Determining the Direct and Indirect Effects of Government Policies: The Case of U.S. Sugar Policy and High Fructose Corn Syrup

P. Lynn Kennedy and Brian M. Hilbun[1]

Introduction

Critics have argued that U.S. policies with respect to certain farm commodities (e.g. corn, wheat, and soybeans) have contributed to overproduction of these products and resulted in a glut on the domestic and international commodity markets. This surplus, many contend, has led to the creation of new markets to siphon off extra supply, often resulting in unintended negative consequences. One example is that of High Fructose Corn Syrup (HFCS), manufactured directly from corn. HFCS was proposed as an economical alternative to Sucrose (table sugar) and as a sweetener for beverages and food products.

At first, the advent of lower input prices for the main sweetening agent of foods and beverages appeared to benefit both manufacturers and consumers alike (lowered production costs for producers would, in turn, lead to lowered purchase prices for consumers). However, recent evidence suggests linkages between increased use of HFCS and higher levels of adult obesity and diabetes. With these increases in obesity and diabetes, medical related costs have skyrocketed, straining limited resources (more often public than private) and diminishing the quality of life for the affected individuals.

Bearing these health issues in mind, it is important to note that American agricultural policy is at a cross-roads of historic proportions. With the ever increasing interest in bio-fuels, the production of ethanol, derived primarily from corn, presents an unusual window of opportunity. The energy sector is emerging as a potential market for

[1] Kennedy is Crescent City Alumni Professor and Hilbun is Research Associate, Louisiana State University AgCenter, Baton Rouge, Louisiana.

grains, which may serve to edge out the HFCS market as a market for corn. A switch in agricultural policy toward a more free market approach in the marketing of agricultural commodities would place less strain on producers of historically subsidized commodities given the increasing demand for bio-fuel feedstock. The same can be said with respect to the corn industry decreasing their dependence on the HFCS industry as a market for corn.

As observers of U.S. agricultural policy have pointed out, the U.S. policy of commodity subsidization has created certain markets for technological innovations (e.g., HFCS). Similar advances appear to be on the horizon with respect to the production of ethanol and its potential to relieve U.S. dependence on foreign oil and, in turn, emerge as another viable market for the excess supply of agricultural commodities. American agriculture faces significant challenges in dealing with this issue. If U.S. policymakers were to eliminate subsidies to commodities such as corn, the increasing demand for corn by the bio-fuel industry has the potential to ameliorate potential transitional losses to producers. Positive benefits to the sugar industry would be realized in increased demand for their product as a replacement for HFCS. Potentially negative impacts to corn producers would be offset and the nation would receive health benefits as it both replaces HFCS with sucrose in its overall diet and cut the overall consumption of sweeteners as prices for foods that are constituted chiefly of sweetening components better reflect a valid market price.

Given this environment, the purpose of this paper is to examine the history of HFCS, its subsequent usage as a sweetener alternative in the United States, and the policy decisions that have contributed to this shift from sucrose to HFCS. Our study will address some of the health-related concerns and related costs that must be examined in light of recent findings as to the impact of increased HFCS usage on the collective health of the U.S. population. An examination of the ethanol market and its demand for corn will be examined and compared with the current market for corn as utilized in the production of HFCS.

Advent of HFCS

Sweeteners have been with mankind from the very beginning of human civilization. Honey was first utilized as a sweetener. After the return of the crusaders from the Middle East in the 11th century, sucrose (sugar) was introduced to Western Europe. Sugar, in turn, was responsible for a major expansion of trade between east and west (Sugar Knowledge International). Refinement of corn for starch began in the United States in the middle of the nineteenth century. With advancements in chemistry, scientists discovered that corn syrup was able to be recovered from enzymic hydrolyzation in the 1920s. With advances in chemical purification techniques in the 1950s, the earliest of the corn based sweeteners, such as crystalline dextrose hydrate, were developed and introduced into the sweetener market in limited quantities to compete with sugar (Corn Refiners Association). With the advent of Enzyme Catalyzed Isomerization (ECI) of glucose to fructose in the 1960s, HFCS production was realized. The first HFCS derived from ECI consisted of roughly 15% fructose and the rest consisting of other sugars (Corn Refiners Association). In 1967, HFCS-42 (42% fructose) came onto the market. With the introduction of HFCS-42 and with advances in production technology/technique, HFCS began to be more widely utilized in the commercial sweetener market (Corn Refiners

Association). Ten years later, HFCS-55 (55% fructose) was introduced onto the market (Bray, et al.).

