"The Fundamental Factors Affecting Corn Price from 1982-2013"

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1

Introduction

        Corn prices have not been stable from 2007 to 2012 and there are many different situations and events that influence corn price. Through my research, I will be exploring and explaining the fundamental reasons that corn prices have become increasingly more volatile. The factors that will be explored are split into two different categories: supply and demand. The influences that follow under supply include planted acreage of corn, expected corn yield, weather, and the effects of commodity programs. The factors under demand include the amount of corn consumption, ethanol production, exchange rates which affect exports and imports, global stocks, and incomes. Most importantly, I will be focusing on effects of weather, ethanol production, planted acreage of corn and expected corn yield. I have observed that corn prices have increased in the past decade and that corn production and ethanol production have increased immensely as well. I am gong to research if and how these two factors are correlated, I will do this by running regressions with corn price data from 1982 to 2013. The current research that I will update and build on are the fundamental factors that are causing corn prices to increase, all though my main focus will be the effect of ethanol production growth on corn prices. The Congressional Budget Office clearly links the increase in corn prices to domestic ethanol demand:

"In 2008, nearly 3 billion bushels of corn were used to produce ethanol in the United States. That amount constituted an increase over the previous year of almost a billion bushels. The demand for corn for ethanol production, along with other factors, exerted upward pressure on corn prices, which rose by more than 50 percent between April 2007 and April 2008."

Corn prices have become more volatile in the past decade and I will research how four

different factors have affected US corn price. These four variables are precipitation, US Weighted Dollar Index, corn production, and ethanol price. I will run regressions, then analyze the results and conclude which of these variables have significantly affected US corn price.

Literature Review

Weather, ethanol, and planted corn acreage/expected corn yield are all fundamental factors that are changing and impacting corn price. Wescott and Jewison (2012) researched and compiled results about the impact that United States weather has had on corn yields. They especially focused on the 2012 drought and its' effects on corn production, which were significantly lower in 2012 compared to past years. Abbott, Hurt, and Tyner (2011) discuss corn production and the specific uses for corn and the effect of different uses on corn prices. Ethanol is another significant influence on corn price. According to Capehart and Vasadava (2012), ethanol's effect on corn price is approximately $0.41/bushel and they concluded that ethanol production has had a positive impact on corn price. Gardebroek and Hernandez (2012) researched volatility transmission in ethanol, oil, and corn prices between 1997 and 2011. They found significant volatility spillovers from corn to ethanol but not from ethanol to corn. Another factor is planted corn acreage and expected corn yield, which according to Wallandar, Claassan, and Nickerson (2011) has increased along with corn prices increasing as well. They state that corn production has not kept up with ethanol production growth, which increases the demand for corn drastically. Condon, Klemick, and Wolverton (2013) calculated the percentage effect of ethanol gallon expansion on corn prices. They found that in the short run that there is a higher impact on corn prices per billion gallons of corn

3

ethanol production. They found that each billion gallons of ethanol would create a 5-10 percent increase in corn price (Condon, Klemick and Wolverton, 2013).

Weather

The last three years, 2012-2014, of United States weather has significantly impacted corn prices. For instance, there was the 2012 drought, which included high temperatures and extended periods with out rain. The drought affected many growing and production regions in the United States. The impact was unfavorable and there was a reduction of corn yields in 2012 to 123.4 bushels per acre. For three years national average corn yields were reduced below trend expectations due to weather (Wescott and Jewison, 2012). Figure 1 displays the predicted corn yield (bushels per acre) each year along with the actual corn yield (bushels per acre) each year (Wescott and Jewison, 2012). Figure 1.0 includes data from 1988 through 2012, which includes both major United States droughts.

