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U.S Sugar Beet Price Analysis

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U.S. SUGAR BEET PRICE ANALYSIS

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Sugar beet production was responsible for 56.6 percent of all U.S. sugar production in 2014. 82 percent of this production came from the states of Minnesota, North Dakota, Idaho, and Michigan. Sugar beets are an important crop for growers in these states so research in this area could be of great value to them. Current U.S. sugar policy protects domestic sugar prices from falling below set target rates. However, there has been very little research that describes the relationship of changing sugar beet prices above these target rates, with different economic variables. This study explores the potential relationship U.S. sugar beet prices have with domestic sugar beet production, world sugar prices, incomes, and U.S. sugar imports. With the results, U.S. sugar beet producers might make better pre-plant decisions such as acreage allotments. Sugar beet processors might have more information available to them for pricing of their sugar products and interest groups might see the possible impacts of proposed policy changes for the U.S. sugar industry.

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CHAPTER 1

INTRODUCTION

German chemist, Andreas Marggraf, was the first to notice that sugar crystals in beets were identical to that of sugar crystals from sugar cane. However, the cultivation of sugar beets for the purpose of obtaining crystalized sugar was not present until the 18th century when Karl Achard, a student of Andreas Marggraf, selectively bred beet hybrids in order to obtain a beet with high sugar content. Achard also created a process for which sugar could be efficiently extracted from the beets. With high sugar content beets and capable production processes, the table was set for the sugar beet industry to start competing with that of the already successful sugarcane industry. According to the American Sugar Beet Growers Association, the first commercial sugar beet factory in the U.S was built by E. H. Dyer in California in 1879. By 1917 there were 91 factories operating in 18 states. In 2005 there was 23 highly efficient operating sugar beet factories in 10 U.S states (www.americansugarbeet.org).

Sugar derived from sugar beets is responsible for over half of all U.S sugar production. Increasing technologies in beet hybrids, farming equipment, and processing techniques has made producing sugar beets a profitable endeavor. It is commonly known that U.S sugar prices are supported by government intervention, such as the tariff-rate quota (TRQ) and price support programs. These government interventions protect U.S sugar prices from falling below set target levels. However, little research has been done to explain the movement of U.S sugar prices above this government supported price or what economic variables have an effect on domestic sugar beet prices.

The main objective of this paper is to identify and statistically show some key economic variables that influence the price U.S sugar beet producers receive for their crop. From this analysis, the economic variables that have a significant impact on U.S sugar beet prices will be discovered, and also a model to possibly forecast future prices will be developed. This study will be using a multiple regression model to demonstrate the relationship between U.S sugar beet prices and the economic variables that have been identified and will be discussed later in this paper. This multiple regression model will demonstrate the simultaneous impact of several key predictor variables on U.S sugar beet prices from 1980 - 2013. There can be much to learn from this study that analyzes U.S sugar beet prices. Previous research on U.S sugar beet prices is limited, so this research could be a stepping stone for further research on the subject. An analysis of sugar beet prices could be of great value to sugar beet producers and processors in the U.S, as well as interest groups such as the American Sugar Beet Association and their member states. These interest groups help promote the growth and sustainability of the sugar beet industry as well as influence policy makers concerning sugar policy.

CHAPTER 2

REVIEW OF LITERATURE

With regards to U.S sugar beet prices, little research has been done in the past. This could be due to the fact that sugar beets are mostly grown in select regions, unlike other commodities such as corn, soybeans, and wheat. However, there has been research done for other commodities concerning production, income, and world prices that could be applied to U.S sugar beet prices. Bazen, Roberts, Travis, and Larson (2008) looked at factors affecting hay supply and demand in Tennessee. The authors found that hay prices were responsive to real per capita income. The authors expected this outcome because real per capita income translates to more purchasing power in a typical household. With an increase in purchasing power, the demand for beef should also increase for these households. Beef is a normal good so as incomes increase, so too does the demand for beef. Since hay is an input factor for the production of beef, it is expected that as incomes and demand for beef increases, so will the price for the hay to feed the cattle (Bazen et al., 2008). The analysis that these authors make in the hay market of Tennessee should translate to the U.S sugar beet market nicely. Sugar is also a normal good, so similar results are expected for this study when per capita income increases.

Planted sugar beet acres in the U.S were relatively stable from 1980 to 2013. This is likely due to the contracting that takes place with sugar beet production, as well as the processors inability to store sugar beets for long periods of time without spoilage. Planted sugar beet acres peaked in 2000 with 1,564,000 acres and has since declined. In 2013, the total acres planted was lower than in 1980, however the production on those acres was nearly 9 million more tons than what was recorded in 1980. This shows that there has been significant improvement in sugar beet

technologies that has allowed production to increase while planted acres decreased. Improvements in sugar beet production include improved genetics, improved fertilizer applications, disease management techniques and reduced tillage (Poindexter, 2014). In 2008, Monsanto introduced roundup ready sugar beets to growers which allowed for a broader spectrum of weed control while also minimizing the use of other herbicides. Genetic improvements of sugar beet seeds have brought increased yield, sugar content, and disease resistance. Seed varieties can now be selected to manage risk from rhizoctonia, a soil born fungus that causes roots to rot, or cyst nematodes, which are a small parasitic roundworm that feeds on plants roots. Zimmermann and Zeddies (2002) examined sugar beet productivity progress in Germany, with special emphasis on breeding contributions. Prior to the 1980's, sugar beet breeding was mainly focused on yield and quality improvements. After the 1980's, the focus shifted towards more technical progress in plant protection, mechanization, and organization. This has led to further yield and quality increases in the sugar beet industry. The authors found that sugar beet breeding contributions in the past 30 years has amounted to 80 DM [an input output development measure] per hectare of value added growth for the industry (Zimmermann and Zeddies, 2002). Advancements in sugar beet technologies have clearly been a major contributing factor as to why production has increased over the past three decades. It can be assumed that these advancements in sugar beet production will certainly have a role in explaining variations in price.

Sugar beet producers in some regions use contracts that have payments based on both total sugar production and sugar beet purity. Other regions have contract types that make payments solely on total sugar production (Hueth and Melkonyan, 2004). Progress in complementary technologies such as seed genetics and disease management are a necessity for

sugar beet growers whose payments are based upon production and quality. These advancements may have strengthened the relationship between growers and processors, which could potentially lead to higher prices for growers.

