	8.7
8425.6	1360.7	3.3	141.9	1725.9	9244.2	0.0	28057.0	8.1
8649.2	1347.8	3.5	287.1	1750.1	9072.6	0.0	28710.0	8.9
7876.0	1306.7	3.5	258.5	2095.5	9210.0	0.0	29798.0	10.1
7398.8	1242.9	3.6	202.4	3435.3	9312.0	0.0	30399.0	9.3
8446.0	1303.6	3.8	421.3	2075.7	8921.6	0.0	28590.0	9.4
8329.0	1247.0	3.9	249.7	2187.9	9336.0	0.0	35022.0	9.5

CoPr ¹	CoIm ¹	CoFeed ¹	CoHf ¹	CoEth ¹	CoOthCon ¹	TCoCon ¹	CoEx ¹	TCoUtil ¹
5840.7	1.5	3581.8	40.2	0.0	480.6	4102.6	1664.5	5767.1
6289.1	2.4	3601.9	59.5	0.0	482.7	4144.1	1645.1	5789.2
6505.0	2.4	3729.7	80.5	0.0	500.5	4310.7	1896.4	6207.1
7267.9	1.1	4274.4	91.4	0.0	516.6	4882.4	2113.1	6995.5
7928.1	0.7	4563.0	126.6	0.0	512.9	5202.5	2401.5	7604.1
6639.3	0.9	4232.1	165.0	35.0	459.2	4891.3	2391.1	7282.4
8118.6	0.6	4244.5	183.0	86.0	464.4	4977.9	1996.8	6974.7
8235.0	0.5	4573.2	214.0	140.0	500.5	5427.7	1821.3	7249.1
4174.2	1.7	3876.3	265.0	160.0	505.1	4806.4	1886.4	6692.8
7672.1	1.7	4114.5	310.0	232.0	525.2	5181.7	1850.3	7032.0
8875.4	9.9	4114.2	327.0	271.0	554.5	5266.7	1227.3	6494.0
8225.7	1.8	4659.5	338.0	290.0	605.4	5892.9	1492.5	7385.4
7131.2	3.4	4789.2	358.0	279.1	614.5	6040.9	1716.4	7757.3
4928.6	2.8	3933.9	361.0	287.4	649.3	5231.7	2028.5	7260.1
7531.9	1.9	4382.5	368.0	321.4	680.6	5752.5	2367.3	8119.8
7934.0	3.4	4608.9	379.0	349.1	697.0	6034.0	1726.6	7760.7
7474.7	19.6	4797.9	391.8	398.3	743.4	6331.4	1583.9	7915.3
9476.6	7.1	5252.1	414.8	425.5	715.5	6807.8	1663.3	8471.1
6337.7	20.8	4679.9	441.0	458.3	714.0	6293.1	1328.3	7621.4
10050.5	9.6	5459.7	458.6	532.8	723.8	7174.9	2177.5	9352.4
7400.0	16.5	4692.5	472.8	395.7	759.6	6320.6	2227.8	8548.4
9232.5	13.3	5277.1	492.3	428.7	793.2	6991.2	1797.4	8788.6
9206.8	8.8	5481.7	512.9	481.1	810.8	7286.6	1504.4	8791.0
9758.6	18.8	5467.9	530.5	525.8	790.0	7314.1	1984.2	9298.3
9430.6	14.8	5665.0	539.5	565.8	807.9	7578.2	1936.6	9514.8
9915.0	6.8	5842.1	529.8	627.6	799.5	7799.0	1941.3	9740.3
9502.5	10.2	5864.2	540.6	705.9	799.9	7910.6	1904.8	9815.4
8966.7	14.4	5562.9	531.8	995.5	812.9	7903.1	1587.9	9491.0
10089.2	14.1	5795.0	530.2	1167.5	839.4	8332.1	1899.8	10231.9
11807.0	10.8	6157.1	520.7	1323.1	843.1	8844.0	1818.1	10662.0
11114.0	8.8	6154.7	528.6	1602.8	849.8	9135.9	2133.8	11269.7
10534.8	12.0	5597.8	510.1	2117.1	860.7	9085.7	2124.7	11210.4
13073.8	15.0	6150.0	500.0	3000.0	860.0	10510.0	2450.0	12960.0