Figure 1.0
Predicted and Actual US Corn Yield
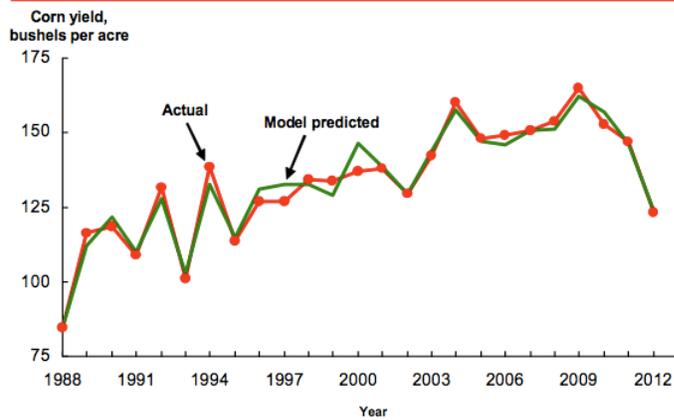
Ethanol

Capehart and Vasadava (2012) state that biofuel production will continue to increase because of the Energy Independence and Security Act (EISA). EISA mandates an increase in biofuel use from 9.0 billion gallons in 2008 to 36 billion gallons in 2022. Capehart and Vasada (2012) used log-log models to calculate short-run price elasticity and corn production. The focus of their work is the effect of each of the following categories of corn demand on US corn price between 1995 and 2006. They figure out the effect by estimating five equations, one equation for each of the following factors: corn supply, corn price, feed demand, export demand, and food/alcohol/industrial demand. Capehart and Vasada (2012) find that increasing demand for FAI (food, alcohol, and industrial demand) is more important in explaining corn price changes than other use categories. The impact of FAI consumption on corn price is the strongest, following that is export consumption, and then feed consumption is last. They estimate that ethanol's effect on corn price is about $.41/bushel, this is calculated using data from 2006-2008 (Capehart and Vasadava, 2012). While $.41 is an increase in price it is not close to actual price appreciation so Capehart and Vasadava (2012) concluded that ethanol production has had a significant and positive impact on corn price but it does not fully explain the corn price increase in the year 2007/2008.

Gardeborek and Hernandez (2012) examined volatility transmissions in corn prices, ethanol, and oil in the United States between 1997 and 2011. They formed a Multivariable Generalized Autoregressive Conditional Heteroskedascity (MGARCH)

5

Model to observe and calculate the volatility transmissions. They also used the MGARCH model to calculate the interdependence, the dynamics, and the cross-dynamics of volatility between corn markets, ethanol, and oil. Gardebroek and Hernandez (2012) also observed the relationship between energy and agricultural markets. They used the BEKK (Baba, Engle, Kraft, and Kroner) model to examine this relationship. This model characterizes the volatility transmission across markets, it also accounts for own and cross volatility spillovers and persistence between markets. They also used a DCC model to observe the change in level of interdependence between markets across time. The DCC does this by approximating the dynamic conditional correlation matrix. The results of these models and calculations indicated a higher interaction between ethanol and corn markets between 2006-2011. After 2006 Gardebroek and Hernandez (2012) found a higher correlation between corn and ethanol markets, prior to 2006 they only observed a strong correlation between oil and ethanol returns. The results also showed large own-volatility effects in the three markets (crude oil, corn, and ethanol), which indicate that there were strong Generalized Autoregressive Conditional Heteroskedascity (GARCH) effects (Gardebroek and Hernandez, 2012). The ethanol markets displayed the lowest own-volatility persistence (Gardebroek and Hernandez, 2012).

Abbott, Hurt, and Tyner (2011) state that since the 2005/06 marketing year 88% of growth in total global corn use has been in the food, seed, and industrial (FSI) category. Ethanol is placed in the FSI category. Since 2005/06 total corn used specifically for ethanol has increased 2.46 billion bushels annually, as a result this

6

increase use of corn for ethanol in the US was 48% of the increase in corn utilization globally over the next 5 years.

According to Condon, Klemick and Wolverton (2013) for each billion gallon expansion in ethanol production there is a 5-10% increase in corn prices. Condon, Klemick and Wolverton (2013) normalized corn price impacts by ethanol quantity to calculate two metrics: percent change in corn prices per 1 billion gallon increase in corn ethanol production and percent change in corn prices per 1% increase in corn ethanol production. Condon, Klemick and Wolverton (2013) found that each billion gallon expansion in corn ethanol production increase 2-3% ong run corn price. From 2000-2012 US ethanol production has increased by more than 700% and that the percent of US corn harvested used for ethanol has increased from 10% to 40%. (Condon, Klemick and Wolverton, 2013)