World sugar prices reflect expected market conditions for sugar producing countries. Brazil, the largest sugar producer and exported in the world, will have an increasing effect on world sugar prices going forward. Events like droughts or natural disasters affecting Brazilian sugar production will be transmitted to world prices. U.S and Brazilian exchange rates also have shown to influence world prices. "ERS analysis reveals a long-term relationship between dollar-denominated Brazilian production costs and world prices. Since 2003/04, the value of the real has been rising, contributing to a 316-percent increase in nominal world sugar prices between 2003/04 and 2011/12" (Haley 2013, p.3). World sugar prices also reflect the expected supply and use of sugar stocks. Lower than expected stocks will lead to higher world prices, while higher than expected sugar stocks can have a negative effect on world prices. Historically, U.S sugar prices have been higher than world prices. However, a reversal in this trend will mean that U.S sugar prices will start to follow world prices. "The implication of this shift is that U.S. raw sugar prices will now vary with world prices, making domestic price support less relevant. With the world raw sugar price serving as the new floor for domestic prices, it becomes more important to understand the dynamics of world prices" (Haley 2013, p.1). This analysis shows that the U.S sugar industry, including both sugar beet and sugarcane, may not be as protected by government support programs as once believed, and is justification for including world sugar prices in the model for this study.

CHAPTER 3

U.S. SUGAR BEET PRODUCTION

Sugar beets are a biennial plant developed during the 18th century in Europe from white fodder beets. During the first year of the two-year life cycle, the sugar beet plant grows its root, stem, and leaves. Sugar is stored in the root of the plant to be used as an energy source for overwintering. Sugar beets are harvested after the first year of growth in order to extract the sugar from the root. Sugar beets contain between 13 percent and 22 percent sugar levels when harvested. Sugar beets are primarily grown in temperate climates, which limits the areas they can be grown in. Planting typically begins between March and April with optimal growing conditions favoring areas with 90 days of average daytime temperatures between 65-80 degrees Fahrenheit followed by nighttime temperatures between 40-50 degrees (www.hort.perdue.edu).

The sugar beet is a chemical-intensive crop that requires frequent attention. Sugar beets are susceptible to disease, insects, and weeds from the time they are planted, until harvest. Farmers use post-emergence applications of herbicides and fungicides to mitigate these risks and ensure a healthy beet crop is grown. Irrigation is often used in the production of sugar beets because yields can be increased substantially. A significant portion of sugar beet acres in the Great Plains and Northwest are under irrigation (Ali, 2004). Harvesting of the sugar beets typically begins in September and October when the nightly temperatures are dropping while daytime temps remain warm. During these cool fall nights, sugar from the leaves moves to the sugar beet. The beets are trucked directly from the field to a processing facility, or to piling grounds where they will later be delivered to the processing facility.

The largest producing region of sugar beets come from the Upper Midwest and is known as the "Red River Valley". The Red River Valley includes 1st and 3rd ranked sugar beet producing states, Minnesota and North Dakota and was responsible for 17,850,000 tons of sugar beets in the 2015/2016 crop year. The second largest producing region is the Far West of the United States and is due to production from Idaho, the second ranked sugar beet producing state in the nation. Finally, the third largest production area of sugar beets is from the Great Lakes Region, led by the 4th largest producing state in the country, Michigan. Michigan produced 4,757,000 tons of sugar beets for the 2015/2016 crop year in the Saginaw Valley and Thumb region of the state. Sugar beets are responsible for over half of all U.S sugar production. In 2014, sugar beet production accounted for 56.6 percent of U.S sugar production. In that same year, the four top producing states of Minnesota, North Dakota, Idaho, and Michigan produced 25,557,000 tons of sugar beets on 976,000 planted acres, which was 82 percent of total U.S production (www.ers.usda.gov).

The U.S sugar beet industry can be categorized as a vertically coordinated industry with strong price transmission from processors to producers. To demonstrate this, a simple correlation matrix was done that included the U.S sugar beet prices and average U.S wholesale refined beet sugar prices. The matrix produces a correlation coefficient of 0.88, which means there is a strong positive relationship between the two price series. This strong relationship between producer prices and processor prices is expected in industries such as the sugar beet, where processors are commonly farmer cooperative owned. Boland and Marsh (2005), apply the concepts of transaction costs economics and property rights theory as a justification for the vertical integration of the sugar beet industry. Once harvested, sugar content in the beets begins to decline as the decaying process starts. Sugar beets are a bulky crop, making them more difficult

to transport over long distances compared to other crops. This means that processing facilities must be located within close proximity to where the crop is grown. The perishable nature of the sugar beet as well as production practices affecting the sugar content of delivered beets means that it is difficult for processors to construct a perfect contract. Crop values, based on sugar content of delivered beets, are not known until delivery, which is many months after contracts are written. Poor weather conditions during the growing year can have an adverse effect on the sugar content of beets, increasing the difficulty to specify exact contract conditions. Contracts between producers and processors based on sugar content, gives producers the incentive to grow high quality beets and to use favorable crop management techniques. Farmer owned cooperatives are a common governance structure for sugar beet processors. Producer owned cooperatives will use the best available method of testing for sugar content, because their contracts are based off of sugar content (Boland and Marsh, 2005). This again favors processors because transaction costs from monitoring production practices are reduced. The next section discussed the processing of sugar beets. The crop has little value until it has been processed into refined sugar.

CHAPTER 4

SUGAR BEET PROCESSING

The following sugar beet processing information was obtained from the Michigan Sugar Companies' website and portrays typical sugar beet processing techniques. Once sugar beets are delivered to a processing facility, the first step is to wash and slice the beets. Washing the beets removes large amounts of dirt and debris. Once washed, they are fed into a machine that slices them into long skinny pieces called cossettes. The cossettes are then transferred to a large tank filled with hot water called a diffuser. The warm water draws the sugar from the cossette leaving a sugar water solution. Filters are used in this process to remove any impurities from the sugar water solution. Once the cossettes are sugarless, they are made into beet pulp, which is used as a feed source for livestock. The sugar water solution is then boiled to remove excess water and the result is a thicker sugar juice. Sugar crystals begin to form in the thick solution and next will be separated from the juice. A centrifugal machine spins at high speeds and separates the sugar crystals. Next the sugar will pass through hot air to dry it before it is stored in silos, and eventually packaged or shipped to buyers. Bi-products of processing include beet pulp, beet lime, molasses, betaine, and raffinate. From the time sugar beets are harvested, the processing plants run twenty-four hours a day, seven days a week, until the all the beets have been processed (www.michigansugar.com).

