IMPLICATIONS OF A RENEWABLE FUELS STANDARD

by

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ABSTRACT

During the past 10 years, ethanol production in the United States has grown exponentially. From 2000 to 2009 U.S. ethanol production increased from 1.6 billion gallons annually to 10.8 billion gallons annually. In 2010, U.S ethanol production increased by 23 percent from 2009 to 13.23 billion gallons. The increase in ethanol production was due to lawmakers reacting to skyrocketing oil prices by implementing a Renewable Fuels Standard (RFS) in 2005 and expanding the RFS in 2007. The RFS requires the use of specified amounts of biofuels, such as ethanol, through the year 2022. The creation of the RFS represented a step beyond lawmakers' usual policy of using the tax code to promote ethanol production. There is a long history of encouraging ethanol production by using the tax code, but the implementation of a biofuels mandate is new and therefore there is not a great deal of research on the effects of such a policy.

This study analyzes U.S. oil, unleaded gasoline, corn and ethanol prices dating back to 1985 to determine the impact that the RFS has had on corn prices. The key question answered is whether the creation and expansion of the RFS has brought the instability of the oil market into the corn market. The prices that an ethanol plant in western Kansas paid for the grain it used to produce ethanol and the price that the plant received for the ethanol that it produced are also analyzed. The plant began operation in January 2004, so it is possible to analyze the grain and ethanol prices both before and after the implementation and expansion of the RFS.

To study the impact of the RFS creation and expansion, the prices were analyzed to see if there was an increase in the correlation after the creation and expansion of the RFS. Regression analysis of the national corn prices and the prices that Western Plains Energy

paid for the grain that it used to produce ethanol; and regression analysis of the national price of ethanol and the price that Western Plains Energy sold its ethanol for were also used to study the impact of the RFS. Finally, the vector autoregression (VAR) model is used to analyze the dynamic relationships between the variables in the system: corn price, oil price, ethanol price and unleaded gasoline price.

The analysis of the correlation reveals that both at the national and plant level grain and oil prices track much more closely together after the creation and then expansion of the RFS. The VAR reveals that there is some relationship between corn and oil prices contemporaneously. The correlation matrix of residuals reveals that there is not a strong correlation between national corn and oil prices. The results suggest the need for greater research in this area. The creation and expansion of the RFS represented a step into uncharted territory and the consequences are still not known.

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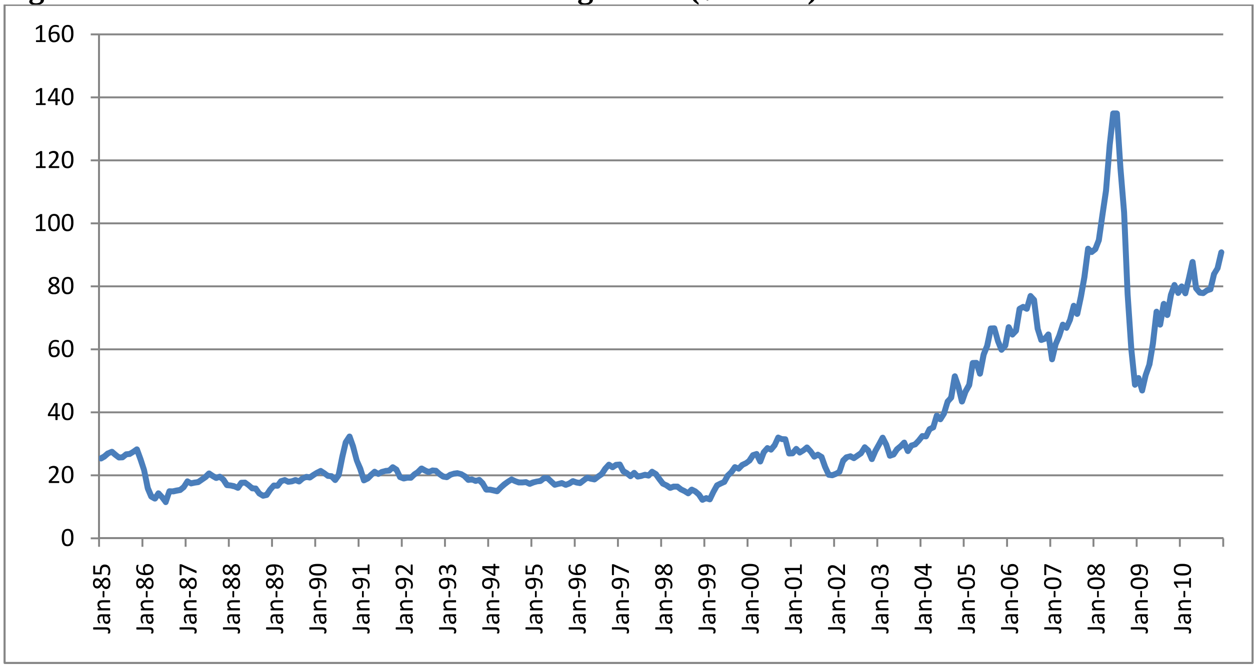
CHAPTER I: INTRODUCTION

Since the 1970s, the U.S. government has supported the growth and development of the ethanol industry. The development of a robust ethanol industry has been seen by supporters as both a way for the U.S. to reduce its dependence on foreign oil and as a way to help the economies in rural communities. Relatively high oil prices of more than $60 per barrel led Congress in 2005 to step beyond its usual policy of using the tax code to promote ethanol production and pass legislation mandating the use of renewable fuels, including ethanol. As oil prices climbed from $60 per barrel to $90 per barrel during 2007, Congress raised the mandate level and extended its length by 10 years. Congress passed the Energy Policy Act of 2005 on July 29, 2005 and President Bush signed it into law on August 8, 2005. The monthly average oil price for July 2005 was $61.07 per barrel and the monthly average for August 2005 was $66.62 per barrel. During July of 2004, oil prices averaged $39.60 per barrel and in July of 2003 they had averaged $29.29 per barrel. Congress passed the Energy Independence and Security Act of 2007 on December 18, 2007 and President Bush signed it into law on December 19, 2007. The average price of oil for the month of December 2007 was $90.92 per barrel. The average price for October 2007 was $82.99 per barrel and the average price for November of 2007 was $91.95 per barrel. Figure 1.1 shows the two oil spikes.

