Impact of Corn Based Ethanol Production on the U.S. High Fructose Corn Syrup (HFCS) and Sugar Markets

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Abstract
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Hassan Marzoughi, Lynn Kennedy, and Brian Hilbun

The objective of this paper is to determine the impact of ethanol production on the sweetener market in the U.S. It was found that ethanol production has increased corn demand and prices, and therefore, may have a negative impact on HFCS production and increase the demand for sugar.

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1- Introduction

The principal objective of this paper is to determine the impact of ethanol production expansion on the sweetener markets, especially sugar and high fructose corn syrup in the U.S. Ethanol has received much attention as a viable alternative to gasoline in many countries including the U.S. A number of factors, such as skyrocketing crude oil prices, energy security issues, environmental and global warming issues, and rural economic development have served to fuel the expansion of ethanol production in the U.S. Based on absolute volume of production, the U.S. is the world's biggest ethanol producer with more than 95% of the total volume of ethanol produced coming from corn. In recent years, the production of ethanol has become a significant and growing source of demand for corn in the U.S. Although ethanol can be produced from a wide range of feedstocks, U.S. ethanol plants mostly utilize corn because, until now, corn had been the cheapest feedstock, in the United States, therefore, the current scheme of ethanol production has helped spur a dramatic increase in the demand for corn.

Corn occupies an essential position in the U.S. food supply. Corn is utilized as feedstock, a sweetener source (High Fructose Corn Syrup (HFCS)), and as a bio-fuel source (ethanol) and also as a major U.S. commodity export. So, any change in any one of these markets that affects demand for corn could have serious consequences for other markets through a change in corn prices. In this regard, fast growing demand for corn to produce corn-based ethanol in the past recent years can possibly exert a negative impact on other industries which use corn as an input (e.g., the HFCS industry).

High fructose Corn Syrup (HFCS) is one of the products that is made from corn and since its introduction has been used widely in numerous foods and beverages commonly found on grocery store shelves in the United States. HFCS is almost a perfect substitute (in a one-to-one ratio) for liquid sugar in the production of some edible products like beverages, soft drinks, and bakery goods. The U.S. Sugar Program has increased sugar prices in the U.S. and, in turn, forced industries that use sugar as a primary input to find a sugar substitute. The U.S. sugar market is a relatively closed market that prevents free access to the market for other countries by using a

combination of both a tariff rate quota and a price support system. The ability to cheaply produce HFCS along with HFCS' substitutability for sugar coupled with high sugar prices has encouraged food processors and beverage producers (especially soft drink producers) to substitute HFCS for sugar.

But rapid growth in the U.S. ethanol market could possibly change this situation. Because of the sharp increase in corn prices in the few past years, HFCS production costs have increased making HFCS a less competitive alternative sweetener for sugar. This is especially evident if we note that sugar is a perfect substitute for HFCS but not vice versa, and if we consider recent growing concern about the relationship between HFCS consumption and obesity levels in the U.S., one could anticipate an even tighter future market for HFCS producers. This means that we can expect a higher demand for sugar in the United States. The U.S. government uses three different tools to control the sugar supply, and de facto U.S. sugar market, in order to support U.S. sugar producers, avoiding forfeitures at the same time. These tools are tariff rate quotas (TRQ), marketing allotments, and nonrecourse loan rates. Import quotas control sugar imports in order to prevent unapproved amounts of sugar being imported into the U.S. market. The USDA is responsible for setting the import quota and price support levels each year. The U.S. Trade Representative allocates the import quota to countries that are eligible to export to the United States. If a rise in corn prices reduces HFCS production seriously we then would expect that government to increase sugar imports.

The remainder of the paper is divided into three sections. First, a historical overview of the U.S. ethanol production is conducted, and pertinent information regarding the HFCS, sugar, and corn markets is provided. The second section presents the relevant economic models and discusses estimation results as to the relationships between variables. Finally, the last section will bring the conclusion of the paper.

2- Literature review

2 - 1 - Ethanol production

Ethanol has received a lot of attention as a possible fuel source in many countries including the U.S. A number of factors have been important in the expansion of ethanol production in the U.S. including: high petroleum price resulting from high oil demand along with limitations to accessible oil resources, environmental concerns especially those regarding the emission of

greenhouse gasses and the specter of global warming, along with a concerted push in finding new markets for agricultural products in order to improve the farmers' income and furthering rural development schemes, the phase-out of MTBE as a gasoline additive, energy security issues, and subsidies for ethanol production. Among these factors, high oil prices (close to $100/barrel) have an important role in ethanol production because high oil prices make ethanol production more profitable and increases the role of ethanol in lowering the U.S. trade deficit. These two issues together serve to stimulate ethanol production.