Uses of HFCS

High Fructose Corn Syrup is utilized in much the same way as sugar. It is added to food and beverage products to impart sweetness, helps to depress crystallization in frozen desserts (e.g., ice cream), and aids in the viscosity of certain liquid condiments (e.g., the ability to pour salad dressing at a sufficient rate). HFCS also aids in texture enhancement for foods, the browning of foods, and also in the fermentability of food (which is utilized by bakeries in the production of bread) (HFCS Facts). From 1970 to 2006, per capita consumption of HFCS increased from 0.5 pounds per year to 58.3 pounds per year (USDA 52). Total deliveries of HFCS as a caloric sweetener for inclusion into food/beverages increased from being nonexistent in 1966 to 8,783,000 short tons in 2006 (as compared to 9,332,000 short tons for refined sugar in 2006) (USDA 49). The production of HFCS is a major enterprise in the United States accounting for 515,000,000 bushels of corn utilized to manufacture HFCS in 2007 alone (USDA 31). The consumption of HFCS has increased 1000% from 1970 to 2000 and now accounts for more than 40% of sweeteners used for processed foods and beverages (Bray, et al.).

HFCS and Health

The use of HFCS as a sugar substitute has not been without controversy. Many experts contend that the rapid increase in obesity among the general U.S. population is directly correlated with intensified usage of HFCS as a sugar substitute. One of the first to examine the effect of HFCS on health was Meira Fields who, in 1984, studied the severity of copper deficiency in rats as determined by the type of dietary carbohydrate. In this study it was proposed that the majority of adult Americans experienced a copper deficiency in their daily diet. It was deemed of interest to examine whether or not the level of severity of copper deficiency could be tempered by changing the dietary carbohydrate to that of either glucose or starch (Fields, et al.). Their study found that dietary fructose aggravated test rats' copper deficiency and that dietary fructose also provoked a more intense glycemic response than that of starch (Fields, et al.).

Bray, Nielsen, and Popkin examined the correlation and causality between fructose consumption in beverages and obesity in the United States. Bray, et al. contend that fructose is processed differently by the body than is sucrose. They state that when sucrose is consumed, a signal goes from the brain to the pancreas, triggering the release of insulin. Along with insulin release, leptins (adipocyte hormones) are also secreted (after a delay of several hours) which in turn act as appetite inhibitors. The emission of leptins was deemed important because studies have linked leptin deficiency with obesity (Farooqi, et al.).

Bray, et al. proposed that because HFCS is metabolized differently than glucose. They state that glucose enters cells by a transport mechanism that operates under the aegis of insulin activators which, in turn, activate cells and allow for the entry of glucose into the cell to be processed or metabolized intracellularly. Bray, et al. state that the metabolization of fructose is handled in an entirely different manner. According to their study, that the entrance of fructose into a cell is not insulin dependent but rather dependent upon a Glut-5 transporter. This transmission method is significant in that with no insulin release by the pancreas, there is no attendant leptin release. Therefore, with the consumption of fructose there are no satiety signals from the digestive system to the brain, thus, in turn, permitting individuals to continue consumption or caloric intake.

Schulze, et al., also examined the correlation and causality between increased HFCS consumption in beverages and increases in weight gain and increased risk of contracting type-2 diabetes in young and middle-aged women. The hypothesis was that with large consumption of HFCS beverages, the sugars were in a readily absorbable state and that their consumption increased young and middle-aged womens' weight gain and incidence of type-2 diabetes. They conclude that evidence suggests a correlation between frequent consumption of beverages sweetened with HFCS and increases in weight gain and incidences of type-2 diabetes in the sample population. They also postulate that the results of weight gain and type-2 diabetes incidence was due, as earlier hypothesized, to the existence of large amounts of rapidly absorbable sugars in beverages sweetened with HFCS (Schulze, et al.).

As has been pointed out, the medical profession has shown a relationship between the existence of HFCS in food and beverages and increases in obesity and type-2 diabetes (along with other health related ailments) in their respective study populations. The usage of HFCS as a low cost alternative to sucrose may have negative externalities as to the well-being of the nation's health. These savings that come to both producer and consumer alike through the usage of HFCS as the principal sweetener component in processed foods and beverages might have long-term negative consequences that could outweigh any gains HFCS poses for the welfare of both consumers and producers.

The Surgeon General of the United States, Dr. Richard H. Carmona, testified in 2003 before the Subcommittee on Education Reform Committee on Education and the

Workforce in the United States House of Representatives as to the impacts both increased obesity and diabetes rates have on the U.S. population. Carmona stated that, "In the year 2000, the total annual cost of obesity in the United States was $117 billion." He also stated that there were, in 2003, 17 million Americans suffering from type-2 diabetes and 16 million Americans with pre-diabetes. Diabetes costs America $132 billion annually (2003). He went on to say that in 2003 alone over 300,000 Americans would die from illnesses related to being overweight and/or obese and that obesity contributes to the number one killer of Americans: heart disease (Carmona). When the costs of obesity and type-2 diabetes alone are considered, one can see that the potential health impacts on America's economy are tremendous.