EthPr ⁷	ddd	Car ⁵	EthCon ⁷	RFS	mand	EthIm ⁷	Cattl ¹	GasP ²
0.0	0.0	106706.0	0.0	0.0	0.0	0.0	10170	181.4
0.0	0.0	110189.0	0.0	0.0	0.0	0.0	12941	185.8
0.0	0.0	112288.0	0.0	0.0	0.0	0.0	12580	186.4
0.0	0.0	116573.0	0.0	0.0	0.0	0.0	13472	176.8
0.0	0.0	118429.0	0.0	0.0	0.0	0.0	13274	214.2
175	1.0	121601.0	175.0	0.0	0.0	0.0	12221	260.2
215	1.0	123098.0	215.0	0.0	0.0	0.0	11598	261.0
350	1.0	123702.0	350.0	0.0	0.0	0.0	10618	231.3
375	1.0	126444.0	375.0	0.0	0.0	0.0	12051	214.6
430	1.0	128158.0	430.0	0.0	0.0	0.0	11594	200.9
610	1.0	127885.0	610.0	0.0	0.0	0.0	12453	192.4
710	1.0	130004.0	710.0	0.0	0.0	0.0	11731	145.6
830	1.0	131482.0	830.0	0.0	0.0	0.0	11277	143.6
845	1.0	133836.0	845.0	0.0	0.0	0.0	11872	137.8
870	1.0	134559.0	870.0	0.0	0.0	0.0	11440	141.8
900	1.0	133700.0	900.0	0.0	0.0	0.0	11626	153.4
950	1.0	128300.0	950.0	0.0	0.0	0.0	12715	144.1
1100	1.0	126581.0	1100.0	0.0	0.0	0.0	11942	138.3
1200	1.0	127327.0	1200.0	0.0	0.0	0.0	12789	132.1
1350	1.0	127883.0	1350.0	0.0	0.0	0.0	13024	129.2
1400	1.0	128387.0	1400.0	0.0	0.0	0.0	12420	129.6
1100	1.0	129728.0	1100.0	0.0	0.0	0.0	12958	135.1
1300	1.0	129749.0	1300.0	0.0	0.0	0.0	13181	132.4
1400	1.0	131839.0	1400.0	0.0	0.0	0.0	13608	111.9
1470	1.0	132432.0	1470.0	0.0	0.0	0.0	13283.5	120.4
1630	1.0	133621.0	1630.0	0.0	0.0	0.0	14073	151.0
1770	1.0	137633.0	1770.0	0.0	0.0	0.0	14276.4	142.1
2130	1.0	135921.0	2175.2	1.0	0.0	45.2	14050.3	130.0
2800	1.0	135670.0	2860.9	1.0	0.0	60.9	13219.8	148.9
3400	1.0	136431.0	3559.9	1.0	0.0	159.9	13812.9	171.4
3904	1.0	136568.0	4039.5	1.0	0.0	135.5	13744.7	202.4
4855	1.0	135400.0	5526.7	1.0	1.0	671.7	14131.9	221.2
6485	1.0	0.0	6847.0	1.0	1.0	435.2	14268.7	232.6