Even though the idea of using ethanol as an alternative motor fuel in the U.S. dates back many years ago when Henry Ford manufactured an alcohol fuel-based car, it was only in the 1970's during the Arab oil embargo that planners/analysts started seriously looking at ethanol.

More than 104 ethanol plants have produced 4.8 billion gallons of ethanol in the US in 2006. Thirty-four new ethanol plants along with expansion in seven current ethanol plants will boost capacity by an additional 2.2 billion gallons (RFA 2006).

While these plants are geographically dispersed all over the country and use different feed stocks, the majority of plants are located in the Midwest states of Iowa, Minnesota, Illinois, Indiana, and Nebraska, America's 'Corn Belt', where corn is utilized most heavily in ethanol production.

Based on absolute volume of production, the US is the biggest ethanol producer in the world. The 2005 energy bill required increases in the levels of ethanol and bio-diesel production to 7.5 billion gallons annually by 2012. If the current growth rate in ethanol production continues, the U.S. will reach its production target sooner than 2012 and even at this production level, the U.S. will have reserve capacity to boost ethanol/bio-diesel production levels even higher.

Although the expansion of the ethanol market in the US is dependent upon petroleum oil price and the magnitude in demand for ethanol, government policies related to other factors (especially air pollution, energy security, and rural development) can have big impacts on the ethanol futures market. Therefore we can expect an increase in the demand for ethanol, continuing into the foreseeable future.

The pertinent questions are 'How does an expansion in ethanol impact high fructose corn syrup production and the sugar market?' and, 'What will be the impact on the corn market?'

In recent years, ethanol has been a significant and growing source of demand for corn in the U.S. Although ethanol can be produced from a wide range of feedstocks, U.S. ethanol plants mostly use corn because, up until now, corn had been the cheapest feedstock from which ethanol could be produced in the U.S. Therefore, U.S. ethanol plants had mainly located in the Midwest part of the country where the Corn Belt states produce an abundant amount of corn. Around 97 percent of U.S. ethanol production uses corn as a feedstock. The U.S. is the largest corn producer in the world, with 2006 corn production at more than 10.5 billion bushels corn. With 39% of world corn production and 68% of world corn exports in 2006, the U.S. has been the biggest corn producer and exporter in the world (NCGA, 2007).

Increased demand for ethanol in the past few years has had a big influence on corn prices, so much so that corn price has increased from $1.82 per bushel in 2000 to $3.2 per bushel in 2006. South Dakota's range of corn prices for week ending Dec 21, 2007 was between $3.75 and $4.13 per bushel. Corn futures increased so that Dec 21 closing bids for 2008 new crops was $4.63 (May, 2007).

U.S. dependency on imported oil has raised big concerns in recent years not only from an economic point of view but also from geopolitical and national security framework standpoints. The U.S. consumes 20 million barrels of oil per day. Of that 20 million barrels, 6 million barrels come from domestic production, with the remainder (14 million barrels) coming from oil imports. (Woolverton, 2006). On the one hand, skyrocketing oil prices (at historic levels ($100 per barrel)) not only plays an important role in the U.S. trade deficit but can also have a negative impact on the growth rate of the entire U.S. economy. The U.S. imports a significant part of its oil from the Middle East, a geo-political region mired in instability. This geo-political instability serves to undermine U.S. energy supplies, threatening U.S. sovereignty. These concerns, along with other factors such as environmental and ecological concerns, have forced the U.S. government to take serious steps in order to find a viable alternative to fossil fuels, not only bearing in mind economic and political concerns but also environmental concerns as well. Until now, ethanol had been thought of as the best substitute for gasoline from the economic and practical points of view. Ethanol is a renewable energy source that can be produced domestically by using a wide range of agricultural crops. Using ethanol decreases crude oil dependency, therefore decreasing the risk to energy security and helping to keep the trade deficit from increasing. Also it helps, when ethanol is mixed with gasoline, in decreasing tailpipe emissions.

The Energy Policy Act of 2005 (EPA-2005) has had a big influence on ethanol production. EPA-2005 established the Renewable Fuel Standard (RFS) and eliminated the oxygenate requirement for the Federal Reformulated Gasoline (RFG) Program as of May 2006. (Tokgoz and Elobeid, 2006)

Under EPA-2005, gasoline sold in the United States must contain a minimum amount (by volume) of renewable fuel. Also, the volume of renewable fuel to be utilized has to increase from 4 billion gallons in 2006 to 7.5 billion gallons in 2012. (EPA) If we assume that we can produce 2.7 gallons of ethanol from one bushel of corn, we would then need to use 2.8 billion bushels corn to produce 7.5 billion gallons of ethanol.