Figure 2.0
Percent of Corn Production Used for Ethanol and Corn Prices
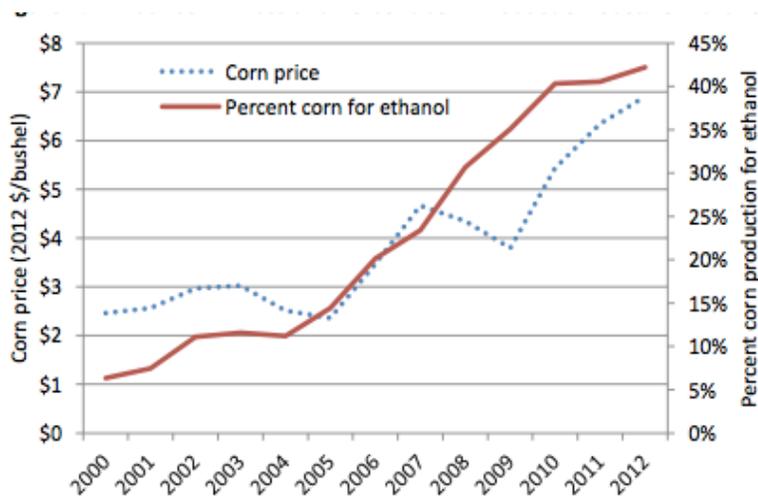
Sources: Capehart and Vasada Economic Research Services Feed Grain Database (2013b)

> **Commented [ACE1]:** Is this a document I can find, or did you use these data to create the figure?

7

Planted Acreage and Expected Yield

Wallander, Claassen, and Nickerson (2011) have found that corn production has increased between 2000-2009 due to increased corn yields and that corn prices increased dramatically between 2006 and 2008. At the same time between 2000 and 2009 US ethanol production has increased by 9.2 billion gallons, moving from 1.6 gallons in 2000 to 10.8 gallons being produced in 2009. During this time US corn production increased a total of 3.2 million bushels and harvested corn increased a total of 7.2 million acres. Corn prices are increasing because corn acreage and corn yield expansion have not kept up with ethanol production growth (Claassen, Nickerson, and Wallander, 2011). Wallander, Claassan, and Nickerson (2011) state that agricultural markets can keep up with the growing demand for ethanol by diverting corn from other uses, increasing corn yields, or increasing the amount of land planted to corn. Through out the past decade all of these changes have occurred and continue to change as ethanol production increases. Figure 3.0 shows that the demand for corn used for corn-based ethanol is increasing rapidly.

Figure 3.0

US Uses for Corn (billion bushels)
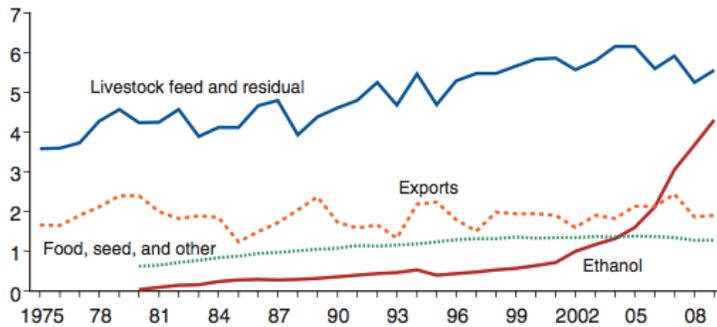
According to Abbot, Hurt, and Tyner (2011) in 2005 7.8 million acres of corn was harvested specifically for ethanol. In 2010 23.7 million acres of corn was harvested specifically for ethanol, this is an increase of 15.9 million acres between 2005 and 2010.

Abbott, Hurt, and Tyner (2011) state that due to the biofuel policy constraints the demand for corn that is used for biofuel is fixed. For example, RFS 2 (Renewable Fuel Standard) mandates gasoline blenders use 15 billion gallons of corn-based ethanol by 2015. In 2010, the US produced 13 billion gallons of ethanol and in 2011 the US produced more than 14 billion gallons of ethanol. The US is quickly approaching the RFS 2 mandate. This will cause growth in this sector of corn production to slow exponentially.

Empirical Model

We wanted to see how precipitation, corn production, ethanol price, and the US Weighted Dollar Index affected US corn price. Figure 4.0 displays the variation of the four independent variables in relation to US corn price. . Since the data does not

have the same units we divided each of the data series by the first data point to make all of the data points out of one. According to Figure 4.0, ethanol price has increased steadily with a major spike around September of 2006. Corn production has also increased fairly steadily with some drops and rises but over all it has increased. This could be due to an increase in technology that has increased production efficiency and capacity. Precipitation is the most volatile independent variable, which one can expect due to the uncertainty of weather. And lastly, the US Dollar Weight index increased towards the beginning but has remained pretty steady with a slight decline towards the end.