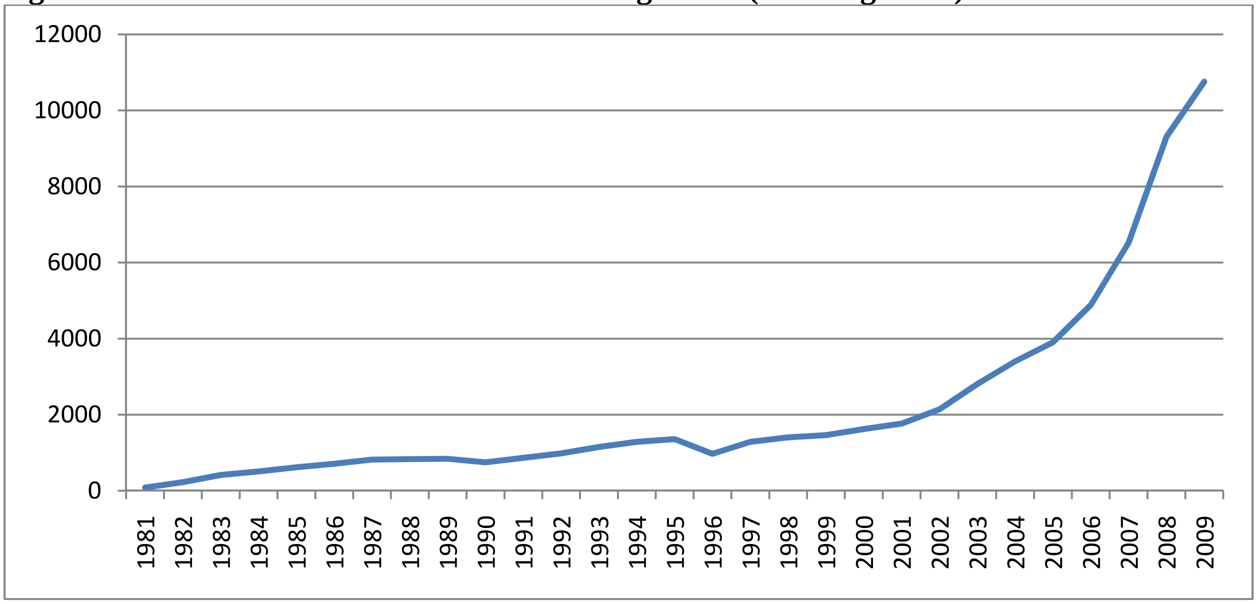
Figure 1.1: U.S. Oil Prices from 1985 through 2010 ($/barrel)



Source: U.S. Energy Information Administration

Whether or not the creation and expansion of the RFS has reduced U.S. dependence on foreign oil remains an open question. However, it is clear that the RFS has played a role in the increase in U.S. ethanol production since 2005. State laws banning the use of Methyl Tertiary Butyl Ether (MTBE) as an octane booster in fuel also played a role in the increase in ethanol production. Most of these state laws banning MTBE were in place by 2005 (Administration n.d.). Ethanol production has increased from 83 million gallons in 1981 to 10.8 billion gallons in 2009 (Figure 1.2). From 2000 to 2009, ethanol production increased from 1.6 billion gallons to 10.8 billion gallons.

Figure 1.2: U.S. Ethanol Production 1981 through 2010 (million gallons)



Source: U.S. Energy Information Administration

http://www.eia.doe.gov/aer/txt/ptb1003.html

This thesis explores the implications of the 2005 and 2007 laws that mandated increased use of ethanol fuel first through 2012 and then through 2022. The supporters of the RFS aimed to reduce U.S. dependence on foreign oil. Prices of corn, oil, ethanol, and unleaded fuel will be examined back to 1985 to examine if the demand created by the RFS has changed the inter-market relationship between corn and oil prices. Both national prices and the prices for Western Plains Energy, LLC, in Oakley, Kansas are analyzed. The price that Western Plains paid for the grain used in the ethanol process and the price received for the ethanol they produced are compared to national prices. This thesis extends the research done by Muhammad and Kebede (2009), who analyzed whether the development of an "agro-energy" sector has brought instability from the energy commodity markets into the agriculture commodity markets, by quantifying how those markets have changed. The economic relationship between oil, ethanol, unleaded gasoline, and corn prices was evaluated. Specifically the degree of correlation was evaluated. Regression analysis and vector autoregression analysis was used to further evaluate the relationship between the prices.

Chapter 2 will discuss the historical development of the ethanol industry. Chapter 3 discusses related research on ethanol and related prices. Chapter 4 discusses the conceptual model and methods. Chapter 5 presents the results and Chapter 6 presents the study's conclusions.

CHAPTER II: HISTORY OF ETHANOL

Ethanol is a clear, colorless chemical compound made from the sugars found in crops such as corn, sugar beets, and sugar cane. It is the same alcohol that is found in alcoholic beverages. "Many of the great scientific minds of the 20th century expressed their support and interest specifically in alcohol as a high quality fuel and the general idea of opening vast new industrial markets for farm products," Radford University historian William Kovarik writes. "These include Henry Ford, Charles Kettering, Alexander Graham Bell in the US, Henry Ricardo in the United Kingdom, and others. In fact, during the early decades of the 20th century the universal assumption that alcohol in some form will be a constituent of the motor fuel of the future" (Kovarik 2001, p. 2). In 1896, Henry Ford built his first automobile, the quadricycle, to run on pure ethanol. When the federal liquor tax was repealed in 1906, Ford declared that ethanol was "the fuel of the future" (Hess 2010). Ford designed his Model T to run on a mixture of gasoline and ethanol.

Excluding World War II, the demand for ethanol as a fuel or an octane booster decreased from the 1920s to the 1970s. The petroleum industry grew and lead, rather than ethanol, was used as the main octane booster. "The modern rationale that ethanol could be used to replace lead as an octane booster was more problematic in the 1920s and 1930s, as the US government certified that there was no health hazard and the US Surgeon General actively promoted leaded gasoline to the health ministers of other nations during the 1920s and 1930s" (Kovarik 2001, p. 4).

2.1 The 1970s and Government Involvement in Ethanol

The early 1970s oil crisis, during which Middle Eastern countries refused to sell oil to the United States, renewed American interest in ethanol as a fuel. For the past 30 years, ethanol has been produced as a fuel in the United States. Corn starch has been the feedstock for the majority of ethanol produced in the U.S. The Energy Policy Act of 1978 provided a 40 cent subsidy for the ethanol industry. Between 1978 and today, the subsidy for blending ethanol into gasoline has ranged from 40 to 60 cents per gallon. Tax legislation signed into law in late December 2010 extended the subsidy for one year at 45 cents. The 1978 law aided ethanol producers by providing a partial excise-tax exemption for blended fuel. The current law provides a tax credit for the entity that blends ethanol with gasoline. Current law also imposes a tariff of 54 cents per gallon on imported ethanol. The tariff was also extended until December 31, 2011 in tax legislation enacted in December 2010.