Economic Implications for the Subsidization of Sugar on the HFCS Market

The use of HFCS in the United States can be linked to U.S. sugar policies designed to support the sugar industry. In this case the U.S. government has supported the domestic price of sugar by means of an import quota. The impact of this policy can be seen in Figure 6. In this case, the free trade world price of sugar is P_F,. At this price U.S. sugar producers will produce sugar at the quantity Q_{PF}, with domestic consumption in the amount Q_{CF}. At these levels domestic consumption exceeds domestic consumption by quantity Q_{TF}, as shown by the intersection of Excess Supply and Excess Demand in the world market. This scenario represents the free trade equilibrium in the world market.

Consider now the case where the domestic country (U.S.) seeks to support its producers by means of an import quota. In this case the government restricts the quantity of imports to Q_{TP}. This restriction will result in insufficient total supply to meet quantity demanded, given the world price, P_F. In order to achieve an equilibrium given the restricted level of imports, quantity supplied must increase to Q_{PP} while quantity demanded will decrease to quantity Q_{CP}. To accomplish this, the domestic price will increase to P_P. This inflated price level not only provides benefits to domestic sugar producers, it also benefits world producers who are able to export their product to the United States.

While domestic producers benefit from this inflated sugar price, consumers are worse off given that they now consume less product at a higher price. In this partial equilibrium analysis, consumers decrease their consumption as a result of higher domestic sugar prices, however, given that consumers have unmet demand, they will seek to increase their utility through the consumption of substitute products. In this case, a product such a HFCS, which may be viewed by consumers as inferior to sucrose, may replace sucrose if the price differential is sufficiently large. Here the increased price of sugar has not only caused increased HFCS consumption, it has acted to spur the construction of additional HFCS manufacturing facilities and increased the competitiveness of the HFCS industry relative to the sugar industry.

Initially, HFCS gained market share due to a change in price competitiveness. This resulted from the inflation of domestic sugar prices relative to those of HFCS. However, the longer term and possibly more damaging impact has resulted through a gain in cost competitiveness by the U.S. HFCS industry due to the growth and development of the HFCS industry resulting from policies initially intended to benefit the U.S. domestic sugar industry.

Empirical Analysis

Previous analyses have modeled the impact of increased sugar-import quotas on the U.S. sugar market. For example, Petrolia and Kennedy (2003) used *Modele Internationale Simplified de Simulation* to analyze increases in the U.S. sugar TRQ to determine the impact of increased exports from Cuba and Mexico. For the purposes of this analysis, a partial-equilibrium framework is developed to determine the impact of a specific import-quota level. Our model considers the United States as a small country relative to the rest of the world. Three sectors are utilized within this framework: domestic production, imports, and domestic consumption. Domestic consumption, Q_C, is comprised of products produced domestically, Q_S, and/or imported, Q_M, such that

(1) $Q_C = Q_S + Q_M,$

where Q_M is determined exogenously by the domestic government through their choice of TRQ level.[2]

The domestic price will adjust to changes in Q_M, which will result in producers adjusting Q_S based on their supply function, and consumers adjusting Q_C based on their demand function. A market-clearing price will be achieved when Q_S and Q_C, resulting from the new Q_M, meet the conditions in equation (1).

Simulations are conducted in this analysis for alternative import quota levels using Microsoft Excel. Given the observed supply and demand quantities at the base-price level, linear supply and demand is used to determine: the market clearing equilibrium in the absence of supply management given a specific import. Domestic

[2] The TRQ employed by the United States uses a tariff of zero for all in-quota imports, and a prohibitive over-quota tariff structure. The over-quota tariff becomes non-prohibitive, given a sufficient decrease in world price and/or an increase in U.S. price.

quantities and prices are then used to calculate the respective changes in producer and consumer surplus resulting from each scenario.

The base-level raw-sugar quantities and prices used in these simulations are based on 2004/05 data obtained from the Sugar and Sweeteners Outlook (USDA 2007). Total U.S. demand was 9.079 million metric tonnes (mmt), which was comprised of 7.597 mmt from domestic production and 1.482 mmt from imports. The status quo price of raw sugar was U.S. 22.92 cents per pound ($505.30 per metric tonne, mt).

The base-level-import quota, used as the status quo in this analysis, was 1.482 mmt. Various scenarios were developed, based on alternative policy strategies, to expand the level of imported sugar by expanding the import quota. The minimum expansion was based on the DR-CAFTA agreement of an additional 100 thousand mt. Other scenarios considered include expansion of the base-level-import quota by 500; 1,000; and 2,000 thousand mt.