Figure 4.0

Independent Variables vs. US Corn Price (1982-2013)
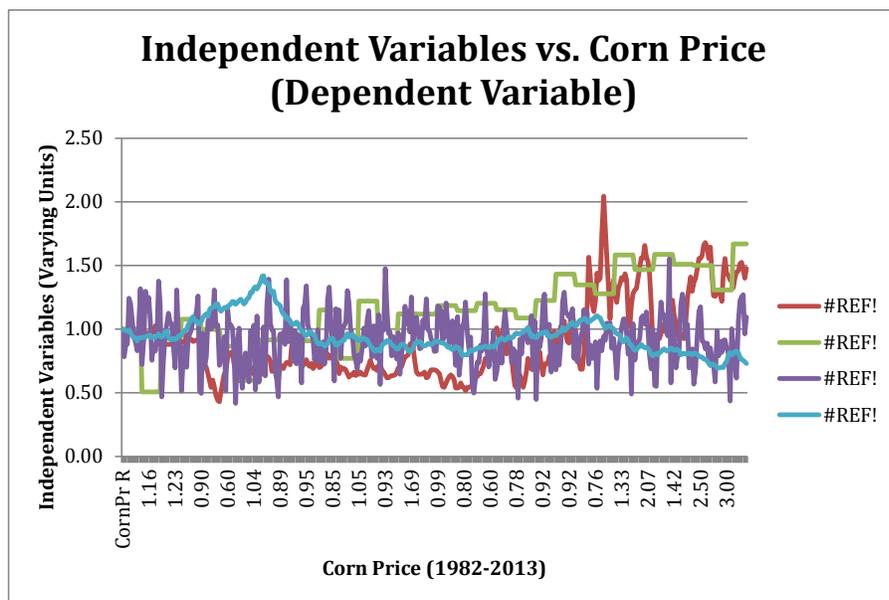
Sources: Erin Whittaker created with data used for the regression

We ran a linear regression to test whether United States average precipitation, ethanol price, corn production, and the United States Dollar Index significantly impacted corn price. Corn price was the dependent variable in our regression and precipitation, ethanol price, corn production, and the United States Dollar Index were the independent variables. The first regression we ran was the base regression.

$$y_{tcp} = \beta_o + \beta_p X_{tp} + \beta_{wv} X_{twv} + \beta_c P_{tc} + \beta_e X_{te} + \varepsilon + Y_{t-n}$$

The left-hand side, y_{tcp}, is the dependent variable, monthly United States corn price. All of the variables on the right-hand side are independent variables meaning that they are the inputs that are tested to see whether or not they affect the dependent variable. The right-hand side includes, β_o, the coefficient and/or intercept. $\beta_p X_{tp}$ is the independent precipitation variable with a monthly subscript of t. Precipitation is the volume of precipitation in the United States. $\beta_{wv} X_{twv}$ is the independent weighted value of the US Dollar variable with a monthly subscript of t. $\beta_c P_{tc}$ is the United States corn production variable with a monthly subscript of t. $\beta_e X_{te}$ is the independent variable for Omaha, Nebraska's ethanol spot price with a monthly subscript of t. ε is the random error term/ residuals and Y_{t-n} are the lag variables included (time minus number of lags which in our case is 1 to 12). After running the first regression we tested for structural change to see if the regression should be split into two different time periods. We split the regression into two different time periods, 1982-2004 and 2004-2013. We selected this place

11

to split our data because it was when the Renewable Fuel Standard program was created under the Energy Policy Act of 2005 which established the first renewable fuel mandate in the US. We were interested in viewing how ethanol impacted corn price.
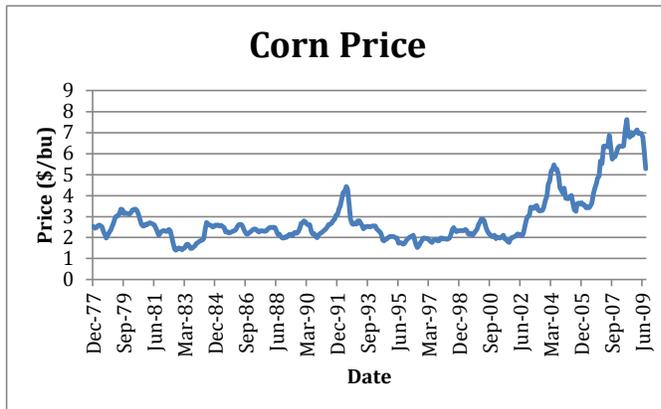
Data and Methodology