In the Energy Policy Act of 2005, Congress created a Renewable Fuels Standard (RFS) that mandates the use of renewable fuels such as ethanol. The 2005 law that President George Bush signed into law on August 8, 2005, set an RFS of 4 billion gallons in 2006 increasing to 7.5 billion gallons in 2012. The Energy Independence and Security Act of 2007, that was signed into law on December 19, 2007, expanded the RFS, requiring the use of 36 billion gallons of renewable fuels by 2022. Table 2.1 reports the ethanol provisions that have been enacted since 1978, while Table 2.2 provides details of the 2007 RFS.

Table 2.1: History of ethanol subsidy legislation

Year	Legislation	Description
1978	Energy Tax Act of 1978	$0.40 per gallon of ethanol tax exemption on the $0.04 gasoline excise tax.
1980	Crude Oil Windfall Profit Tax Act and the Energy Security Act	Promoted energy conservation and domestic fuel development.
1982	Surface Transportation Assistance Act	Increased tax exemption to $0.50 per gallon of ethanol and increased the gasoline excise tax to $0.09 per gallon.
1984	Tax Reform Act	Increased tax exemption to $0.06 per gallon.
1988	Alternative Motor Fuels Act	Created research and development programs and provided fuel economy credits to automakers.
1990	Omnibus Budget Reconciliation Act	Ethanol tax incentive extended to 2000 but decreased to $0.54 per gallon of ethanol.
1990	Clean Air Act amendments	Acknowledged contribution of motor fuels to air pollution–oxygen requirements for motor fuels.
1992	Energy Policy Act Tax	Tax deductions allowed on vehicles that could run on E85.
1998	Transportation Efficiency Act of the 21st Century	Ethanol subsidies extended through 2007 but reduced to $0.51 per gallon of ethanol by 2005.
2004	Jobs Creation Act	Changed the mechanism of the ethanol subsidy to a blender tax credit (VEETC) instead of the previous excise tax exemption. Also extended the ethanol tax exemption to 2010.
2005	Energy Policy Act	Established the renewable fuel standard starting at 4 billion gallons in 2006 and rising to 7.5 billion in 2012. Eliminated the oxygen requirement for gasoline, but failed to provide MTBE legal immunity.
2007	Energy Independence and Security Act of 2007	Established a renewable fuel standard totaling 36 billion gallons (1 billion biodiesel) by 2022
2008	Food Conservation and Energy Act of 2008	Blender tax credit extended through 2010 but reduced to $0.45 per gallon. Extended the $0.54 per gallon tariff through 2010.
2010	Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010	Blender tax credit extended through 2011 at $0.45 per gallon. Extended the $0.54 per gallon ethanol tariff through 2011.

(Tyner 2008) 2010 section done by Monoson

Table 2.2: Mandated Use of Renewable Fuels from the 2007 Energy Independence and Security Act

Year	Renewable Biofuel	Advanced Biofuel	Cellulosic Biofuel	Biomass-based Diesel	Undifferentiated Advanced Biofuel	Total RFS
2008	9					9
2009	10.5	.6		.5	0.1	11
2010	12	.95	.1	.65	0.2	12.95
2011	12.6	1.35	.25	.8	0.3	13.95
2012	13.2	2	.5	1	0.5	15.2
2013	13.8	2.75	1		1.75	16.55
2014	14.4	3.75	1.75		2	18.15
2015	15	5.5	3		2.5	20.5
2016	15	7.25	4.25		3	22.25
2017	15	9	5.5		3.5	24
2018	15	11	7		4	26
2019	15	13	8.5		4.5	28
2020	15	15	10.5		4.5	30
2021	15	18	13.5		4.5	33
2022	15	21	16		5	36

All numbers are billions of gallons
Source: Renewable Fuels Association (http://www.ethanolrfa.org/pages/renewable-fuels-standard)

Cellulosic Biofuel, Biomass-based Diesel, and Undifferentiated Advanced Biofuel are all subsets of the Renewable and Advanced Biofuel categories in Table 2.2. Ethanol produced from corn starch ethanol qualifies as a Renewable Biofuel in the 2007 law, but is prohibited from qualifying as an Advanced Biofuel. Unless this is changed in future legislation, this prohibition may limit the future impact of the RFS on corn prices. The law requires Advanced Biofuels to produce 60 percent less carbon dioxide than petroleum, but prohibits ethanol produced from corn starch from qualifying as an Advanced Biofuel even if it produces 60 percent less carbon dioxide than petroleum.

A discussion of government involvement in the ethanol industry and the production increases that started in 2006 would be incomplete without a mention of the bans on Methyl Tertiary Butyl Ether (MTBE). Fuel companies have added oxygenates, or oxygen enhancers to fuel since the 1930s to prevent engine "knocking." Engine knocking in an internal combustion engine occurs when a pocket of air and fuel ignites at a time after the initial spark plug ignition. The fuel air charge is meant to be ignited by the spark plug only, and at a precise time in the engine piston's stroke cycle. Engine knocking is both bad for the functioning of the engine and bad for the environment. One of the causes of engine knocking is a fuel mixture that does not contain enough oxygen.

As mentioned earlier, up until the 1970s, lead was the oxygenate of choice in motor fuel. After the use of lead in fuel was banned for health reasons, MTBE, made primarily from natural gas or petroleum, was used as an oxygen enhancer in fuel in low levels starting in the 1970s. As Table 2.1 shows, the 1990 Clean Air Act Amendments included oxygenate requirements. These oxygenate requirements were imposed because oxygen helps gasoline burn cleaner reducing harmful tailpipe emissions. "After MTBE was proven to be a carcinogenic groundwater pollutant, many states banned MTBE, which accelerated the use of ethanol as the only economically feasible fuel additive for states with air quality problems. The Energy Policy Act of 2005 further accelerated the demise of MTBE in that gasoline marketers were no longer required to use an oxygenate, but they also did not receive the MTBE liability protection that they had petitioned for. This put refiners at a liability risk if they continued to use MTBE after an oxygenate was no longer required by law. Predictably, the demand for ethanol increased at unprecedented rates as most refiners replaced MTBE with ethanol" (Texas State Energy Conservation Office n.d.).