The literature shows U.S. own-price sugar supply elasticities ranging from 0.10 to 0.70 (Tyers and Anderson 1992; Lopez 1989; Lopez 1990). Gardiner et al. (1989) used an aggregate own-price sugar supply elasticity of 0.50 which we adopt in this analysis. Demand elasticities, in the literature, range from -0.10 to -0.60 (Lopez 1989; Lopez 1990; Tyers and Anderson 1992; Gardiner et al. 1989; Uri and Boyd 1999). Based on these estimates, we employ a demand elasticity of -0.30.

Import-Quota Levels

We show the impacts of alternative import-quota levels (Table 1). In these scenarios, the domestic market price adjusts to achieve equilibria where domestic production plus imports equal domestic consumption. These results show consistently that an increase in the total import quota causes: (1) the market-clearing price to decline, (2) market-clearing production levels to decrease, (3) producer surplus to decrease, and (4) consumer surplus to increase. Given a demand elasticity of −0.3 and a supply elasticity of 0.5, producer rents fall by roughly U.S. $1 billion for an increase in imports of 2.0 mmt to 3,482 thousand mt. On the other hand, consumers gain roughly U.S. $1.5 billion from expanded imports.

The counter argument can be used to show the impact of imposition of the import quota on producer and consumer surplus. Table 1 presents five scenarios based on alternative import quota levels. The scenario using 1,482 thousand MT represents the current import quota level, while the scenario using 3,727 thousand MT represents the level of imports at which the U.S. domestic price would be equivalent to the world price of sugar (15.03 cents/pound, raw value). The difference between producer and consumer surplus between these two scenarios represents the gains or losses to consumers or producers resulting from the imposition of an import quota. The imposition of an import quota in the amount of 1,482 thousand MT increases producer surplus by 1.30 billion dollars while decreasing consumer surplus by 1.81 billion dollars.

Based on this analysis, it is clear that the losses to consumers with respect to the sugar import quota program outweigh the gains to producers by over half of a billion dollars. In addition to this, it was presented earlier that the U.S. Surgeon General indicated that the total annual cost of obesity in the United States was $117 billion, with the annual cost of diabetes at $132 billion. If the increased use of HFCS in the American diet accounts for only a fraction of this amount, it is possible that the indirect costs of the U.S. sugar import quota program well exceed the direct costs.

Price Support and New Industry Creation

As is the case in many situations, externalities occur that were/are either unforeseen or unintended. The negative side effects of HFCS as to health are controversial but warrant further investigation especially as to the impacts from which heightened HFCS consumption has had on the public health and just exactly, from an economic perspective, what do these effects portend for future U.S. economic viability in light of continued mass HFCS usage and consumption. When industries are allowed to gain a foothold in a market it is important for policy makers and analysts alike to account for and anticipate unintended consequences or negative externalities.

With price supports and tariff rate quotas as they currently stand, the U.S. domestic price for sugar is higher than HFCS prices, making HFCS a more attractive option to industries whose primary input of production are sweeteners. Ethanol, with its intense demand for corn, could introduce a paradigm shift into the traditional sweeteners market as it currently stands in the United States. With the emergence of ethanol in the United States as an alternative fuel source, a window of opportunity has opened that may encourage all players concerned (corn producers, sugar producers, and cost-sensitive industries dependent on cheap sweeteners) to shift away from corn derived HFCS to sugar. Such a shift would help alleviate some of the negative externalities which would come as a result of a lessening HFCS usage for human consumption (by replacing HFCS with sugar) without having corn farmers suffer the effects of lessened corn demand for

HFCS usage as ethanol would bridge the gap and help to support or increase corn demand.

Table 1. Alternative U.S. Sugar Import Quota Levels under Market Clearing Conditions

Demand/Supply Elasticities		Total Import Quota (1000 MT)				
		1482	**1582**	**1982**	**2482**	**3727**
-0.3/0.5	Market Clearing Price (cents/lb)	22.92	22.57	21.16	19.41	15.03
	Market Clearing Production (1,000 mt)	7,597	7,539	7,306	7,015	6,290
	Producer Surplus ($1,000)	2,879,586	2,820,944	2,590,890	2,313,476	1,671,738
	Consumer Surplus ($1,000)	7,647,393	7,717,906	8,003,193	8,367,083	9,308,320