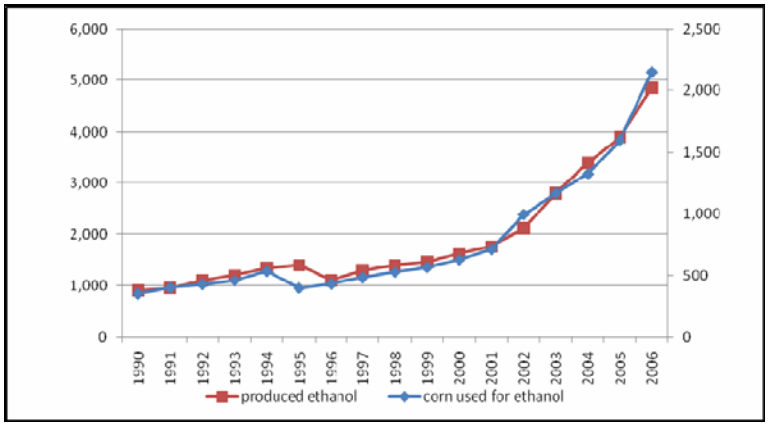

Figure 1- Ethanol Production and Amount of Corn Used for Ethanol Production in the U.S

Source : USDA

As figure 1 shows, ethanol production has increased from less than 0.5 billion gallons in 1990 to around 5 billion gallons in 2006, this is 10 times the volume for 1999. This increase in production substantially increased after 2001 so that the volume of ethanol production increase between 1990 and 2001 is around 0.5 billion gallons while the volume of produced ethanol has increased to around 3 billion gallons between 2001 and 2006.

The same trend has been happening in allocations of the amount of corn that had been used for producing ethanol. Corn use in the ethanol industry has increased from 0.35 billion bushels (4.4% of total U.S. corn production) in 1990 to 2.15 billion bushels (20% of total U.S. corn production) in 2006. This dramatic increase in corn demand, especially after 2001, has helped raise corn prices in the U.S.

Figure 2 shows the ethanol's share along with other sectors' shares for the total amount of corn produced in the U.S. in 2006. Corn demand for food and residual uses consist of more than 50 percent of total corn produced. Ethanol for fuel and HFCS uses, respectively, 20% and 5% of total corn production. (USDA).

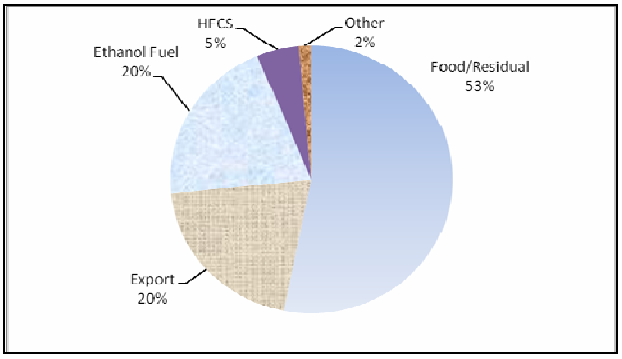

Figure 2 – U.S. Corn Usage by Sector in 2006
Source: USDA

There has been a good deal of research done that has studied the impact of high oil prices and ethanol production expansion on agricultural products. But the problem with this research is that none of them have had any expectation for crude oil prices at $100 per barrel and therefore their estimated prices for ethanol and especially corn is much lower than what we now know.

One of these studies that is closer in its current pricing levels is the CARD Briefing Paper. This paper examines different scenarios for crude oil price and calculates resultant ethanol production and corn price based on each scenario (Elobeid et al, 2006). Based on this study, the break-even corn price would be $4.05 per bushel if ethanol tax policy, prices of crude oil, natural gas, and distillers grains stays at 2006 levels. In this case, the U.S. could produce 31.5 billion gallons of corn-based ethanol annually by 2015, with this amount being equivalent to 20% of estimated U.S. fuel consumption in this year. This study has assumed five different prices for crude oil (40, 50, 60, 70, and 80 dollars/barrel) and then estimated the gasoline price, ethanol price, and corn price based on each level of crude oil price. In the last scenario, closest in terms of crude oil price to the current situation ($100/barrel for crude oil), gasoline price would be $2.76 per gallon and ethanol and corn prices would be $2.35 per gallon and $5.43 per bushel, respectively. This study anticipates that corn based ethanol expansion will continue until corn reaches $4.05 per bushel and after that point, the related markets would be in equilibrium. At this price,

$4.05/bushel, the U.S. would use approximately 11 billion bushels of corn, in turn, yielding 31.5 billion gallons of ethanol.