2.2 Western Plains Energy, LLC

Western Plains Energy is a Kansas limited liability company that was formed on July 10, 2001 to build and operate a 30 million gallon ethanol production facility in Gove County, Kansas. The plant is located six miles east of Oakley, Kansas, near the town of

Campus, Kansas. Construction on the plant began on April 13, 2003, and ethanol production began in January 2004. The plant produces fuel grade ethanol, distiller's dried grains with solubles, and distiller's wet grains with solubles from corn and milo (grain sorghum) supplied by members and other local farmers. Figures 2.1 and 2.2 depict the site before and after the plant was built. Because the plant was in operation before the 2005 Energy Bill that set the initial RFS was signed into law on August 8, 2005, grain and ethanol prices can be evaluated both before and after the RFS.

In 2005, the plant's name plate capacity was increased from 30 million gallons of ethanol per year to 38 million gallons of ethanol per year. As of January 2011, the plant's name plate capacity was 48 million gallons of ethanol per year. The name plate capacity of an ethanol plant is the amount of ethanol it is designed to produce. Depending on economic conditions, ethanol plants can produce a few million gallons below or above the name plate capacity. Within limits, an existing plant can be modified to increase the amount of ethanol that it is designed to produce.

Figure 2.1: Photograph of site before plant was built

Figure 2.2: Photograph of site after plant was built

CHAPTER III: LITERATURE REVIEW

There is significant research on the relationship between corn, ethanol, and oil prices. The analysis can be broken down into research completed before passage of the Energy Policy Act of 2005 that created the renewable fuels standard, those completed after passage of the law but before the oil spikes of 2008, and those completed after the oil spike of 2008. The pre-2005 energy law analysis, such as McNew and Griffith (2005), find a relationship between corn and ethanol prices and find that ethanol plants increase local corn prices. The analysis done after the creation of the renewable fuels standard, but before the oil price spike of 2008, find a relationship between corn and oil prices. The analysis completed after the oil spike, finds that there is a strong relationship between corn, ethanol, and oil prices, with one group of economists finding that "agro-energy" has brought instability from the energy commodity markets into the agriculture commodity markets. Several economists find that the Energy Policy Act of 2005 linked the corn, oil, and ethanol markets.

McNew and Griffith (2005) analyzed the impact that 12 ethanol plants opened in 2001 and 2002 had on local grain prices. They found that on average, corn prices increased by 12.5 cents per bushel at the plant site, and some positive price response was found as far as 68 miles away from the plant. They note that "positive price impacts on corn prices may actually be a detriment to the profitability of an ethanol plant. Corn costs account for around 50% of the operating costs of an ethanol plant. Thus, higher corn prices will reduce the profitability of an ethanol plant" (McNew and Griffith 2005, p. 176).

Elobeid, et al. (2006) estimate the long-run potential for ethanol production by calculating the corn price at which the incentive to expand ethanol production disappears.

They determined that if ethanol tax policy and the prices of crude oil, natural gas and distillers grains stayed at 2006 levels, the corn price at which the incentive to expand ethanol production disappears is $4.05 per bushel. They project that with corn at $4.05 per bushel, ethanol production would reach 31.5 billion gallons per year or 20% of the projected vehicle feul market in 2015. “These results should not be viewed as a prediction of what will eventually materialize,” they write. “Rather, they indicate a logical end point to the current incentives to invest in corn-based ethanol plants” (Elobeid, et al. 2006, p. 2). They use the market price of crude oil to find the market price of unleaded gasoline. They then find the market price that causes flex fuel vehicle owners to switch from unleaded gasoline to E85. They use the long-run ethanol price to calculate the corn price that ethanol facilities can pay while still covering all their costs. Their analysis was based on the assumption that crude oil prices would stay at $60 per barrel, which translates into a wholesale gasoline price of $2.07 per gallon. Their sensitivity analysis found that the results are most sensitive to changes in the price of crude oil and the tax credit for ethanol blenders.

Eidman (2007) analyzes the operating cost of ethanol plants based on alternative prices for crude oil. He determines that the Volumetric Excise Ethanol Tax Credit and Small Producer Income Tax Credit are important for the ethanol industry if oil is below $50 per barrel (Eidman August 2007).

Taheripour and Tyner (2007) “develop stylized analytical general and partial equilibrium models in the context of the theory of tax incidence to investigate distributional impacts of these (ethanol) subsidies” (Taheripour and Tyner 2007). They develop a model to determine who in the ethanol supply and distribution chain receives the benefit of the ethanol subsidy. They found that the ethanol industry passes a portion of the ethanol subsidy to the corn producer. The amount that the corn producer receives increases as the size of the ethanol industry increases.

Tyner (2008) argues that the ethanol boom in the mid-2000s was due to a fixed ethanol subsidy that was based on $20 per barrel oil combined with a spike in oil prices. He concludes that the ethanol boom of 2006 and 2007 was driven by ethanol policy and high oil prices. He also concluded that ethanol production is likely to peak at 15 billion gallons per year because of higher corn prices will "choke off further growth in the industry" (Tyner 2008, p. 653).

Serra, et al. (2008) use a smooth vector error correction model to assess price relationships within the U.S. ethanol industry. They looked at daily prices from mid-2005 to mid-2007 and found that there is an equilibrium relationship between corn, oil, and ethanol prices. They cite increasing crude oil prices and worldwide climate change and energy security-related policies as the cause of the increase in ethanol production. They model U.S. corn, ethanol, and oil prices using the "the smooth transition vector error correction models (STVECM) that allow for long-run relationships among the variables of the model, as well as for nonlinear adjustments towards long-run equilibrium" (Serra, et al. 2008, p. 4). They concluded that there is a long run relationship between corn, ethanol, and oil prices.

Tokgoz, et al. (2008) projected U.S. ethanol production and its impact on planted acreage, crop prices, livestock production, trade, and retail food costs. Their results indicate that increases in ethanol production cause long-run crop prices to increase. They also found that if crude oil prices increase, the U.S. ethanol industry expands. Tokgoz, et al. (2008) assert that the development of the ethanol industry has increased the agriculture sector's susceptibility to volatility in energy markets. They note that while in the past, higher energy prices had an impact on the agriculture sector's cost of production, with the development of the ethanol industry, higher energy prices have a direct impact on agriculture. They analyze a scenario where there are higher crude oil prices but with constrained demand for ethanol due to a lack of ethanol infrastructure and find that even with the constrained demand for ethanol, higher oil prices raise the net returns to ethanol producers and promote growth in the ethanol industry. They write, "Our results indicate that this size of a crude oil price shock would greatly increase ethanol production and corn prices even with an ethanol demand bottleneck" (Tokgoz, et al. 2008, p. 621). Corn prices under the scenario are 20% higher than baseline levels, increasing feed costs and leading to a reduction in meat production of 1% to 2%. They also analyze a short-crop scenario that mimics the 1988 drought. In this scenario, they assume that there is an ethanol mandate in place that sets a lower boundary on how much ethanol must be produced. In the study, they also account for the impact that the production of dried distiller grains has on commodity markets. They found that both ethanol and use of corn for feed are reduced from baseline levels. In this scenario, the renewable fuels mandate prevents ethanol production from dropping substantially.