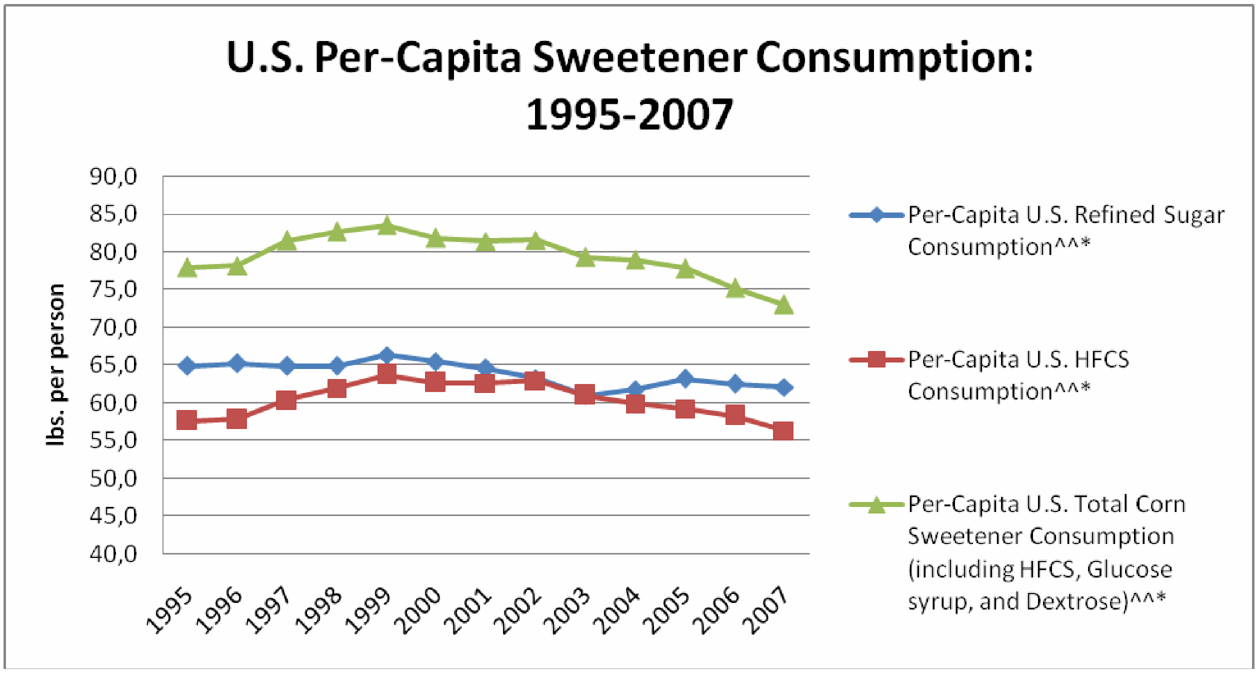

Figure 1. U.S. Per-Capita Sweetener Consumption: 1995-2007
Source: USDA

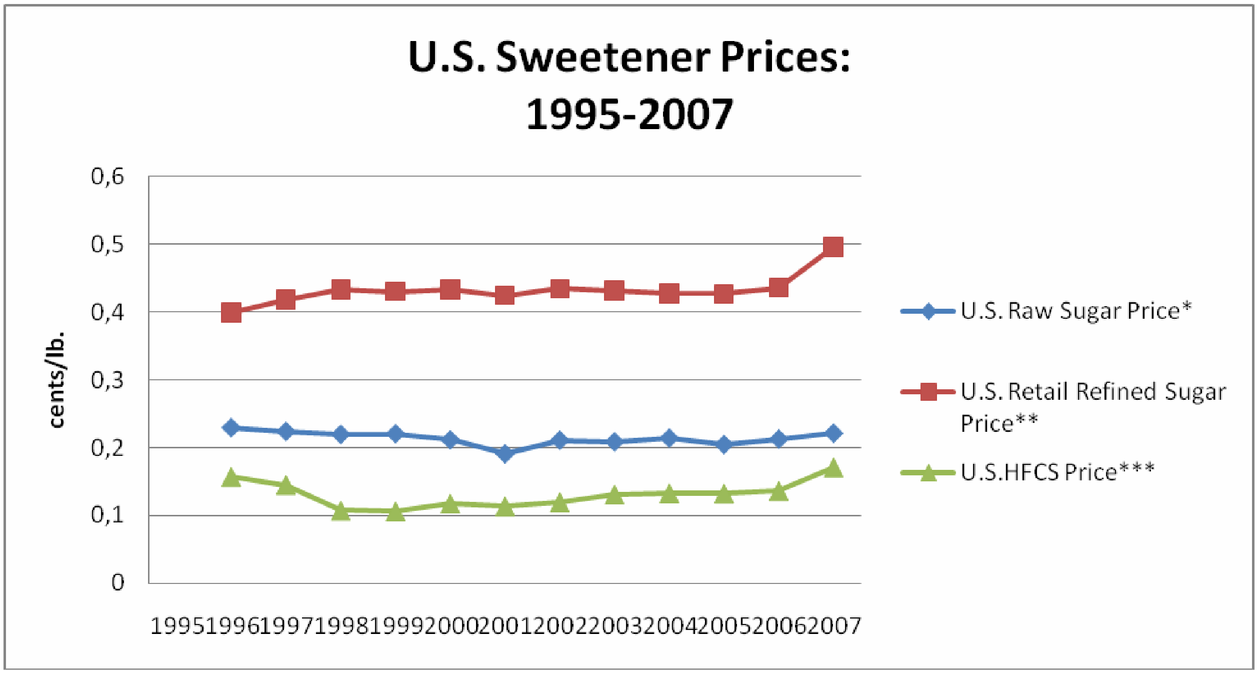

Figure 2. U.S. Sweetener Prices: 1995-2007
Source: USDA