FIP ³	CPI ⁶	DHF ¹	WHF ¹	WSuP ⁶	DRaSuP ¹	DRfSuP ¹	DRtRfSuP ¹	WRaSuP ¹
199.7	31.3	22.7	0.0	20.6	22.5	27.6	37.2	20.5
199.7	33.1	14.0	0.0	11.6	13.3	16.9	24.0	11.6
199.7	35.2	12.4	0.0	8.1	11.0	15.1	21.6	8.1
200.2	37.9	12.1	0.0	7.8	13.9	18.7	23.7	7.8
198.3	42.2	13.2	0.0	9.7	15.6	19.7	24.9	9.7
191.6	47.9	23.6	0.0	28.7	30.1	38.3	42.7	29.0
184.3	52.8	21.5	0.0	16.9	19.7	28.3	40.0	16.9
176.3	56.0	14.3	44.8	8.4	19.9	27.6	34.3	8.4
171.7	57.8	18.6	48.1	8.5	22.0	26.1	36.2	8.5
169.0	60.3	19.9	33.8	5.2	21.7	25.7	36.3	5.2
168.6	62.5	17.8	42.3	4.1	20.3	23.2	35.3	4.0
167.6	63.6	18.1	18.2	6.1	21.0	23.4	35.1	6.1
162.9	66.0	16.5	8.2	6.8	21.8	23.6	35.3	6.7
161.1	68.7	16.5	29.3	10.2	22.1	25.4	36.6	10.2
166.9	72.0	19.2	24.4	12.8	22.8	29.1	40.0	12.8
164.9	75.9	19.7	27.9	12.5	23.3	30.0	42.8	12.5
158.9	79.1	20.9	25.2	9.0	21.6	25.7	42.8	9.0
162.7	81.5	20.7	23.8	9.1	21.3	25.4	41.5	9.1
157.9	83.9	20.4	21.5	10.0	21.6	25.1	40.5	10.0
156.6	86.1	18.8	23.1	12.1	22.0	25.2	40.0	12.1
159.1	88.5	15.6	25.8	13.3	23.0	25.8	39.8	13.4
166.4	91.1	14.5	26.0	12.0	22.4	29.2	41.8	12.2
167.6	93.2	10.7	23.5	11.4	22.0	27.1	43.3	12.1
168.0	94.7	10.6	22.0	8.9	22.1	26.1	43.0	9.7
166.4	96.7	11.7	20.3	6.3	21.2	26.7	43.3	6.5
160.2	100.0	11.3	21.0	8.1	19.1	20.8	42.4	8.5
159.8	102.8	11.9	22.9	8.2	21.1	23.3	43.4	9.1
163.7	104.5	13.1	29.9	6.2	20.9	25.8	43.1	7.9
167.0	106.8	13.2	33.0	6.9	21.4	26.2	42.7	7.5
162.1	109.7	13.2	38.2	7.5	20.5	23.5	42.6	8.6
158.3	113.4	13.6	26.0	10.1	21.3	29.5	43.5	11.4
155.6	117.1	17.0	21.8	14.8	22.1	33.1	49.6	15.5
159.1	120.4	21.2	23.4	10.0	21.0	25.1	51.5	11.6

GlP ¹	DxP ¹	SuCaLR ¹	SuBeLR ¹	CoLR ¹	DCoP ¹	WCoP ¹	DdgP ¹	GfP ¹
10.6	21.0	0.0	0.0	1.1	2.8	2.9	112.4	86.0
10.6	15.5	0.0	0.0	1.5	2.4	2.6	132.4	100.2
10.6	14.1	0.0	0.0	2.0	2.2	2.5	121.2	101.4
10.6	16.4	13.5	15.6	2.0	2.5	2.8	127.8	96.8
10.6	17.3	14.7	17.0	2.1	2.8	3.0	137.8	126.2
10.6	29.1	13.0	15.2	2.3	3.4	3.6	161.9	124.7
10.6	29.5	0.0	0.0	2.4	2.6	2.9	146.7	115.1
10.6	27.1	16.8	19.7	2.6	2.8	3.1	142.6	113.5
10.6	26.1	17.0	20.2	2.7	3.5	3.7	172.5	123.8
10.6	26.4	17.5	20.9	2.6	2.8	3.0	97.7	94.1
11.1	24.1	17.8	20.8	2.6	2.3	2.5	107.9	75.6
10.6	23.6	18.0	21.1	1.9	1.6	1.8	117.1	94.8
10.1	22.7	18.0	21.1	1.8	2.1	2.4	136.8	98.3
11.7	25.4	18.0	21.2	1.8	2.7	2.9	141.0	122.0
13.7	25.3	18.0	21.4	1.7	2.5	2.8	124.4	113.2
14.2	24.5	18.0	21.5	1.6	2.4	2.7	126.8	100.2
15.4	24.5	18.0	21.9	1.6	2.5	2.7	122.3	101.5
15.2	24.5	18.0	22.9	1.7	2.2	2.5	122.8	102.8
13.2	24.5	18.0	23.3	1.7	2.7	2.8	123.8	88.0
15.3	25.9	18.0	23.6	1.9	2.4	2.8	105.7	89.6
14.5	25.5	18.0	22.9	1.9	4.0	4.3	151.4	88.3
16.4	25.5	18.0	22.9	1.9	2.8	3.1	142.9	116.2
10.9	25.5	18.0	22.9	1.9	2.6	2.8	107.8	84.0
12.7	29.8	18.0	22.9	1.9	2.1	2.4	84.9	64.9
12.6	19.2	18.0	22.9	1.9	2.0	2.2	81.3	58.8
12.8	15.8	18.0	22.9	1.9	2.0	2.2	83.1	51.7
14.3	16.1	18.0	22.9	1.9	2.1	2.4	77.1	62.5
15.0	17.9	18.0	22.9	2.0	2.5	2.7	80.1	60.3
16.0	19.9	18.0	22.9	2.0	2.7	2.9	115.9	72.2
16.8	21.0	18.0	22.9	2.0	2.1	2.5	76.0	72.0
17.5	22.1	18.0	22.9	2.0	2.1	2.7	85.6	51.3
18.3	24.0	18.0	22.9	2.0	3.5	3.9	109.1	59.9
22.0	28.2	18.0	22.9	2.0	4.5	4.5	147.4	73.5