Muhammad and Kebede (2009) analyze whether the development of an "agro-energy" sector has brought instability from the energy commodity markets into the agriculture commodity markets. Unlike Tyner (2008), and Serra et al (2008), they say government policy, rather than high oil prices are responsible for the rise in corn prices. They graph the monthly oil and corn prices both before and after the 2005 Energy Policy

Act that created a renewable fuels standard. They argue “prior to 2005, there was little relationship between oil and corn prices. Empirical research shows that from 1990 through 2004, the relationship between oil and corn prices was statistically weak and that less than 2% of the change in corn prices could be explained by oil price movements” (Muhammad and Kebede 2009, p. 13). They speculate that corn and ethanol prices did not follow corn prices down in 2009 because the Renewable Fuels Standard had set a floor under corn and ethanol prices.

Harri, Nalley, and Hudson (2009) analyze the link between oil prices and agricultural commodities. They use the Johansen model to examine the relationship among exchange rates, crude oil prices, and agricultural crop prices. With most commodities they found that oil impacts the input markets, but with corn they found that oil impacts the output market. They find “clear evidence” of the link between corn and oil prices and they trace that link back to the implementation of the Renewable Fuels Standard in the Energy Policy Act of 2005.

These works provide a view of the changes that have taken place in the ethanol industry since 2000. They reveal the impact that both implementation of the Renewable Fuels Standard and volatility in commodity markets have had on the corn, ethanol, and oil industry. Many of the economists note that by passing an energy law in 2005 that imposed a Renewable Fuels Standard, lawmakers yoked the corn, ethanol, and oil prices together.

CHAPTER IV: METHODS

In the economic model, the monthly average price of corn, ethanol, oil and unleaded gasoline are examined. The relationship between the national ethanol and unleaded fuel prices are analyzed as is the relationship between the national corn and oil prices. The correlation between monthly prices is determined for 1985 to 2010, for 1985 to 2000, for 2000 to 2005, and for 2006 to 2010. The prices are compared for the 1985 to 2010 period to establish what the long-term relationship has been. The prices between 2000 and 2005 and between 2006 and 2010 are compared to determine the impact that the enactment of the RFS has had on oil, ethanol, unleaded gasoline, and corn prices.

In the economic model, the monthly average price that Western Plains Energy paid for grain for producing ethanol and the monthly average price that Western Plains Energy received for the ethanol it produced are analyzed. The correlation between the prices is determined from January 2004 when Western Plains Energy began producing ethanol through December 2010. The correlation between the prices the plant paid for grain and the national oil price are analyzed from January 2004 through December 2010; from January 2004 through July 2005; from August 2005 through December 2010; and from January 2008 through December 2010. The correlation between the prices the plant received for the ethanol it produced and the national price of unleaded gasoline are determined for the same five time periods.

In looking at the correlation between corn and oil prices, the hypothesis tested is whether after the RFS was enacted, the prices moved more closely. If the price of corn moves up when the price of oil moves down or if the price corn moves down when the price of oil moves up, then the correlation coefficient between the prices of the two commodities would approach -1. If the correlation coefficient is -1 that would mean that the opposite proportional movement between the prices of the two commodities was perfect. If the price of corn moved proportionally up when the price of oil moved up or if the price of corn moved down when the price of oil moved down, then the correlation coefficient between the prices of the two commodities would approach 1. If the correlation coefficient is 1, that would mean the proportional movement between the prices of the two commodities is perfect. If the correlation coefficient between the two prices is 0, then the prices are independent.

-1 = Prices of corn and oil move perfectly in opposite directions.

0 = the prices of corn and oil move independently of each other

1 = Prices of corn and oil move perfectly in the same direction.

The economic model also included regression analysis of the national corn prices and the prices that Western Plains Energy paid for the grain that it used to produce ethanol; and regression analysis of the national price of ethanol and the price that Western Plains Energy sold its ethanol for. This analysis examines how closely a firm's price for inputs and outputs matches the national market.

Finally, the vector autoregression (VAR) model is used to analyze the dynamic relationships between the variables in the system: corn price, oil prices, ethanol prices, and unleaded gasoline prices. All the variables in VAR model are treated symmetrically by including for each variable an equation explaining its evolution based on its own lags and lags of all other variables in the model. Using the VAR reveals how an exogenous shift in the system will trace out in other variables. With the VAR system, each of the prices is allowed to influence the other prices with lags. The number of lags in the system must be analyzed to determine what number of lags is best for predicting future prices. A three lagged model is the best for predicting future prices of oil, unleaded gasoline, corn, and oil based on the Hannan Quinn method. One to 12 lags were tested in the model and it was determined that a three lagged model is best for predicting future prices for oil, unleaded gasoline, ethanol, and corn.

<u>Oil Price Equation</u>:

Oil Prices = f(lagged oil, unleaded gasoline, corn, and ethanol prices, constant, trend) (1)

<u>Unleaded Gasoline Price Equation</u>:

Unleaded Gasoline Price = f(lagged oil, unleaded gasoline, corn, and ethanol prices, constant, trend) (2)

<u>Ethanol Price Equation</u>:

Ethanol Price = f(lagged oil, unleaded gasoline, corn, and ethanol prices, constant, trend) (3)

<u>Corn Price Equation</u>:

Corn Price= f(lagged oil, unleaded gasoline, corn, and ethanol prices, constant, trend) (4)

The best way to evaluate a vector autoregression model is to analyze the response of the system to typical random shocks, which are referred to as impulse response functions. “These ‘typical shocks’ are positive residuals of a one standard deviation unit in each equation. The residuals from the estimated equation are often referred to as innovations” (Featherstone and Baker 1987, p. 537). “The response of the system to the innovations in variable is the best way to examine the magnitude and direction of the dynamic relationships in the model” (Featherstone and Baker 1987, p. 539).

Variance decomposition indicates how much information each variable contributes to the other variables in a vector autoregression model. By determining how much each of the variables contributes to each of the other variables, it is possible to also determine the impact of exogenous shocks.