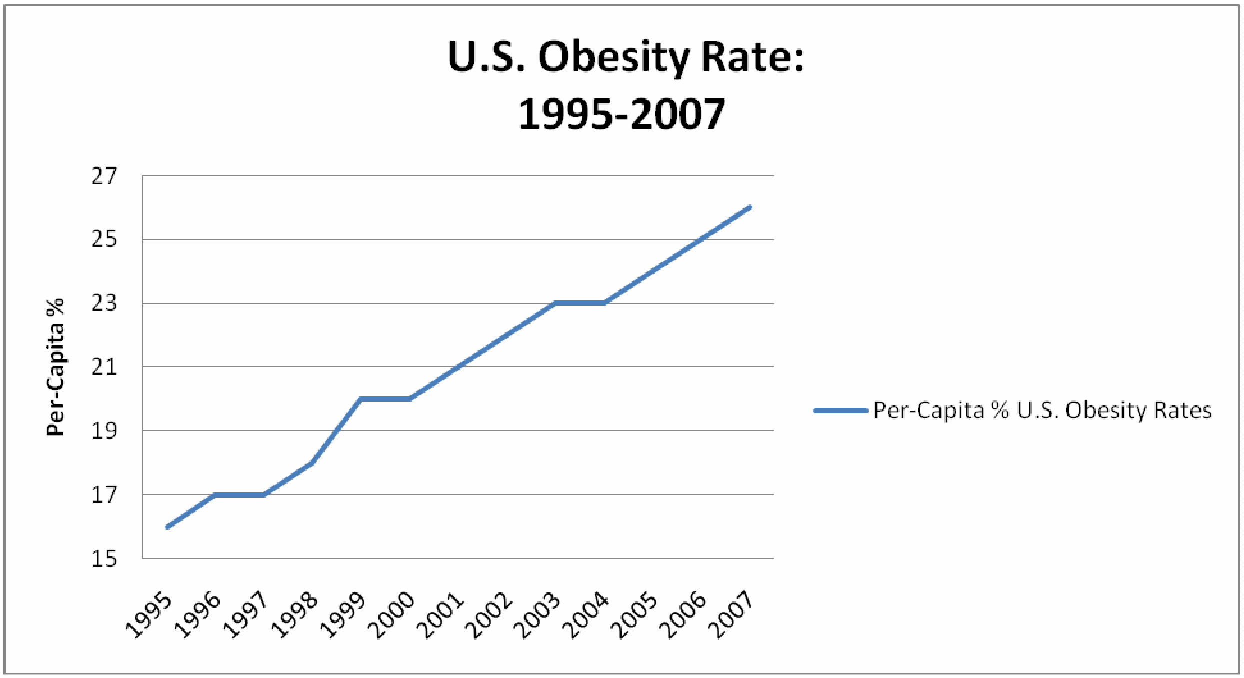

Figure 3. U.S. Obesity Rate: 1995-2007
Source: Centers for Disease Control

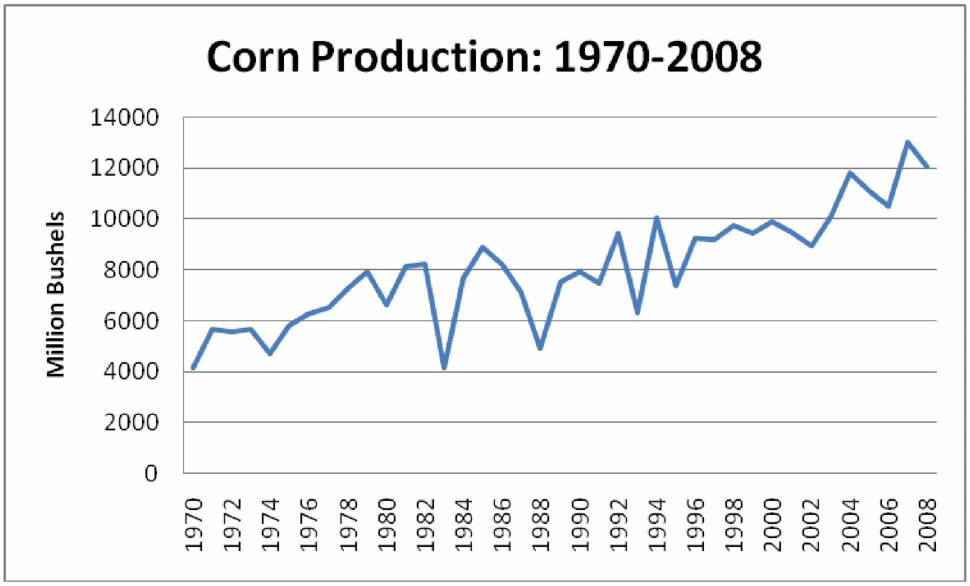

Figure 4. Corn Production, 1970-2008
Source: USDA.