CHAPTER 5

U.S. SUGAR POLICY

For almost as long as America has existed, the government has had their hand in sugar policy in one way or another. U.S. sugar policy has been scrutinized by industries that use sugar for their products because the policies keep domestic sugar prices higher than if free trade were present. However, the sugar policies do protect both sugar beet and sugarcane producers in the U.S. This section of the paper highlights some of the important sugar policy events that have shaped the industry into what it is today.

The first major event in sugar policy for the U.S was only thirteen years after the country was established. In 1789, before sugar beets were even grown in the U.S, a tax on sugar imports was implemented. This tax was not used to protect sugarcane producers, but instead used as a source of revenue. In 1890, this tax was replaced by a bounty of two cents that was paid to domestic producers of sugar. This was the first policy that was implemented to support the domestic sugar producers. The U.S sugar industry quickly found out it could not compete with the international market, so in 1894 the tax on imported sugar was added back and the bounty paid to sugar producers was ended. In 1934, the Jones-Costigan amendment was added to the Agricultural Adjustment Act. This amendment is also known as the Sugar Act of 1934. The amendment recognized sugarcane and sugar beets as a basic commodity so that they were covered by the provisions of the Agricultural Adjustment Act. President Franklin D. Roosevelt focused the act on six principal objectives. The first objective was to assure that sugarcane and sugar beet producers received fair returns for their crops. This was done by way of benefit payments from funds created from a processing tax on sugar. The second objective was to ensure

that laborers in the sugar beet and sugarcane industries earned a fair share of the benefits of the act. The third objective's focus was to stabilize the price of sugar at levels that would be profitable to the producers. U.S sugar prices, along with any other commodity prices in the country, dropped significantly during the Great Depression and struggled to rise. This third objective was the first use of a quota on the domestic sugar producing areas, as well as countries exporting sugar to the U.S. The fourth objective was yet another supply control mechanism. Production in the Philippines, Hawaii, Puerto Rico, and Virgin Islands would be stabilized at a level that would keep pace with sugar consumption in the U.S. The fifth objective relaxed bans on Cuban sugar in an attempt to promote U.S agricultural exports to the country. The final objective was for the Secretary of Agriculture to have control over mediation between producers and processors concerning contractual agreements (Roosevelt, 1938).

In 1974, The Sugar act of 1934 expired and import taxes on sugar were then raised significantly but there was no quota in place for sugar imports. It was not until President Reagan that import quotas were again established to support domestic sugar prices established in the 1981 farm bill. In 1990, President George H.W. Bush signed the Food, Agriculture and Trade Act of 1990. This act imposed marketing allotments for sugar processors. President Clinton signed the Federal Agriculture Improvement and Reform Act in 1996, which set the refined beet sugar loan rate at 22.9 cents per pound and the raw sugarcane loan rate at 18 cents per pound (www.sugarreform.org).

Current U.S sugar policy comes from the 2008 Farm Bill, which is quite complicated. For 2008, the loan rates for refined beet sugar and raw cane sugar remained at 22.9 and 18 cents respectively. However, the raw sugarcane sugar loan rate was increased to 18.25 cents per pound for 2009, 18.5 cents per pound for 2010, and 18.75 cents per pound for 2011 and 2012. The

refined beet sugar loan rate was left at 22.9 cents per pound for 2008, but then was changed to equal 128.5 percent of the sugarcane sugar loan rate. Therefore, the refined sugar beet sugar loan rate was 23.5 cents per pound in 2009, 23.8 cents per pound in 2010, and 24.09 cents per pound in 2011 and 2012. An overall allotment quantity, as well as tariff rate quotas were also established in the 2008 Farm Bill. The tariff rate quota is set as the beginning of the quota year by the Secretary of Agriculture and must meet World Trade Organization minimum levels. WTO minimum levels were 1,231,484 short tons for raw imported sugar and 24,251 for refined sugar imports. The tariff rate quota is allocated to 40 countries and amounts are based on the time period of 1975-1981. The in-tariff quota rate is equal to 0.625 cents per pound and the out of quota tariff is equal to 15.36 cents per pound for raw sugar and 16.21 cents per pound for refined sugar (www.ers.usda.gov).

The 2014 Farm Bill was passed by Congress, and did not make any changes to the loan rates specified in the 2008 Farm Bill. The loans are paid only to processors and not producers. However, in order to qualify for the loans, processors must agree to provide sugarcane and sugar beet producers with payments commensurate to quantities provided to the processors. The loans are non-recourse loans which means that when the loan matures, sugar is used as collateral instead of cash. The overall allotment quantities are issued to processors to ensure that the sugar loan program runs at zero cost to the Federal Government. Processors who exceed their allotment quantity cannot forfeit that amount of sugar under the sugar loan program. Allotment quantities are given as 54.35 percent of domestic consumption to refined beet sugar processors and 45.65 percent of domestic consumption to raw sugarcane sugar processors. If part of an allotment cannot be marketed by a processor, that portion of the allotment is reassigned to another processor in the same state. If no other processor in the same state can market the

additional allotment, it will be reassigned to a processor in a different sugar producing state. Finally, if no other processor in any other state can market the additional allotment of sugar, it is given to the Commodity Credit Corporation for sale. The Feedstock Flexibility Program was included in the 2014 Farm Bill to avoid sugar being forfeited to the Commodity Credit Corporation. This program states that sugar for food use consumption can be sold to ethanol producers if it is not able to be marketed for food use (www.ers.usda.gov).

From this short summary of U.S sugar policy, it is clear that the government has always had an impact on the sugar industry. Many of the early reforms were aimed at helping sugar beet and sugarcane producers. The latter half of the 20th century saw sugar policy change from payments to producers, to supply restrictions such as quotas and marketing allotments. Sugar processors also began to benefit from government set loan rates during this time period and still will today if price levels drop below set loan rates.