GmP ¹	CoOilP ¹	FePindex ¹	FeP ¹	EthP ⁴	BaP ¹	WhP ¹	CotP ¹	SoyP ¹
215.6	32.4	81.7	196.9	0.0	2.4	3.6	0.5	4.9
249.1	25.8	67.2	143.3	0.0	2.3	2.7	0.6	6.8
252.5	30.7	65.9	142.9	0.0	1.8	2.3	0.5	5.9
234.6	36.0	66.4	143.3	0.0	1.9	3.0	0.6	6.7
274.5	32.4	72.3	146.8	0.0	2.3	3.8	0.6	6.3
255.5	26.3	91.6	195.8	1.8	2.8	4.0	0.7	7.6
257.0	23.8	101.2	205.4	1.7	2.5	3.7	0.5	6.1
235.3	23.8	100.0	207.3	1.7	2.2	3.5	0.6	5.7
267.2	24.7	93.1	191.6	1.7	2.5	3.5	0.7	7.8
243.1	29.8	97.2	204.4	1.6	2.3	3.4	0.6	5.8
200.4	26.3	94.3	193.1	1.6	2.0	3.1	0.6	5.1
213.9	18.5	86.1	170.8	1.1	1.6	2.4	0.5	4.8
251.6	21.5	87.9	160.9	1.2	1.8	2.6	0.6	5.9
306.1	23.6	99.2	183.0	1.1	2.8	3.7	0.6	7.4
281.4	21.1	101.2	196.1	1.2	2.4	3.7	0.7	5.7
245.6	26.6	95.2	178.0	1.4	2.1	2.6	0.7	5.7
256.1	28.4	99.0	187.9	1.3	2.1	3.0	0.6	5.6
259.7	23.9	94.5	182.0	1.3	2.0	3.2	0.5	5.6
296.5	21.5	90.7	178.8	1.2	2.0	3.3	0.6	6.4
262.5	27.2	103.7	191.9	1.2	2.0	3.5	0.7	5.5
244.0	26.7	119.0	227.8	1.2	2.9	4.6	0.8	6.7
332.4	24.5	123.5	235.6	1.4	2.7	4.3	0.7	7.4
345.2	24.9	120.7	226.6	1.2	2.4	3.4	0.7	6.5
260.5	29.9	111.9	205.3	1.1	2.0	2.7	0.6	4.9
231.9	23.6	106.0	194.3	1.0	2.1	2.5	0.5	4.6
237.6	14.7	106.8	194.6	1.4	2.1	2.6	0.5	4.5
254.0	15.8	116.1	246.3	1.5	2.2	2.8	0.3	4.4
243.7	20.8	103.8	195.3	1.1	2.7	3.6	0.5	5.5
251.4	28.7	126.0	236.4	1.4	2.8	3.4	0.6	7.3
308.4	27.6	141.0	253.0	1.7	2.5	3.4	0.4	5.7
288.1	28.4	156.0	293.3	1.8	2.5	3.4	0.5	5.7
264.9	25.1	163.0	335.1	2.6	2.9	4.3	0.5	6.4
351.0	31.0	0.0	382.9	2.2	4.1	6.7	0.6	10.4