2 - 2 – The Corn Market

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 U.S. corn price is utilized as the base price for world corn price. Corn has an essential position in the U.S. food, feed, sweeteners, and bio-fuel markets and world corn export. So any change in any one of these markets that affects corn demand for corn, can have serious consequences for other markets through a change(s) in corn prices. In this regard, fast growing demand for corn to produce corn-based ethanol in the past recent years can possibly have a negative impact on other industries which use corn as a primary input (including the HFCS industry). Figure 3 shows the amount of corn used to produce food, feed, HFCS, fuel and the amount of corn exports. As we can see, between 1990 and 2006, the biggest change (increase) has happened in the amount of corn being used for producing ethanol. The share of corn for fuel in U.S. total corn crops has increased from less than 5% in 1990 to more than 20% in 2006. In this period of time, total U.S. corn production has increased by 33% from 7.9 billion bushels in 1990 to 10.5 billion bushels in 2006. A part of this increase comes from increases in the area of corn planted - from 67.7 million acres to 71.5 million acres - and with the other part coming as a result of increased corn yields stemming from the use of genetically improved corn varieties– from 117.2 bushels per acre to147.4 bushels per acre. (USDA) As figure 3 shows that, until now, increases in demand for corn to produce ethanol have mostly been compensated by increases in corn production and therefore had a negative impact on other sectors – from the standpoint of volume, not price - has not been that great. But increases in corn production can increase corn production costs. For example, land prices have increased dramatically in the Corn Belt states in recent years as demand for land to produce corn, resulting from boosts in ethanol production, have shot up substantially. (The Digest, 2007) Increases in corn cost production in turn will increase corn prices and therefore increase production costs in other industries such as HFCS which uses corn as an input. Corn price has increased from $1.85/bushel in 2000 to between $3.35 and $3.95 in 2007, around a 100% increase in price (USDA, Dec 2007). This means that between 2000 to 2007, the cost of using corn in producing HFCS has doubled.

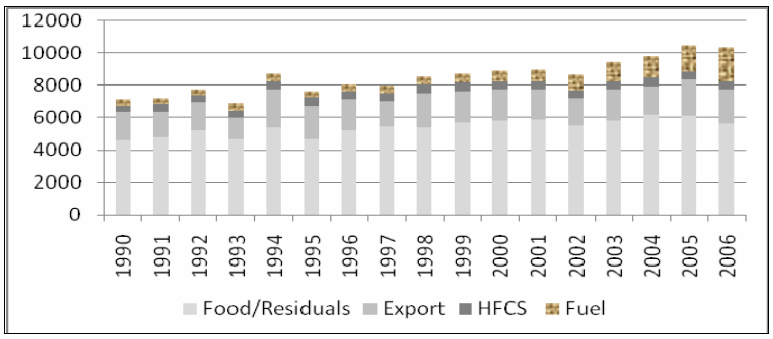

Figure 3 - U.S. Corn Usage by Sector
Source: USDA

2 - 3 The HFCS Market

High fructose corn syrup (HFCS) is made from corn and since its introduction has been used widely in numerous foods and beverages that can be commonly found on grocery store shelves in the United States. Usually wet milling producers are capable of producing ethanol or HFCS along with byproducts such as corn oil, gluten meal, gluten feed, and carbon dioxide (CO_2). There are two different kinds of HFCS, HFCS42 and HFCS55. HFCS42 contains 42 percent fructose and 53 percent glucose and is not quite as sweet as sugar while HFCS55 is 55 percent fructose, 42 percent glucose and is almost as sweet as sugar (regular sugar is composed of 50 percent fructose and 50 percent glucose). HFCS55 is mostly used in the carbonated soft drinks while HFCS42 is used more in non-carbonated beverages, baked goods and other food items.

The U.S. sugar program has increased sugar price in the U.S. forcing industries that used sugar as an input to look for a comparable sugar substitute. The U.S. sugar market is a relatively closed market which prevents free market access for other countries by using a tariff rate quota along with a price support system. Based on this system, only 40 countries have access to the U.S. sugar market. An artificial import ceiling of about 1.2 million tons is imposed by the USDA annually. This import ceiling has raised domestic sugar price dramatically so that in some periods this price is 3 times world sugar price.. High sugar prices have subsequently forced U.S. food producers that used sugar as a major to search for other, cheaper sugar substitutes. On the other hand, with producing an abundant amount of relatively cheap corn has been capable of producing cheap HFCS historically. The cheap produced HFCS with ability of being the best substitute for liquid sugar along with high sugar prices has encouraged the food processors and beverage producers and especially soft drink producers to substitute HFCS for sugar.