CHAPTER 6

DATA AND METHODS

The research procedures for this time series analysis required data to be collected for U.S average sugar beet prices, U.S sugar beet production, total U.S sugar imports, per capita income, and world sugar prices spanning from 1980 to 2013. Population data was also collected to transform production, imports, and income to a per capita basis to reflect changing U.S population between 1980 and 2013. Average sugar beet prices were collected from the USDA's Sugar and Sweeteners Yearbook tables' collection. This price is an average of what producers received for their crop in all sugar beet producing states. The price is denominated in dollars per short ton. U.S sugar beet production was also collected from the USDA Sugar and Sweeteners Yearbook tables' collection. This data measures total production from all states and is measured in short tons. Production data was divided by the respective year's population to get per capita production. Total U.S sugar import quantities were collected from the Foreign Agricultural Service's online production, supply, and distribution database. Imports were initially given in metric tons, so they were converted to the U.S short ton, as well as divided by the respective year's population to get a per capita level of sugar imports. Income and population data was collected from the Bureau of Economic Analysis website. Income levels were measured as per capita personal income, so no transformations were needed. The last variable, world sugar price, was again collected from the USDA yearbook tables. This world price is the refined sugar price traded as the number five contract on the London International Financial Futures and Options Exchange. Average yearly prices were given in cents per pound so they were converted to dollars per short ton to maintain consistency between variables.

The model used to show the relationship between the variables will be a multiple regression model. The ordinary least squares (OLS) estimator will be utilized to determine coefficients for the explanatory variables. The OLS method is used for estimating unknown parameters in linear regression models. The objective of the OLS estimator is to minimize the error sums of squares. This will produce a line of best fit where predicted values are closest to actual observed values for the data set. Several assumptions are needed in order to use to OLS estimator. The first assumption is that the dependent variable is a linear function of independent variables with the addition of an error term. The second assumption is that the number of randomly selected sample observations should be larger than the number of parameters in the model. The third assumption is that independent variables should be non-random. This assumption means that there is unilateral association between the independent and dependent variables. Variations in the independent variables should cause change to the dependent variable, while changes in the dependent variable will not cause changes in the independent variables. The fourth assumption is that the error terms will follow a normal distribution centered on a mean equal to zero and there will be no relationship with the independent variables. The fifth assumption is that the error terms will have equal variances, or homoscedasticity. The violation of this assumption is heteroscedasticity and means that variance in the error terms changes with different observations. The sixth assumption is no auto correlation between error terms. Error terms should not be correlated to previous error terms. The last assumption needed to use the OLS estimator is that there should be no perfect multicollinearity between independent variables. In other words, the independent variables should not be highly correlated and follow a perfectly linear relationship. Given these assumptions, the model used for this study can be expressed as:

(1a) U.S sugar beet price = $\beta_0 + \beta_1$(production) + β_2 (imports) + β_3 (income) + β_4(world Price) +ε_i

Using this equation (1a), U.S sugar beet price was set as a function of the four independent variables, production, imports, income, and world price. The expected sign of the coefficient for production will be negative, indicating that an increase in sugar beet production will lead to a lower price paid to producers for their sugar beets. An increase in production will lead to an increased amount of supply of sugar beets to be processed into sugar. This scenario can be illustrated on a supply/demand graph, where the supply curve would be shifted downward due to increased production, which would lead to a lower price (assuming demand does not change). The expected sign of the coefficient for imports will also be negative. Imports in this study were measured as the total of all sugar imports. If import levels are increased, the supply of sugar in the U.S would increase, resulting in the same scenario as production, a reduced price for what sugar beet producers receive for their crop. The income coefficient is expected to be positive. As incomes increase, consumers would be more likely to purchase non-essential goods containing sugar, such as soda, ice cream, candy, and other baked goods. Consumers purchasing more of these sugar sweetened goods should cause an increase in demand for sugar, resulting in a shift of the demand curve outward with a higher price. Lastly, it is expected that the coefficient for world sugar price will also be positive. Historically, U.S sugar beet prices have followed world sugar prices very closely.

Several hypothesis tests will be done in this study. A t-test will be done for each independent variable to see whether the estimated beta coefficient is statistically different from zero. Rejection of a null hypothesis will indicate that the estimated coefficients is statistically different from zero. Failure to reject a null hypothesis will mean that the estimated coefficient is statistically no different than zero and therefore will have no significant impact on the dependent

variable. An F-test will also be done to test the hypothesis that the R^2 value is equal to zero. The R^2 value gives the explanatory value of the estimated model, so failure to reject the null hypothesis in this case would mean that the models independent variables do a poor job in explaining variation in the dependent variable. A test statistic will be calculated for each hypothesis test and compared to a corresponding critical value. Test statistics greater than the critical value for that test will mean that the null hypothesis can be rejected. Hypothesis tests for this study can be expressed as:

TABLE 1: Hypothesis Tests

1. H_0: Production = 0
2. H_0: Imports = 0
3. H_0: Income = 0
4. H_0: World Price = 0
5. H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$

CHAPTER 7

RESULTS

The following OLS estimation was used for this study and the test statistics are shown below the coefficient estimates.

(1b) U.S sugar beet price = −1.394 -0.559(production) -0.089(imports) + 0.141(income) + 0.355(world price)
(-1.42) (-2.31) (-0.84) (2.27) (4.27)

The coefficients were transformed to logarithmic values for ease of interpretation and an explanation of the variables is provided in Table 2 of the appendices. As expected, the coefficients for both production and imports is negative. The production coefficient for production indicates that a one percent increase in production per capita will result in a 0.559 percent decrease in U.S sugar beet prices. The import coefficient indicates that a one percent increase in imports per capita will decrease sugar beet prices by 0.089 percent. Income and world price coefficients both had positive values, as expected. The positive income coefficient means that a one percent increase in income per capita will lead to a 0.141 percent increase in sugar beet prices. Lastly, the world price coefficient indicates that a one percent increase in world sugar prices will result in a 0.355 percent increase in prices of U.S sugar beets. The R^2 for this estimated model is 0.74, which means that 74 percent of the variation in U.S sugar beets prices can be explained by the variation in production, imports, income, and world prices.