OatP ¹	GasP ²	NGP ²	BvP ³	BakP ³	DCroidP ²	Ir ⁶	RicP ¹	SuInd ¹	SuNoInd ¹
1.5	56.7	1.0	41.3	64.7	7.7	7.9	8.4	5716.0	3238.9
1.6	61.4	1.2	49.4	64.7	8.2	6.8	7.0	6045.5	3497.9
1.1	65.6	1.5	74.4	64.7	8.6	6.8	9.5	6466.6	3509.5
1.2	67.0	1.7	78.7	68.0	9.0	9.1	8.2	6493.3	3358.7
1.3	90.3	2.0	82.6	66.9	12.6	12.7	10.5	6162.5	3438.2
1.7	124.5	2.6	91.4	83.8	21.6	15.3	12.8	5914.7	3292.2
1.9	137.8	3.1	95.3	91.8	31.8	18.9	9.1	5693.3	3388.6
1.5	129.6	3.9	98.0	96.2	28.5	14.9	7.9	5304.6	3214.1
1.6	124.1	4.2	99.8	99.7	26.2	10.8	8.6	5123.0	3076.0
1.7	121.2	4.2	102.3	104.2	25.9	12.0	8.0	4809.8	3053.2
1.2	120.2	4.0	104.3	108.2	24.1	9.9	6.5	4348.9	3123.4
1.2	92.7	3.2	110.4	111.1	12.5	8.3	3.8	4163.5	3075.1
1.6	94.8	2.9	107.5	115.1	15.4	8.2	7.3	4400.1	3198.8
2.6	94.6	3.0	107.5	121.8	12.6	9.3	6.8	4283.2	3315.0
1.5	102.1	3.0	111.3	131.5	15.9	10.9	7.4	4465.0	3258.0
1.1	116.4	2.9	113.5	139.2	20.0	10.0	6.7	4660.0	3391.0
1.2	114.0	2.7	114.1	144.7	16.5	8.5	7.6	4594.0	3469.0
1.3	112.7	2.8	114.3	150.4	16.0	6.3	5.9	4591.0	3668.0
1.4	110.8	3.1	114.6	155.7	14.3	6.0	8.0	4805.0	3589.0
1.2	111.2	3.1	123.2	161.9	13.2	7.1	6.8	4977.0	3598.0
1.7	114.7	2.7	131.7	167.4	14.6	8.8	9.2	5102.8	3701.3
2.0	123.1	3.4	128.6	176.1	18.5	8.3	10.0	5202.0	3759.0
1.6	123.4	3.6	133.4	181.1	17.2	8.4	9.7	5272.4	3828.1
1.1	105.9	3.1	133.0	185.4	10.9	8.4	8.9	5555.8	3760.3
1.1	116.5	3.1	134.3	189.4	15.6	8.0	5.9	5629.8	3803.9
1.1	151.0	4.5	137.8	194.1	26.7	9.2	5.6	5490.8	3892.5
1.6	146.1	5.2	139.2	201.3	21.8	6.9	4.3	5414.3	3926.7
1.8	135.8	4.0	139.2	206.1	22.5	4.7	4.5	5135.9	4108.3
1.5	159.1	5.9	139.8	211.7	27.6	4.1	8.1	5033.9	4038.7
1.5	188.0	6.5	140.4	216.2	36.8	4.3	7.3	5253.9	3956.2
1.6	229.5	8.6	144.4	220.5	50.3	6.2	7.7	5286.0	4026.0
1.9	258.9	7.9	147.4	226.4	59.7	8.0	10.0	5057.3	3864.3
2.5	280.1	7.6	153.4	236.6	66.5	8.1	11.5	5459.3	3877.0

Source:

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VITA

Hassan Marzoughi was born in August 1965, in Iran. After completing his high school studies, he attended Shiraz University, in Shiraz, Iran, where he earned a bachelor's degree in theoretical economics in 1990. In 1991, he enrolled at the Shahid Beheshti University, Tehran, Iran, and received his master's degree in economics in 1994.

He joined the Institute for Trade Studies and Research, Ministry of Commerce, Tehran, Iran, in 1996, as a research assistant, and was working there until 2001. He worked on several projects related to international trade as a project director and/or project assistant. Two of these projects were published as book chapters. He also, was the vice general director for the Training Bureau, Ministry of Cooperatives, Tehran, Iran, from 1999 to 2001.

His work experience also includes teaching undergraduate courses including international trade, principles of economics, and money and banking science between 1997 and 2001.

In 2002 he returned to college to pursue a doctoral degree. In 2003, he entered the doctoral program in the Department of Agricultural Economics and Agribusiness at Louisiana State University, and currently he is a candidate for the degree of Doctor of Philosophy which will be awarded in August 2009.