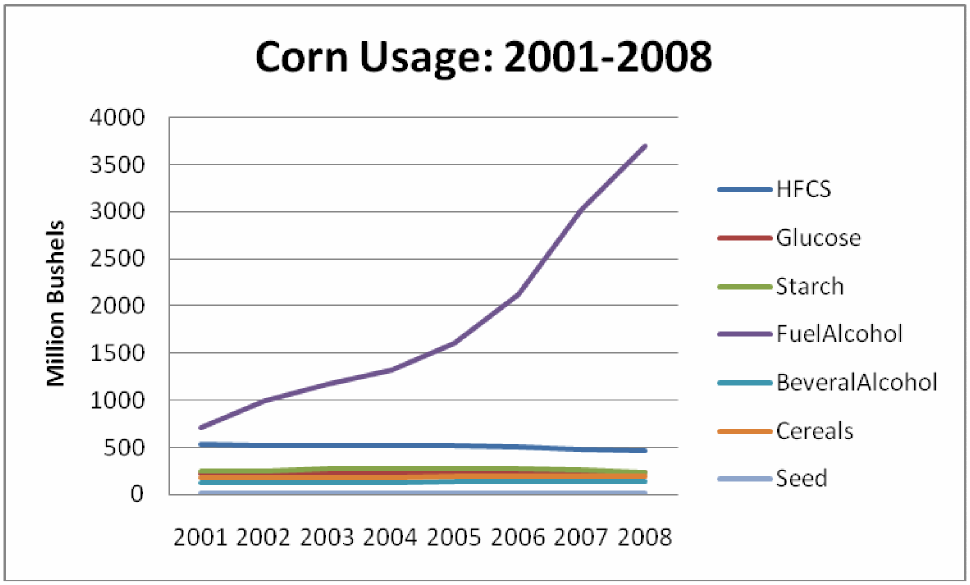

Figure 5. Corn Usage: 2001-2008
Source: USDA

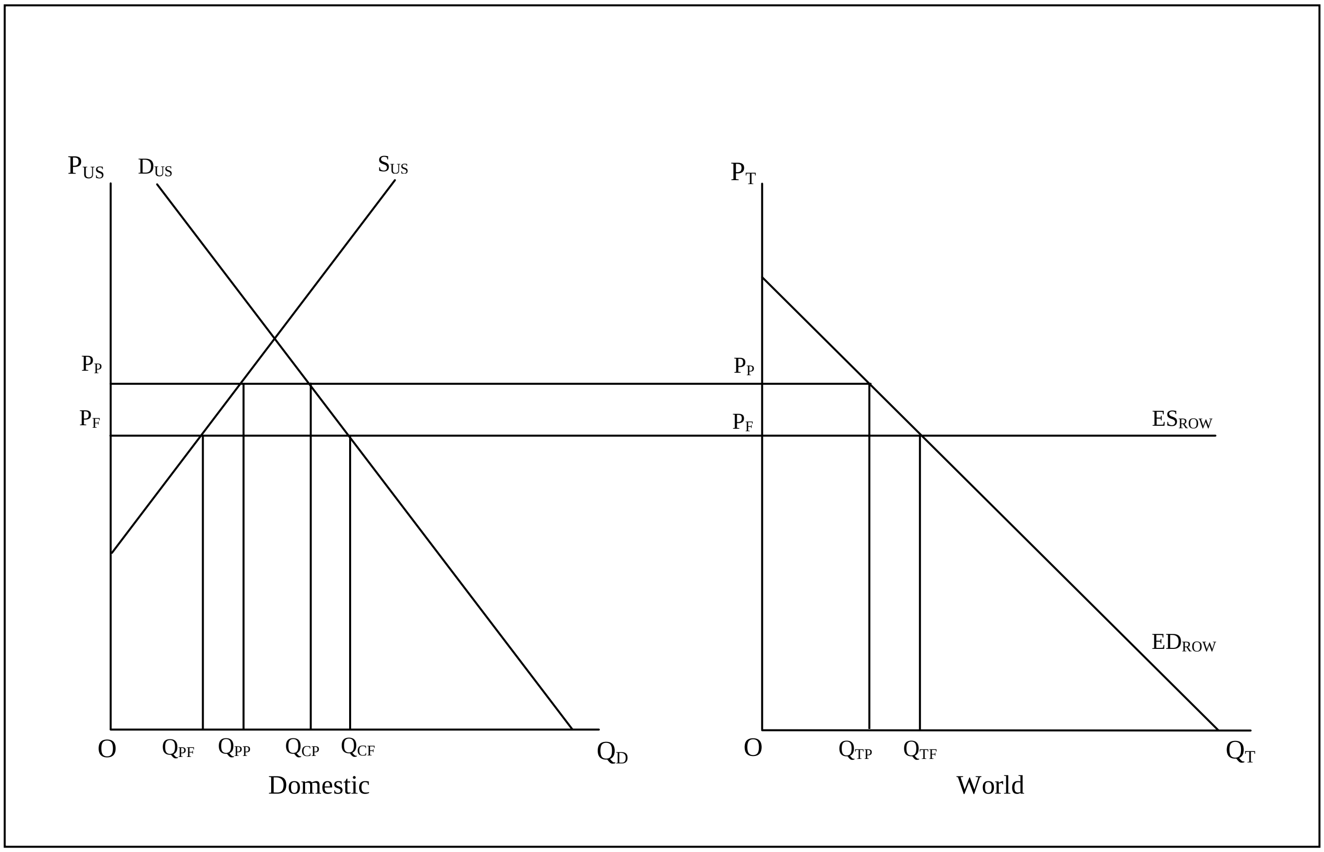

Figure 6. Impact of an Import Quota, A Small Country Example

Bibliography

Bray, G.A., Samara Joy Nielsen, and Barry M. Popkin. (2004). "Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity." *The American Journal of Clinical Nutrition.* 2004(79) pp. 537-43.

Carmona, Richard H. MD., (2003) "The Obesity Crisis in America." *Testimony Before the Subcommittee on Education Reform Committee on Education and the Workforce United States House of Representatives*. *July 16, 2003.* Web accessed from: http://www.surgeongeneral.gov/news/testimony/obesity07162003.htm on 9/23/2007.

Corn Refiners Association. (2007). Corn Refiners Association Web-Site. Accessed from: http://www.corn.org/web/history.htm on 09/14/2007.

Centers for Disease Control. *Health, United States, 2007. With Chartbook on Trends in the Health of Americans*. Accessed from: http://www.cdc.gov/nchs/data/hus/hus07.pdf on 09/17/2007.

Farooqi, I. Sadaf, Guiseppe Matarese, Graham M. Lrod, Julia M. Keogh, Elizabeth Lawrence, Chizo Agwu, Veronica Sanna, Susan A. Jebb, Francesco Perna, Silvia Fontana, Robert I. Lechler, Alex M. DePaoli, and Stephen O'Rahilly. (2002). "Beneficial effects of leptin on obesity, T cell hyporesponsiveness, and neuroendocr- ine/metabolic dysfunction of human congenital leptin deficiency." *The Journal of Clinical Investigation.* 2002(110) No. 8. pp.1093-1103.