The critical value for the t-tests conducted was +/- 2.045. Production had a test statistic of -2.307, so the statistical decision is that the null hypothesis can be rejected. The test statistic for imports was -0.84, which is not greater than +/- 2.045 so the null hypothesis in this case fails to be rejected. This means that the coefficient for imports is statistically no different from zero, so

in this data set, imports did not influence U.S sugar beet prices. The test statistics for income and world prices were 2.273 and 4.274, so the null hypothesis can be rejected for both cases. P-values were also computed for each variable. The P-value is the likelihood that the null hypothesis is correct, and is also another way to test the statistical significance of the independent variables. Production (0.028), income (0.031), and world prices (<0.000), all had P-values well below the alpha level of 0.05, so the null hypotheses for these variables can be rejected. However, the P-value for imports was 0.404, higher than the alpha level of 0.05, so the same statistical decision is made for imports as was made when comparting the test statistic to the critical value. The F-statistic for the null hypothesis of H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ is 20.93, which is well above the critical value of 2.68, so the null hypothesis can be rejected.

In testing for the assumption of no auto correlation between error terms, the Durbin-Watson test is used. As a general rule of thumb, test statistics for the Durbin-Watson test greater than 1.5 but less than 2.5 do not raise any large amount of suspicion of auto correlation. More specifically, upper and lower critical values are calculated for this test. A test statistic greater than the upper critical value means there is no statistical evidence that the error terms are positively auto correlated. If the test statistic lies in between the critical values, the test is inconclusive for positive auto correlation. If 4 minus the test statistic is greater than the upper critical value, there is no statistical evidence that the error terms are negatively auto correlated. In this study the lower and upper critical values at an alpha level of 0.05, are 1.21 and 1.73. The Durbin-Watson test statistic is 1.57 for this study, therefore it is inconclusive whether there is any positive auto correlation between error terms. Using the rule for negative auto correlation, there is no statistical evidence found for negative auto correlation between error terms in this study. A correlation matrix of the independent variables is used to check for the assumption of

no perfect multicollinearity. The correlation matrix shows no concern for multicollinearity in this study. The highest correlation is between the world sugar price and the total level of imports. This pairing produced a 0.58 correlation, which means world sugar prices and imports are positively correlated, but not to such a degree that it becomes problematic.

CHAPTER 8

DISCUSSION

The results of this study show a distinct relationship between U.S sugar beet prices and production, world sugar prices, and incomes. Total sugar imports showed to be the only independent variable that did not have a significant impact on U.S sugar beet prices. This is because of the small variation in total sugar imports for this 33 year data set. Sugar imports per capita varied by only 0.016 tons per capita during this time period, which equates to a 32 pound difference per person from the lowest data point to the highest data point. This is a small difference when considering the average American in 1999 consumed 153.2 pounds of caloric sweeteners a year, according to the USDA. A key result of this study was that world sugar prices were significant in explaining variation in U.S sugar beet prices. This implies that although the U.S sugar market has government support, outside events influencing the price of world sugar may also have an effect on U.S sugar beet prices. One major influence on world sugar prices is oil. As oil prices rise, the demand for alternative fuels such as ethanol derived from sugar may increase. Sugar is a key component for ethanol production in areas such as Brazil [the world's largest sugar producer] and the European Union. Although the U.S ethanol market relies primarily on corn as a source for ethanol, advanced bio fuel mandates and research showing the economic feasibility of sugar beets (Maung and Gustafson, 2010) as a source for ethanol may strengthen the relationship between oil and sugar beet prices in the future.

One possible limitation to this study was that an average annual price for all U.S sugar beet producing states was used. This means that the results of this study may not necessarily apply equally to all states. Smaller sugar beet producing states such as Colorado, Oregon, or

Washington may not see the same effect from the economic variables used in this study as would the larger producing states like North Dakota, Minnesota, Idaho, and Michigan. There exists some significant variation in prices amongst the sugar beet producing states so it could be important to disaggregate the data and study the regional economic factors influencing the prices in those individual states.

If sugar beets prove to be economically feasible for ethanol production in the U.S, future studies may want to examine the relationship that oil prices have with sugar beet prices. Future studies may also want to disaggregate the data to an individual state level to see if the economic variables used in this study also apply at the individual state level. Even though import levels were not significant in explaining variation in U.S sugar beet prices for this study, it could be important to also look at how trade liberalization policies, such as the Trans Pacific Partnership, could affect domestic sugar beet prices. Consumer health behaviors could also be important for future studies. As consumers become more aware of the adverse health effects from consuming too much sugar, such as heart disease and obesity, the demand for sugar or food products containing sugar may decline and have an influence on the price that producers receive for their sugar beets. Furthermore, as the popular concerns about genetically modified organisms increase, the use of sugar beet sugar in food products could decline. Considering most sugar beets planted in the U.S are now genetically modified, the decline in use of beet sugar demand could have an adverse effect on the price producers receive for their crop.

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APPENDICES

APPENDIX

Table 2: Explanation of Variables

Variable	Explanation
LOG_SB	U.S Average Sugar Beet Price
LOG_WHOL	Wholesale Refined Beet Sugar Price
LOG_PROD	Total U.S Sugar Beet Production In Tons Per Capita
LOG_IMP	Total U.S Sugar Imports In Tons Per Capita
LOG_INC	Per Capita Income
LOG_WORL	Number Five Refined Sugar Futures Contract Price

*Variable labels to be used for the following tables

Table 3: 1980-2013 Univariate Summary Statistics

Univariate statistics

Number of Observations: 34

	Mean	Std Dev	Minimum	Maximum
LOG_SB	3.72742	0.19162	3.37417	4.23989
LOG_PROD	-2.26485	0.092741	-2.42592	-2.11150
LOG_IMP	-4.71062	0.33641	-5.26220	-3.84223
LOG_INC	10.10094	0.43925	9.22552	10.70185
LOG_WORL	5.64713	0.39954	4.91118	6.47080

	Sum	Variance	Skewness	Kurtosis
LOG_SB	126.73215	0.036717	1.26591	1.94232
LOG_PROD	-77.00482	0.0086009	-0.060892	-1.03558
LOG_IMP	-160.16096	0.11317	0.30650	-0.22871
LOG_INC	343.43208	0.19294	-0.36259	-1.00690
LOG_WORL	192.00251	0.15963	0.38467	-0.43526