Data

Corn price has been volatile and has increased drastically in the last five to ten years as you can see in Figure 5.0.

Figure 5.0

US Corn Price 1982-2013

Sources: Created by Erin Whittaker, data from National Agricultural Statistics Service

Our research shows how certain fundamental factors have affected corn price. The dependent variable is the nearby futures corn price and is measured in dollars per bushel. Precipitation, the weighted value of the US dollar, corn production, and ethanol price were the independent variables used. The data and models were evaluated from 1982 to 2013; these years were selected because of the increase in ethanol volume in 2005. The regression was split into two time periods. The time before the Renewable Fuel Standard program was created (1982-2004) and the time period after the RFS1 was established (2005-2013).

Weather impact is measured as the average United States precipitation in inches per month. This independent variable was chosen to display the effect of precipitation on corn price. The weighted value of the US dollar is measured as the US trade-weighted value of the United States against the major currencies. A trade-weighted index is the average of the exchange rates of a country's currency with the currencies of its most important trading partners. It is weighted to reflect each trading partners' importance to the country's trade (glossary.reuters.com). This independent variable was chosen to measure the effect of exports and the effect that the strength of the US dollar compared to other currencies has on corn price. Corn production is measured in millions of bushels of corn harvested in the United States annually. This variable was chosen to display the effects of corn supply on corn price. Ethanol price is measured as the United States ethanol spot price FOB (free on board) for Omaha in US dollars. This variable was chosen to display the effect that ethanol has had on corn price since its' introduction to the corn market.

13

Methodology

   To begin analyzing the data we ran the Dickey-Fuller test on corn price to test whether or not corn price was stationary. Since corn price is so volatile we ran the Dickey-Fuller test with first differences. Our pt-1 (corn price with one lag) coefficient was -3.04 so we rejected the null hypothesis meaning that with first differences corn price is stationary. We also rejected the null hypothesis at the 5% significance level. Once it was proven that the first differences were strongly stationary, we ran a regression with the data from 1982-2013 to see which independent variables were significant. After considering ethanol policy and mandates we split the data into two different periods, one from 1982-2004 and the second from 2005-2013. We decided to split the data in 2005 when the United States became a large and influential producer of ethanol. The US Energy Policy Act of 2005 mandated that gasoline contain 7.5 billion gallons of renewable fuel annually by 2012. Since then that Act has been changed, in 2007 the RFS required 9 billion gallons of renewable fuels in 2008 and required that to increase to 15.2 billion gallons in 2012 and to 36 billion gallons in 2022 (Energy Policy Act of 2005).

Results

   Before running the regression and obtaining the results we hypothesized what we expected the signs on the coefficients for each independent variable. We expected the US Weighted Dollar Index to have a negative coefficient. This is because as the US dollar becomes weaker, other countries want to buy more US corn because it is cheaper. The US ends up exporting more corn which lowers the supply

of corn in the US market which causes US corn price to increase. We expected US precipitation to have a negative coefficient as well because if there is a decrease in precipitation then there will be a decrease in harvest size. This will cause a decrease in US corn supply and raise the US corn price. We expected corn production to also have a negative coefficient because as corn production decreases, the US corn supply decreases, and US corn price rises. We expected US ethanol spot price to have a positive coefficient. We assumed that as US ethanol spot price rises then US corn price should increase as well.