HFCS is an almost perfect substitute for liquid sugar in producing some products like beverages, soft drinks, and bakery goods while it is not so good a substitute in producing other products (e.g., confectionary goods). HFCS was first introduced in the 1970's and because of the constraint on sugar imports, serving to increase sugar prices, HFCS consumption grew at a rapid pace going on to replace sugar in beverages and as the main sweetener in the canned food industry. Because of high sugar prices in the U.S., carbonated soft drink producers began to switch from sugar to HFCS in 1980. Coca-Cola and Pepsi replaced sugar with HFCS in 1980 partially and in 1983 they used HFCS in 75% of caloric cola soft drinks and by 1984 they had totally substituted 100% sugar with HFCS.

HFCS consumption has increased very fast so that the per-capita consumption of HFCS has increased from less than 1 pound in 1970 to more than 58 pounds in 2006 while per-capita consumption of refined sugar has decreased from more than 101 pounds in 1970 to less than 63 pounds in 2006 (figures 4 and 5). Figure 6 shows that sugar's share of total consumed sweeteners in the U.S. has decreased from 86% in 1966 to 44.7% in 2006 while HFCS' share has increased from zero to 42% for the same period. HFCS had captured 42% of the U.S. caloric sweetener market by 2006 which was very close to sugar's share (44.7%) of this market. It is very interesting to note that both sugar and HFCS' share of the total sweetener market has been fairly stable from 1992 to 2006.

Traditionally, the U.S. has been the lowest HFCS cost producer in the world - because of having a lot of cheap corn – and therefore HFCS producers have been able to sell HFCS at a relatively cheaper price than sugar. Based on USDA data, raw and refined sugar prices have been stable between 1982 and 2005 while HFCS price has had a decreasing trend in this period (figure 7). In 2005, raw sugar price and refined sugar price have been 21.28¢/lb. and 29.54¢/lb., respectively, while HFCS price has been 12.93¢/lb. As can be seen, sugar price is almost twice that of HFCS. As we saw in figure 2, the HFCS industry used 5% of total U.S. corn production to produce 8.8 million tons of HFCS in 2006 (USDA).

But because of fast growth in the U.S. ethanol market, this situation will not remain the same. Because of sharp increases in corn prices in the past recent years turn to increase the costs of HFCS production, HFCS price increases, making it (HFCS) less competitive to sugar. This is especially true if we notice that sugar is a perfect substitute for HFCS (but not vice versa), and if

we include recent growing concerns about the relationship between HFCS consumption and obesity in the U.S., we can then anticipate an even tighter future market for HFCS producers. This means that we can expect a higher demand for sugar in the U.S. A study by the Renewable Fuels Association (RFA) examines the impact of ethanol production on the corn prices in the U.S. from 1961 to 1995. The results show that a 100 million bushel increase in the ethanol demand would increase corn prices 9¢/bushel.