Table 4: 1980-2013 Independent Variables Correlation Matrix

Correlation Matrix

	LOG_PROD	LOG_IMP	LOG_INC	LOG_WORL
LOG_PROD	1.00000			
LOG_IMP	-0.33026	1.0000		
LOG_INC	-0.0089155	-0.32142	1.00000	
LOG_WORL	0.050627	0.58239	0.29515	1.0000

Table 5: 1980-2013 U.S Sugarbeet/Wholesale Refined Beet Sugar Price Correlation Matrix

Correlation Matrix

	LOG_SB	LOG_WHOL
LOG_SB	1.0000	
LOG_WHOL	0.87627	1.00000

Table 6: 1980-2013 Time Series Regression Output

```
Dependent variable: LOG_SB
Current sample:  1980 to 2013
Number of observations:  34

        Mean of dep. var. = 3.72742
   Std. dev. of dep. var. = .191616
 Sum of squared residuals = .311713
    Variance of residuals = .010749
 Std. error of regression = .103676
               R-squared = .742738
       Adjusted R-squared = .707253
            LM het. test = 1.08353 [.298]
           Durbin-Watson = 1.56665 [<.273]
Wald nonlin. AR1 vs. lags = 2.78005 [.595]
              ARCH test = .258201 [.611]
             CuSum test = .393302 [.941]
          CuSumSq test = .369046 [.011]
             Chow test = 2.39216 [.068]
      Chow het. rob. test = 2.38254 [.069]
   LR het. test (w/ Chow) = 7.38693 [.007]
         Jarque-Bera test = .079411 [.961]
          Ramsey's RESET2 = 12.6414 [.001]
          F (zero slopes) = 20.9313 [.000]
           Schwarz B.I.C. = -22.7048
           Log likelihood = 31.5207

            Estimated    Standard
Variable    Coefficient     Error       t-statistic   P-value
Constant    -1.39426      .984148       -1.41672       [.167]
LOG_PROD     -.559158      .242383        -2.30692      [.028]
LOG_IMP     -.089902      .106251       -.846126       [.404]
LOG_INC     .141118       .062087       2.27292        [.031]
LOG_WORL     .355285       .083127        4.27400       [.000]
```