Petrolia, D.R. and P.L. Kennedy. (2003). Increasing the United States tariff-rate sugar quota forCuba and Mexico: A partial-equilibrium simulation. *Journal of Agricultural and Applied Economics* 35(3): 589-597.

Sugar Knowledge International. (2007). Sugar Knowledge International Web-site. Accessed from:http://www.sucrose.com/lhist.html on 09/14/2007.

HFCS Facts. (2007). "The Facts about High Fructose Corn Syrup." Web-site. Accessed from: http://www.hfcsfacts.com/index.html on 09/14/2007.

Schulze, Matthias B. DrPH, JoAnn E. Manson, MD, David S. Ludwig, MD, Graham A. Colditz, MD, Meir J. Stampfer, MD, Walter C. Willett, MD, Frank B. Hu, MD. (2004). "Sugar-Sweetened Beverages, Weight Gain, and Incidence of Type-2 Diabetes in Young and Middle-Aged Women." *JAMA, The Journal of The American Medical Association.* 2004(292), No. 8. pp. 927-934.

USDA. Sugar and Sweeteners: Recommended Data: Web-site. Accessed from: http://www.ers.usda.gov/Briefing/Sugar/Data.htm on 09/21/2007.

USDA 31. Feed Grains Database: Yearbook Tables-Table 31 "Corn:Food, Seed, and Industrial Use." Accessed from: http://www.ers.usda.gov/Data/Feedgrains/StandardReports/YBtable31.htm on 09/21/2007.

USDA 49. Sugar and Sweeteners: Recommended Data-Table 49 "U.S. total estimated deliveries of caloric sweeteners for domestic food and beverage use, by calendar year." Accessed from: http://www.ers.usda.gov/Briefing/Sugar/Data.htm on 09/21/2007.

USDA 52. Sugar and Sweeteners: Recommended Data-Table 52 "High fructose corn syrup: estimated number of per capita calories consumed daily, by calendar year." Accessed from: http://www.ers.usda.gov/Briefing/Sugar/Data.htm on 09/21/2007.