CHAPTER V: ANALYSIS

Average national monthly oil, corn, ethanol, and unleaded gasoline prices from January 1985 to December 2010 are analyzed first. The prices are examined to see what, if any, degree of correlation there is between the prices of the commodities. The prices are examined for the overall 25 year period and during specific sub-time periods to determine if there has been a change in the relationship between the prices

The average monthly prices that Western Plains Energy paid for grain used to produce ethanol and for ethanol from when it began operating in January 2004 to December 2010 are compared to the national monthly prices. The prices are examined to see what, if any, degree of correlation exists for the full six year period and during specific sub-time periods to determine if there has been a change in the relationship between the prices.

Regression analysis is used to examine the relationship between the prices that Western Plains Energy paid for the grain that it used to produce ethanol and on the price that it received for the ethanol that it produced. The price that Western Plains Energy paid for the grain and received for the ethanol are the dependent variables, while the national corn and ethanol prices are the independent variables. The regression analysis is done to determine the impact that the national prices have on the Western Plains Energy prices.

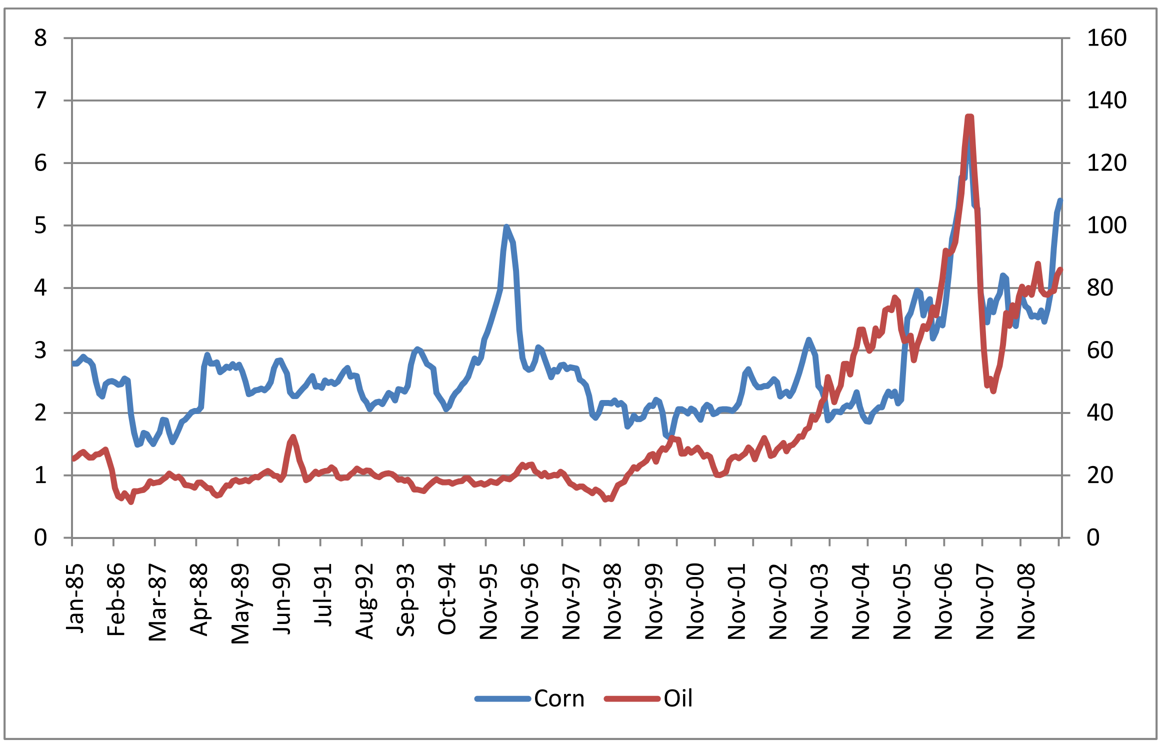
Finally, a vector autoregression (VAR) model is used to analyze the dynamic relationships between the variables in the system: corn price, oil prices, ethanol prices and unleaded gasoline prices. All the variables in a VAR model are treated symmetrically by including for each variable an equation explaining its evolution based on its own lags and lags of all other variables in the model. Using the VAR reveals how an exogenous innovation in the system will trace out in other variables.

Correlations

5.1 Monthly Average Corn and Oil Prices from 1985 to 2010

Figure 5.1 depicts the corn and oil prices from 1985 to 2010. The correlation coefficient between corn and oil prices from 1985 to 2010 is 0.64. This correlation coefficient reveals that from 1985 to 2010 corn and oil prices have generally moved in the same direction. They have not moved together perfectly, but they have clearly moved together.

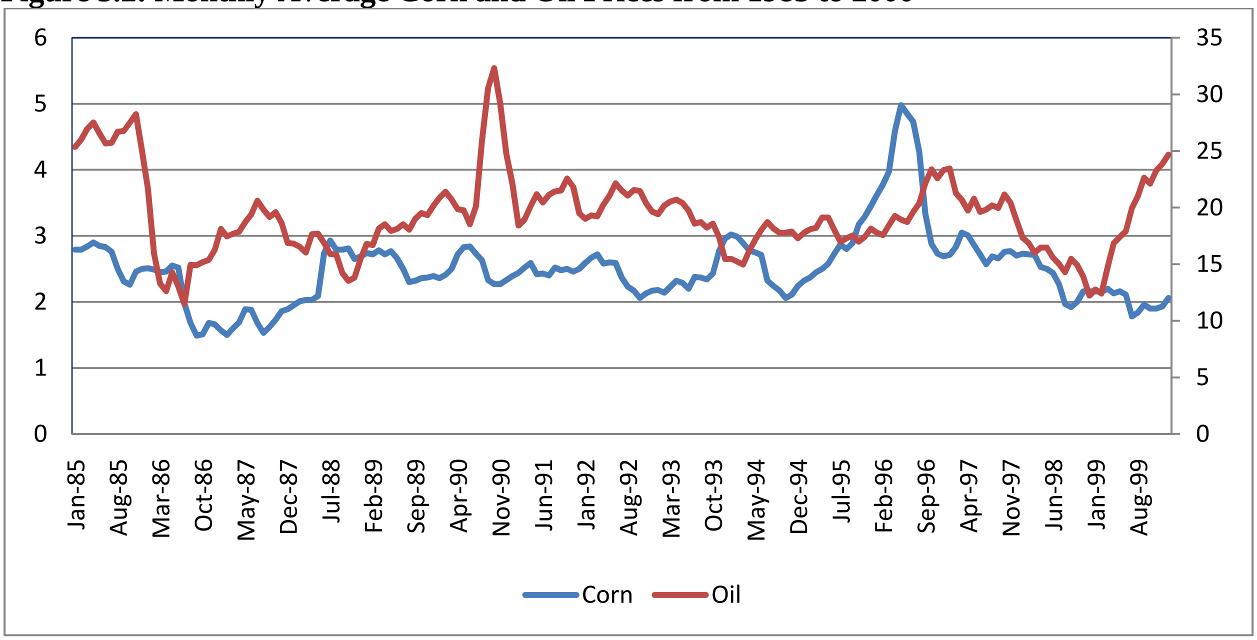
Figure 5.1: Monthly Average Corn and Oil Prices from 1985 to 2010



5.2 Monthly Average Corn and Oil Prices from 1985 to 2000

Figure 5.2 depicts corn and oil prices from 1985 to 2000. The correlation coefficient between the prices for these years is 0.06. They move in the same direction, but the relationship is not as strong as it is for the full 25 year period. In fact, the series are nearly independent.