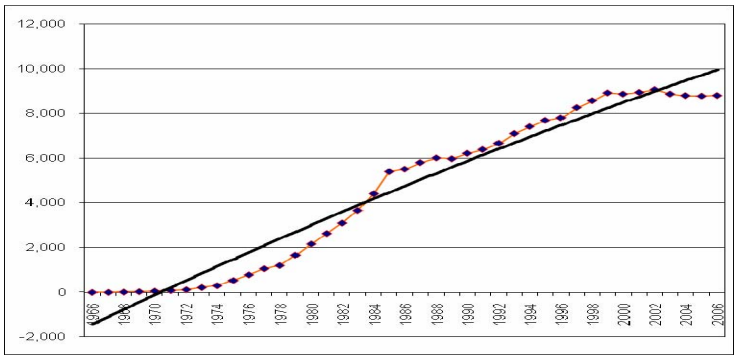

Figure 4 – HFCS consumption (1,000 short tons)
Source: USDA

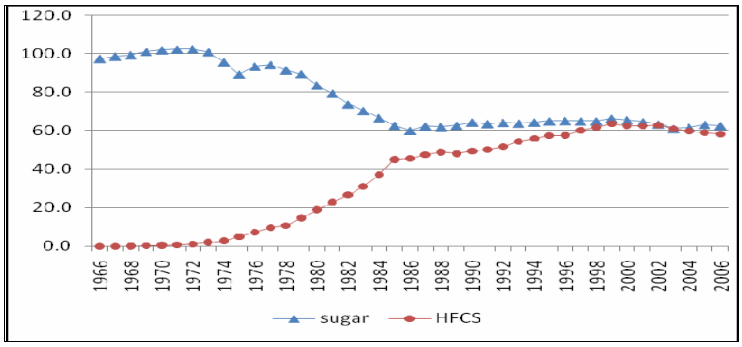

Figure 5 – Per-Capita U.S. HFCS and Sugar Consumption (lbs.)
Source: USDA

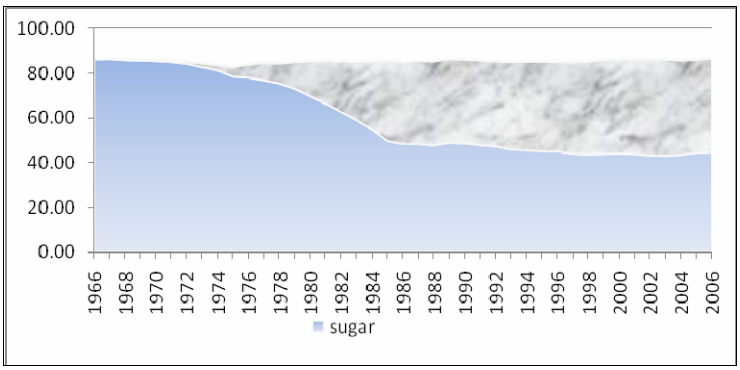

Figure 6 - Share of Sugar and HFCS in the U.S.: Total Deliveries of Caloric Sweeteners for Domestic Food and Beverage Use
Source: USDA

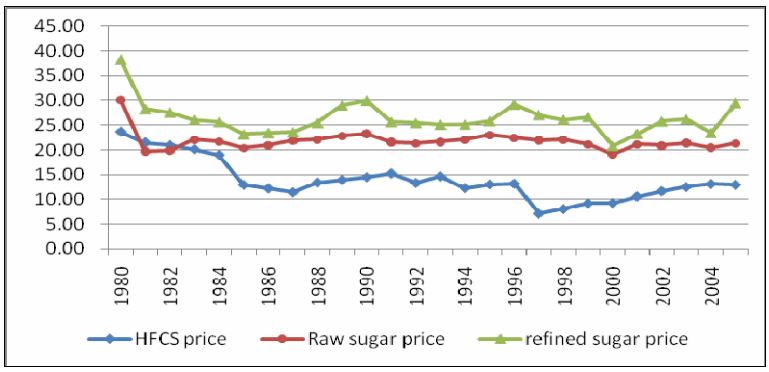

Figure 7 – U.S. HFCS, Raw Sugar, and Refined Sugar Prices
Source: USDA

2 - 4 – The Sugar Market

The U.S. Sugar support program is one of the oldest and strongest agricultural support programs in the United States that has always had governmental and political support. In order to keep the domestic sugar price high through imposing restriction on imports, representatives of sugar refineries and constituencies that benefit from the sugar program have vigorously lobbied the Agriculture Committee of the U.S. House of Representatives to maintain a high domestic price support. Industries and consumers that demand sugar for production or consumptive purposes have usually been against the sugar support program because not only have they had to pay taxes for funding the price support for sugar producers they have also had to pay more than double for produced sugar relative to world market sugar price.

The U.S. government uses three different tools to control the sugar supply, in order to support U.S. sugar producers while avoiding forfeitures at the same time. These tools are the tariff rate quota (TRQ), marketing allotments, and non-recourse loan rates. Import quotas control sugar imports in order to prevent unapproved amounts of sugar from being imported into the U.S. 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. The federal loan rates for raw cane sugar and refined sugar were 18 cents and 22.9 cents per pound in 2005, respectively. This is because the U.S. sugar program guarantees a minimum price for sugar producers.

The U.S sugar market has enjoyed governmental support for domestic sugar production for a long time. In fact, governmental involvement started in the early 18th century and since that time the U.S. government has used different tools, such as tariffs, producers support programs, and import quotas, to increase the domestic sugar production and decrease foreign countries' access to the U.S. sugar market. In 1789 the first congress of the U.S. imposed a tariff upon sugar imported from other countries in order to provide revenue for the government. But the current sugar program framework basically stems from the 1930's farm support program that was set up to support suffering farmers during the Great Depression. Because of high world market prices, the sugar program was suspended for three years (1974-77) with reinstatement of the program coming in the 1977 food and agricultural act by way of introducing government loans and buying surplus sugar from producers (Rippel et al, 2006).