Figure 6.0

Regression Results

Variables	Jan82-Sep13	Jan82-Dec04	Jan05-Sep13
Dollweight	-0.0011279 *	-0.0008187 *	-0.009141 **
	(0.0007579)	(0.0005088)	(0.0045124)
Precip	-0.0389235 ***	-0.0218294 **	-0.0565015
	(0.0157752)	(0.0116739)	(0.0517999)
Cornprod	-0.0056663	-0.0118184 ***	-0.0259414
	(0.0051846)	(0.0041013)	(0.0278963)
Ethanol	0.0549747 **	0.0100957	-0.002739
	(0.0252033)	(0.0268664)	(0.0771736)
Cons	0.2623873 ***	0.3328253 ***	1.602646 **
	(0.1110592)	(0.09248431)	(0.6770418)
Lag 1	1.36008 *	1.586716 *	1.200908 *
	(0.0523747)	(0.0612895)	(0.1066578)
Lag 2	-0.4036909 *	-0.8071678 *	-0.2306007 ***
	(0.0859694)	(0.1149313)	(0.1580647)
Lag 3	0.0216757	0.2205117 **	0.0681811
	(0.0873796)	(0.1247931)	(0.1589391)
Lag 4	0.127874 ***	-0.0368858	0.1371531
	(0.0861016)	(0.1251702)	(0.1573468)
Lag 5	-0.261129 *	-0.1151269	-0.281777 **
	(0.0855896)	(0.1253042)	(0.1545822)
Lag 6	0.1533024 **	0.1298885	0.105057
	(0.0867538)	(0.1259629)	(0.157571)
Lag 7	0.0042943	-0.0115024	-0.0599574
	(0.0867872)	(0.1265203)	(0.1574654)
Lag 8	-0.2036954 *	-0.0419208	-0.2388603 ***
	(0.0859844)	(0.1266776)	(0.1566052)
Lag 9	0.3087641 *	0.1266684	0.3041676 *

	(0.0862328)	(0.126911)	(0.1568636)
Lag 10	-0.320782 * (0.0862328)	-0.1943659 *** (0.1265025)	-0.2699342 ** (0.1609045)
Lag 11	0.4234947 * (0.0875094)	0.1943659 *** (0.1166274)	0.5046003 * (0.1624261)
Lag 12	-0.2399798 * (0.0533673)	-0.0952329 *** (0.0618591)	-0.3182365 * (0.1084092)
R-Squared	0.9857	0.9604	0.9778
N	381	276	105

*If the P-Value is < 0.01
**If the P-Value is <0.05
***If the P-value is <0.15

The results concluded from running the Chow Test solidified that the combined regression should be separated and run as two different regressions. It showed that there was a change in significance in the independent variables when the regressions were run together and then separately. The results from the combined regression (January 1982-September 2013) showed that the US Dollar Weight Index, precipitation, and ethanol were all significant independent variables. Precipitation being a significant variable was expected because the amount of precipitation directly correlates with the amount of corn grown and harvested. The coefficient on precipitation is negative because typically the more precipitation that occurs the more corn is grown and harvested which increases the supply of corn in the commodity market. With an increase in corn supply, the corn price is expected to decrease. Ethanol is significant in the combined regression because through out this time period ethanol was introduced and had grown exponentially. The combined regression (1982-2013) showed that ethanol was significant at the 95% confidence level, meaning it did have an impact on US corn price overall. According

to the mandate in the Energy Policy Act of 2005, gasoline was mandated to have 7.5 billion gallons of renewable fuel by 2012. That means that a certain amount of corn has to go towards filling that mandate which will remove corn from the domestic market, and affect corn price. With the ethanol mandates, a certain amount of corn must be first sent to ethanol production and then the left over can be sold for other sectors of the corn market. This impacts price greatly. For example, if there was a drought like in 2012 then the corn harvest would not be high and the same amount must still go to ethanol (due to the mandate) so there was a decrease in corn supply and corn price increased immensely. The US Weighted Dollar Index is significant because it is the measure of value of the US dollar relative to its most important trading partners (investopedia.com), which relates all of their exchange rates to the US dollar. This can affect US corn price when US corn is exported and traded globally which has a significant impact on corn price. As stated before, we expected the coefficient for the US Weighted Dollar Index to be negative because the weaker the US dollar the higher the exports which in turn will increase corn price. We found that the US weighted dollar was the most consistently significant variable through out all three of our regressions. The coefficient sign was also negative for all three regressions, which was what we expected.

The early period regression focused on the data from January 1982 to December 2004. We found that the US Dollar Weight Index, precipitation, and corn production were all significant. During this period there were two large droughts in the United States, which could have affected the significance of the precipitation and corn production variables. The signs for all of the independent variable's coefficients

17

in the 1982-2004 regression were what we expected. The US Dollar Weight Index, precipitation, and corn production were all negative and ethanol was positive.