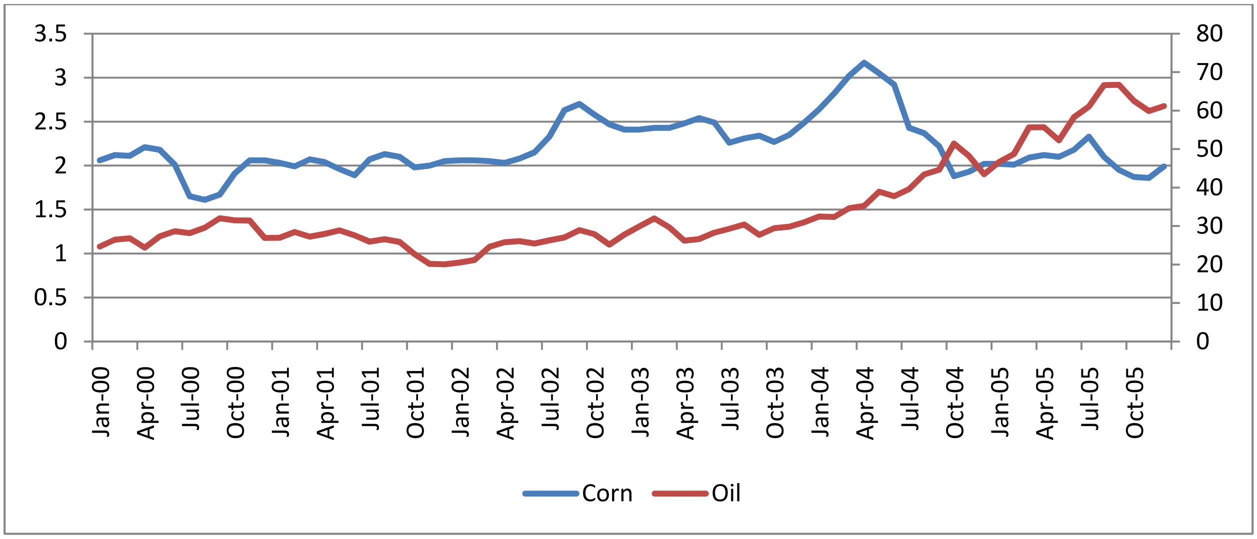
Figure 5.2: Monthly Average Corn and Oil Prices from 1985 to 2000



5.3 Monthly Average Corn and Oil Prices from 2000 to 2005

Figure 5.3 depicts the relationship between corn and oil prices from 2000 to 2005. The correlation coefficient between corn and oil prices for these years is -0.12. Even though over the full 25 year time period corn and oil prices move in the same direction, during this five year period they have a tendency to move in opposite directions.

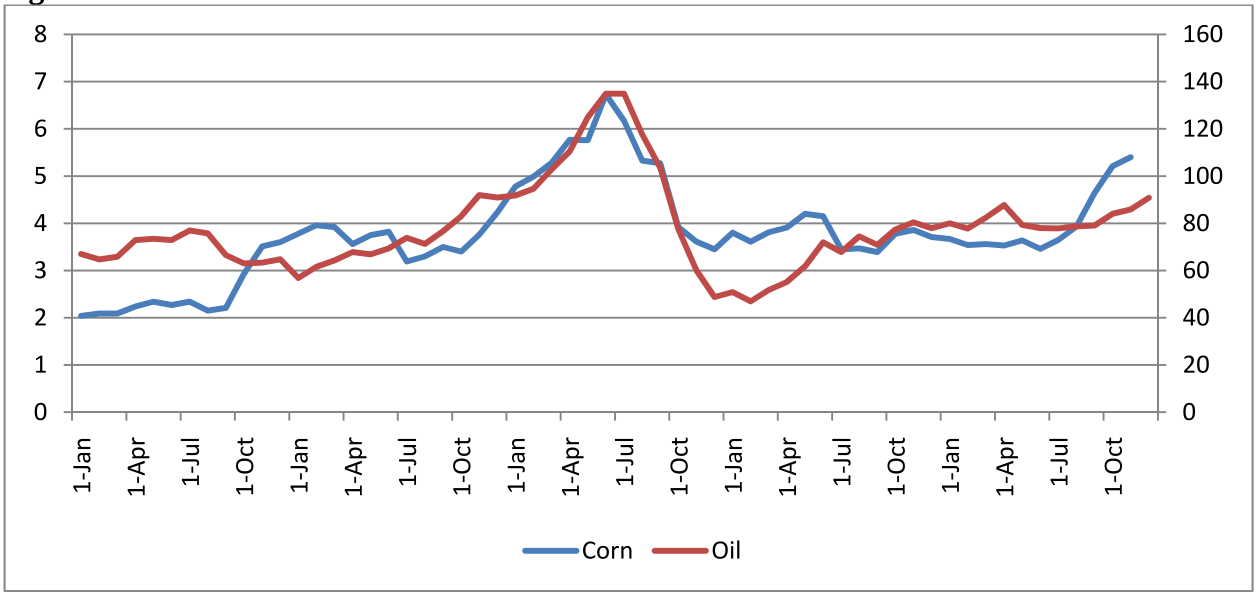
Figure 5.3: Corn and Oil Prices from 2000 to 2005



5.4 Corn and Oil Prices from 2006 to 2010

Figure 5.4 depicts corn and oil prices from 2006 to 2010. The correlation coefficient for corn and oil prices during this time period is 0.70. This correlation coefficient reveals that during this four year time period, corn and oil prices more closely moved together than they did during the 25 year period, the initial 15 year period, or the five year period before the RFS was enacted.

Figure 5.4: Corn and Oil Prices from 2006 to 2010



5.5 Overall Assessment of National Oil and Corn Prices

There is a significantly greater degree of correlation between monthly average oil and corn prices after the passage of the RFS. There is a stark difference between the five years before and after creation of the RFS. The oil and corn prices are not correlated in the five years before passage and in the five years after there is a high level of correlation.