In 1982 the new system of tariffs which was based on a country-by-country basis was established by the President in which he also modified the fee system and increased import duties. The 1990 Farm Act provided for marketing allotments on domestically produced sugar if "estimated sugar imports" was less than 1.25 million tons, raw value. 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. If allotments were implemented, the Agricultural Secretary sets the overall allotment quantity by adding consumption and reasonable ending stocks, and then subtracts that value from the sum of beginning stocks and 1.25 million short tons. The allotment was then further allocated between beet and cane sugar based on three factors: past marketing, processing and refining capacity,

and the ability to market. If either the beet or cane sector cannot fill its allocation, imports must fill the gap.

The 1996 Farm Bill, also known as the "Federal Agricultural Improvement and Reform (FAIR) Act," was in effect from 1996 to 2002 for crops. The loan rate remained at 18 cents per pound. Loans were a recourse when the tariff rate (TRQ) quota on sugar imports was at 1.5 million tons or below and non-recourse when the TRQ exceeded that level. Cane processors must pay a penalty of one cent per pound of sugar forfeited to the government, and beet processors must pay 1.07 cents per pound penalty. President Bush signed the 2002 U.S. Farm Bill which was almost identical to the1996 Farm Bill, in this Farm Bill the sugar support program again consisted of a loan rate support and sugar price was kept high through the imposition of import quotas.

The U.S. sugar program has had different impacts on U.S. sugar consumption and production. While this program has increased U.S. sugar production, it has had a negative impact on sugar consumption. Especially with the introduction of HFCS, the vast majority of beverage and food industries substituted sugar with HFCS, since HFCS was the cheaper alternative sweetener to sugar.

The U.S. produced 5.79 million tons sugar in 1977 with reinstatement of the U.S. sugar support program in this year (1977), sugar production continued to expand, producing 8.49 million tons in 2006. On the other hand, the amount of sugar consumed has decreased from 10.62 million tons in 1970 to 8.92 million tons in 2006. The biggest decrease in sugar consumption happened in the 1980's when both the beverage and food industries began to replace sugar with HFCS (USDA, 2006). Because of the increase in U.S. population, per-capita consumption gives us a better picture of changes in sugar consumption. Per-capita sugar consumption has decreased from 101.8 pounds in 1970 to 62.5 pounds in 2006, while per-capita U.S. HFCS consumption has increased from 0.5 pound to 58.3 pounds in the same period. Therefore, even though per-capita consumption of total sugar and HFCS has increased from 102.3 pounds to 120.8 pounds, this increase has come from increased HFCS consumption (USDA, 2006). Figure 8 shows total U.S estimated deliveries of caloric sweeteners for domestic food and beverage use. Based on this figure, between 1966 and 1999, the U.S. total sweeteners consumption increased continuously to the point that total sweeteners consumption in 1999 is more than twice as much as it was in

1966. But, in this time period, sugar consumption has decreased dramatically from 1977 to 1985 remaining stable at 1985 levels while HFCS consumption has grown at a rapid pace..

The amount of sugar imported into the U.S. has decreased by 62 percent, from 5.29 million tons in 1977 to 2.03 million tons in 2006 (USDA, 2006). As we can see, the U.S. sugar support program has spurred higher sugar production, lower sugar consumption and imports, and helped maintain higher sugar prices in the United States relative to world sugar prices. As shown in Figure 9, raw and refined sugar prices in the United States are well above world sugar prices (more than two times).

Several studies have investigated the relationship between HFCS and sugar prices in the U.S. Williams and Bessler tried to find a dynamic relationship between HFCS and refined sugar prices by using cointegration econometrics. By using price data from January 1975 to May 1991, they showed that refined sugar and HFCS prices have been cointegrated over a 7 year span (1984-91) to such a degree that HFCS price was subsequently being determined by refined sugar price in this period. Therefore, HFCS producers have set base HFCS prices on that of refined sugar prices (Williams and Bessler, 1997).

In another study, Moss and Schmitz used cointegration analysis to investigate the relationship between sugar and HFCS prices for the period of 1983-1996. Results based on this study showed that HFCS and Sugar prices moved together in this period (Moss and Schmitz, 2002). From the above discussion, we can then expect that any increase in HFCS prices resulting from increases in corn prices can, in turn, stimulate demand for sugar, since sugar is a perfect for HFCS.

3 – Estimations and Empirical results

In this section, we will first estimate the relationship between ethanol and corn prices and then we will examine the relationship between corn and high fructose corn syrup prices. Our data covers a twenty-five year time span (1980-2005).