In the second half of the regression, which focused on the data form January 2005-September 2013, we found that the US Dollar Weight Index was the most significant factor. We also found that the coefficient signs for all four variables were negative. These were not the results we originally expected, which were that ethanol would be significant and have a positive coefficient. The fact that ethanol had a negative coefficient meant that as ethanol price increased US corn price decreased, we expected that as ethanol price increased that US corn price would too. Considering what happened between 2005 and 2013 with the United States economy, ethanol production, and weather patterns the results do in fact make sense. Even though ethanol changed the corn price market it is not significant because other events occurred during this time period that created price volatility in the corn price market. In 2008, the United States experienced a financial crisis, which was also deemed as the Global Financial Crisis (Global Britannica). This financial crisis was considered by many to be the worst economic crisis since the stock market crash in the 1929 followed by the Great Depression. A United States drought started in the southern states in 2012 and spread to the Midwest and northern states drastically hurting crop growth and harvest. The 2012 drought had a huge impact on corn prices. We hypothesize that even though ethanol had a large impact on corn price and changed the way that corn flows through the market that it was still small in comparison to other significant events. We hypothesize that these significant events had a drastic effect on corn price, which overshadowed ethanol's

18

significance. This is not stating that ethanol is insignificant because as stated above when the combined regression was run it proved that overall ethanol is a significant factor in the corn market.

Discussion and Conclusions

We found that from 1982 to 2004 that US Dollar Weight Index, precipitation, and corn production were significant factors in impacting the US corn price. Then that changed from 2005 to 2013 where the only significant factor impacting US corn price was the US Dollar Weight Index. When we ran the regression combined (1982-2013) we found that precipitation, US Dollar Weight Index, and ethanol were all significant. In the combined regression (1982-2013) ethanol was significant at the 95% confidence level, which showed that it impacted corn price although it did not show up as significant from 2005-2013. We did not expect ethanol to be significant in the first time period (1982-2004) because the volume of ethanol was not high enough. We hypothesize that ethanol was not significant in 2005-2013 because there were other significant events occurring at the same time that were influencing the corn market. These events included the 2008 financial crisis and the 2012-2013 droughts.

Capehart and Vasada's (2012) findings were consistent with our findings they said that one of the most influential factors was export consumption and in our research we found that the US Dollar Weight Index was the most significant factor, which is inline with US corn exports. Capehart and Vasada (2012) also stated that ethanol had a significant impact in corn price but that it could not alone explain the

19

corn price increase in 2007 and 2008. Our research showed us that in the combined regression it was important but when we focused on the 2005 to 2013 period when ethanol was expected to be influential, ethanol was not significant in the regression on corn prices.

The second time period we used for the second regression (2005-2013) is a new time period so the historical data is not always as useful so we now have to research and fully understand all of the factors impacting corn price. This paper only focuses on a few of the fundamental factors that drive corn prices. As of now, we do not have enough data to know exactly what the trend looks like and which factors affect corn price more than others. There have been many articles written on the potential factors that will affect corn price during this new time period. One influential factor is ethanol and the Renewable Fuels Standards mandate how many billions of gallons will be used for ethanol production. The EPA just recently announced their preliminary decision for 2014, which was very controversial due to the idea to lower the renewable mandate, form 14.4 billion gallons to 13 billion gallons (Irwin and Good, 2013). Ethanol policy directly impacts corn price so the EPA holds a lot of power when deciding the mandates and updating them. According to an article from February 2014 there is an increase in corn being demanded for ethanol exports (Irwin and Good, 2014). Due to gasoline prices in relation to ethanol prices will make ethanol more attractive to consumers globally (Irwin and Good, 2014). Since US ethanol is competitively priced in the world market it has caused an increase in demand for US ethanol for exports (Irwin and Good, 2014).

Future Research

20

If I had more time to conduct research I would re-run the regressions using dummy variables during the time periods where significant events could have affected corn price that would alter the results. These significant events would include the 2012-2014 drought and the 2008 economic financial crisis. I could also revisit this research in 10 years so that I would have more data and a longer time period for my second regression. For example, I could run is from 2004 to 2024.

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22

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