Figure 1: 1980-2013 U.S Average Sugar Beet Price

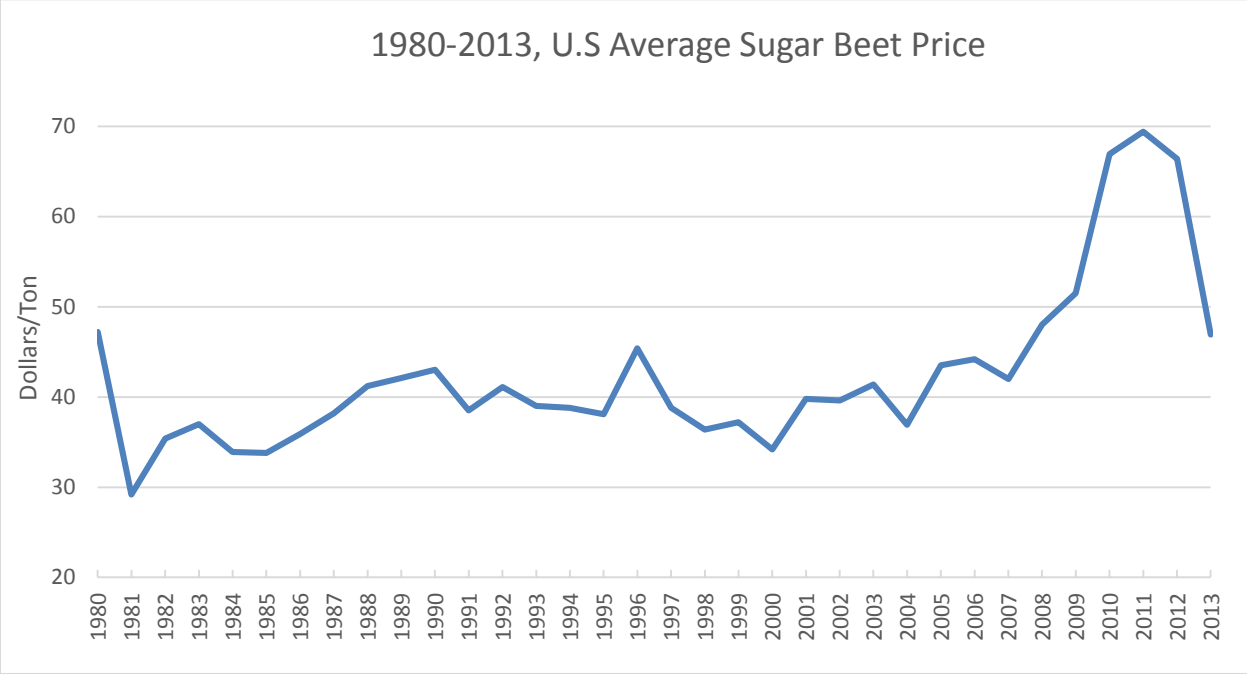


Figure 2: 1980-2013 World Raw Sugar Price

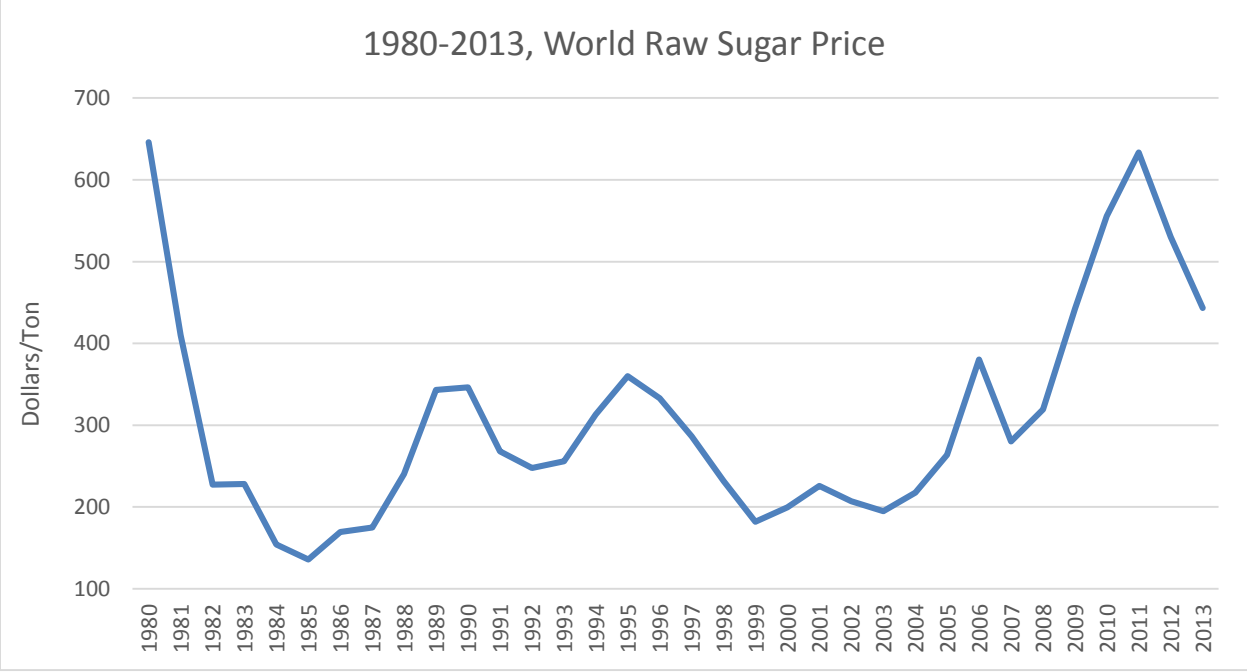


Figure 3: 1980-2013 U.S Sugar Beet Production

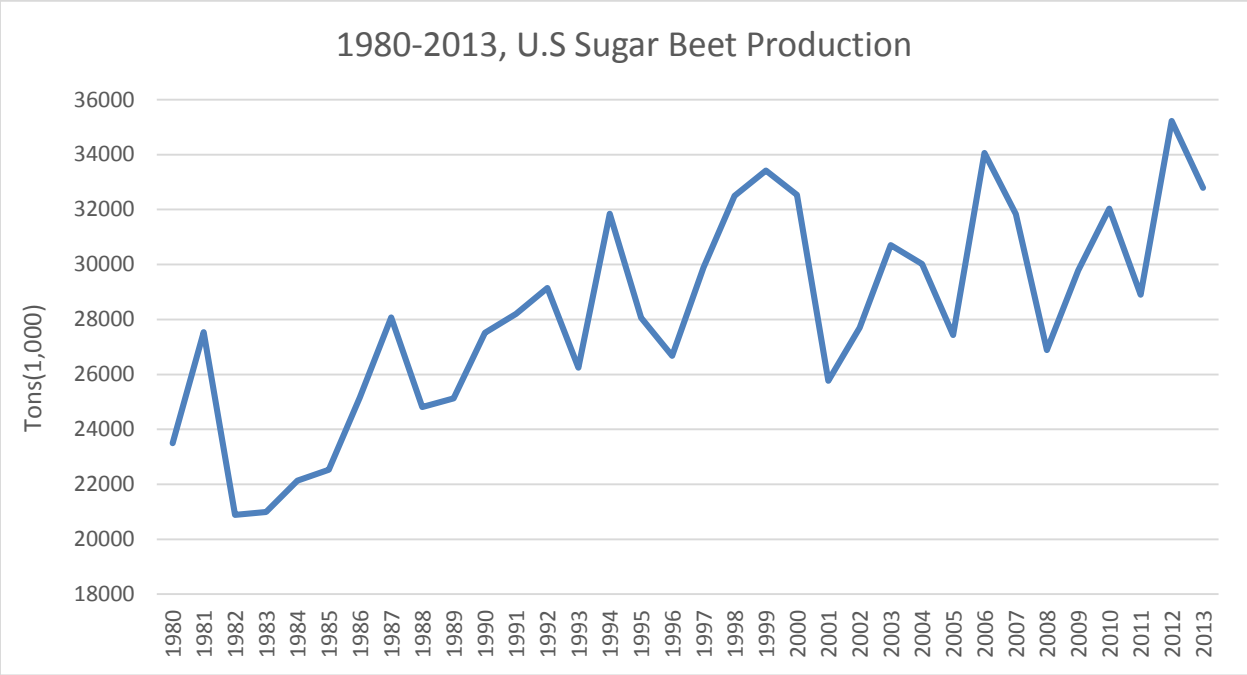


Figure 4: 1980-2013 U.S Sugar Imports