In order to estimate the relationship between ethanol demand and corn prices we set up a model as follows:

(1) Dcop = f (Ethp, Coy, Flp, Fep, Gasp)

In this equation *Dcop*, *Ethp*, *Coy*, *Flp*, *Fep*, and *Gasp* are domestic corn prices, corn production yield, flour prices, fertilizer prices, and fuel prices, respectively. Equation (2) shows the estimated results:

$$(2) \quad Dcop = 1.66 + 1.43\,Ethp - 0.024\,Coy + 0.013\,Flp + 0.015\,Fep - 0.014\,Gasp \qquad R^2 = 0.71$$

$$t \qquad (2.72) \quad (5.30) \quad (2.19) \quad (2.14) \quad (2.38)$$

All coefficients in this equation have the expected signs except for *Gasp*, gas price, which it was supposed would have a positive impact on corn price. Coefficients for ethanol price and corn yield (*Ethp* and *Coy* respectively) were significant at the p=1% confidence level and coefficients for flour prices, fertilizer prices, and gas prices (*Flp*, *Fep*, and *Gasp* respectively) were significant at the p=5% confidence level. Based on these results, an increase in ethanol price has a positive effect on domestic corn price, so that a $1 per gallon increase in the ethanol price would result in a $1.43 per bushel increase in domestic corn price.

Equation (3) shows the model used for estimating the relationship between domestic corn price and high fructose corn price.

$$(3) \quad Dhfp = f(Dcop, Hfpr, Flp, Drtrfsup, Ngp, Trf)$$

In this equation Dhfp shows domestic HFCS prices and *Hfpr*, *Drtrfsup*, *Ngp*, and *Trf* are used for HFCS production, domestic retail refined sugar prices, natural gas prices, and tariff rate quota equivalent, respectively. Dcop and Flp are as before. The estimated results are shown in equation (4).

$$(4) \quad Dhfp = 1.40 + 1.86\,Dcop - 0.003\,Hfpr + 0.11\,Flp + 0.32\,Drtrfsup + 0.34\,Ngp + 0.07\,Trf \qquad R^2 = .93$$

$$t \qquad (2.31) \quad (4.94) \quad (2.12) \quad (4.75) \quad (1.01) \quad (0.61)$$

Based on these results all the variables had their expected signs and *Hfpr* and *DRtRfSup* were significant at the p=1% confidence level while *Dcop* and *Flp* were significant at the p=5% confidence level. *Ngp* and *Trf* were not significant.

The results show that a $1/bushel increase in the price of corn would result in a 1.86¢/lb. increase in domestic HFCS price. Based on figure 7, in 2005, raw sugar price and HFCS price have been 21.28¢ and 12.93¢/lb. , respectively. The difference between these two prices is 8.35¢ that can be filled with around $4.50 increase in corn prices assuming that other variables do not

change. U.S. domestic corn price in 2005 was $2/bushel, we therefore expect that a switch from HFCS to sugar would occur when corn price exceeded $6.50 per bushel ($2.00 + $4.50 = $6.50).

As was initially expected, based on estimation results, ethanol production raises domestic corn price resulting from the net increase in corn demand and an increase in corn prices would, in turn, increase the price for HFCS (since corn, a primary input for HFCS production, would cost more). Increases in HFCS prices would diminish any price advantage HFCS held over sugar and therefore increased HFCS cost would increase sugar demand if increases in corn prices were substantial enough to diminish the difference in cost between HFCS and sugar.

Recently there have been some arguments about replacing HFCS with sugar in soft drinks if ethanol production pushes corn/HFCS prices too hard. In this case, several million tons (which according to early 1980's USDA data would be some 2 million tons) of HFCS would be replaced by sugar and therefore demand for sugar would skyrocket. If this happened, the only way then to keep sugar prices at parity – which are already far higher than world price – would be to increase the ceiling for sugar imports. Therefore, one can expect that ethanol program will increase HFCS prices and stimulate growth in sugar imports.

4 - Conclusion

This study has shown that the effect of increases in demand for corn resulting from an increase in ethanol production will raise both prices for corn and HFCS . This means then that an enactment of an ethanol program will, in effect, serve to diminish use of HFCS offset with increased use of sugar in the course of the next few years. Based on these results, increases in ethanol prices have a positive effect on domestic corn prices so that a $1/gallon increase in the price of ethanol would result in a $1.43/bushel increase in domestic corn price. Also, a $1/bushel increase in the price of corn would result in a 1.86¢/lb. increase in domestic HFCS price. Based on our estimation results and the current gap extant between HFCS prices and sugar prices, we would expect HFCS users to replace HFCS with sugar when the price of corn reached a threshold value of $6.50 per bushel.

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