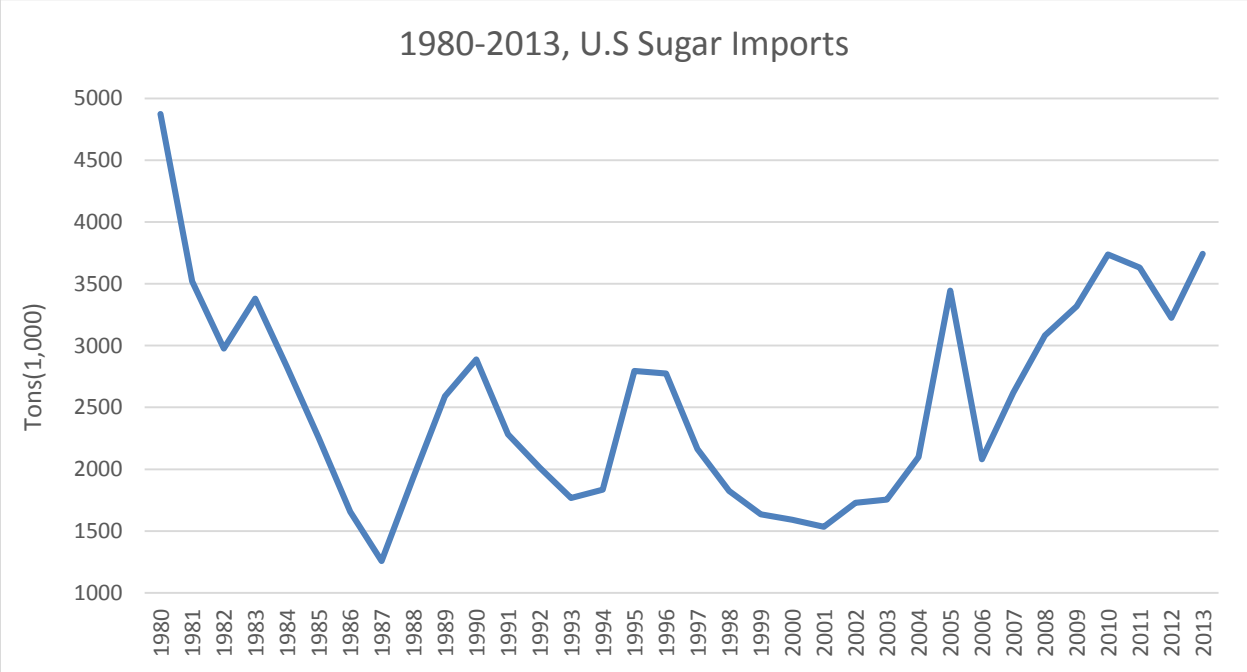


Figure 5: 1980-2013 U.S Per Capita Income

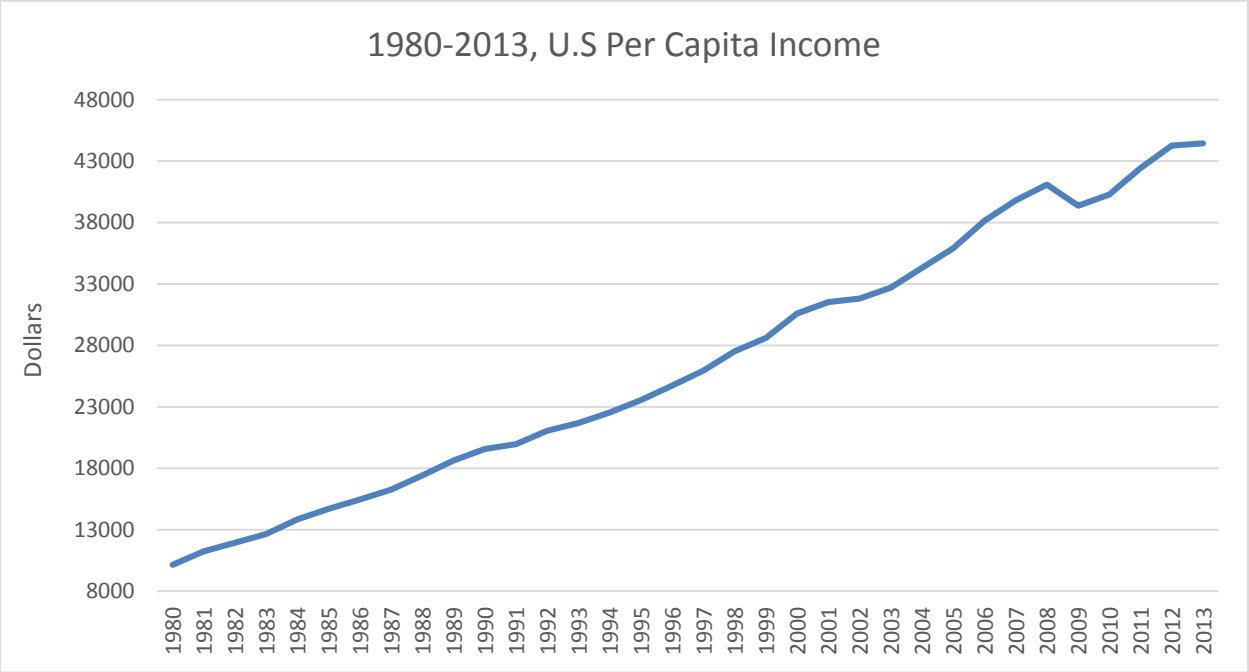
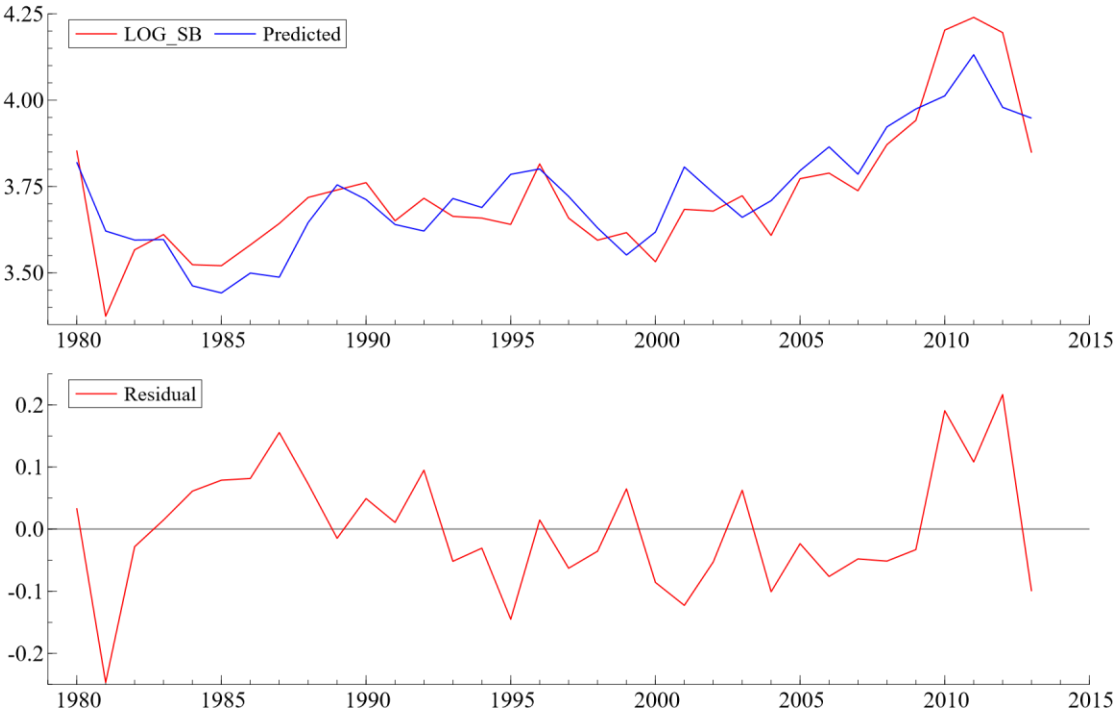


Figure 6: 1980-2013 Time Series Regression Plot



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