5.6 Monthly Average Ethanol, Oil, and Unleaded Gasoline Prices from 1985 to 2010

Figure 5.5 depicts ethanol and oil prices from 1985 to 2010 and figure 5.6 depicts ethanol and unleaded gasoline prices from 1985 to 2010. The correlation coefficient between ethanol and oil prices during the 25 year period is 0.86. The correlation coefficient between ethanol and unleaded gasoline prices during the 25 year period is 0.88. This analysis reveals that during the 25 year period ethanol, oil, and unleaded gasoline prices usually move together.

Figure 5.5: Monthly Average Ethanol and Oil Prices from 1985 to 2010

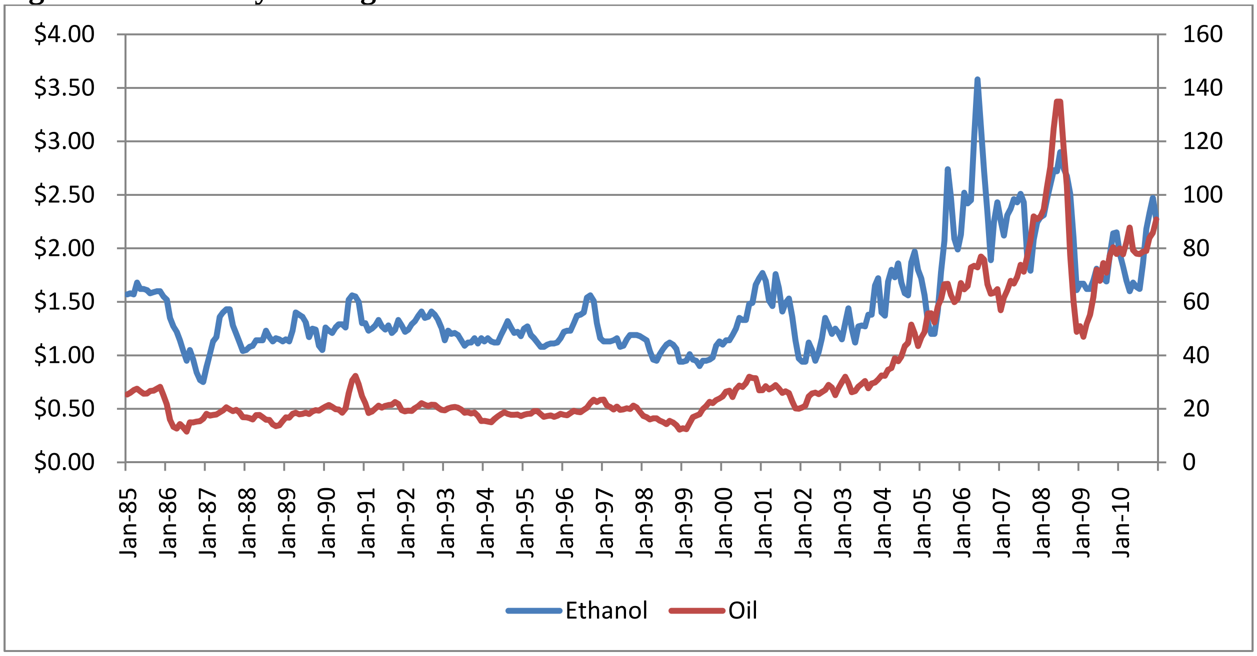
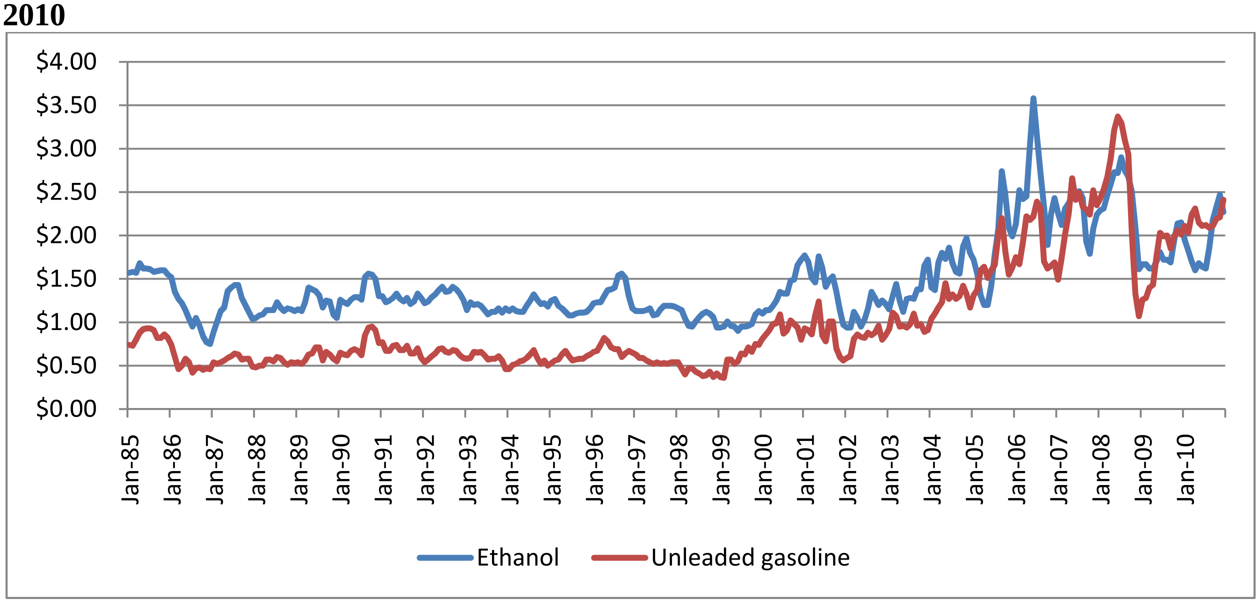


Figure 5.6: Monthly Average Ethanol and Unleaded Gasoline Prices from 1985 to 2010



5.7 Monthly Average Ethanol, Oil, and Unleaded Gasoline Price from 1985 to 2000

Figure 5.7 depicts ethanol and oil prices from 1985 to 2000 and figure 5.8 depicts ethanol and unleaded gasoline prices from 1985 to 2000. The correlation coefficient for ethanol and oil prices from 1985 to 2000 is 0.70. The correlation coefficient for ethanol and unleaded gasoline prices from 1985 to 2000 is 0.77. This analysis reveals that during this time period ethanol prices very often moved together.

Figure 5.7: Monthly Average Ethanol and Oil Prices from 1985 to 2000

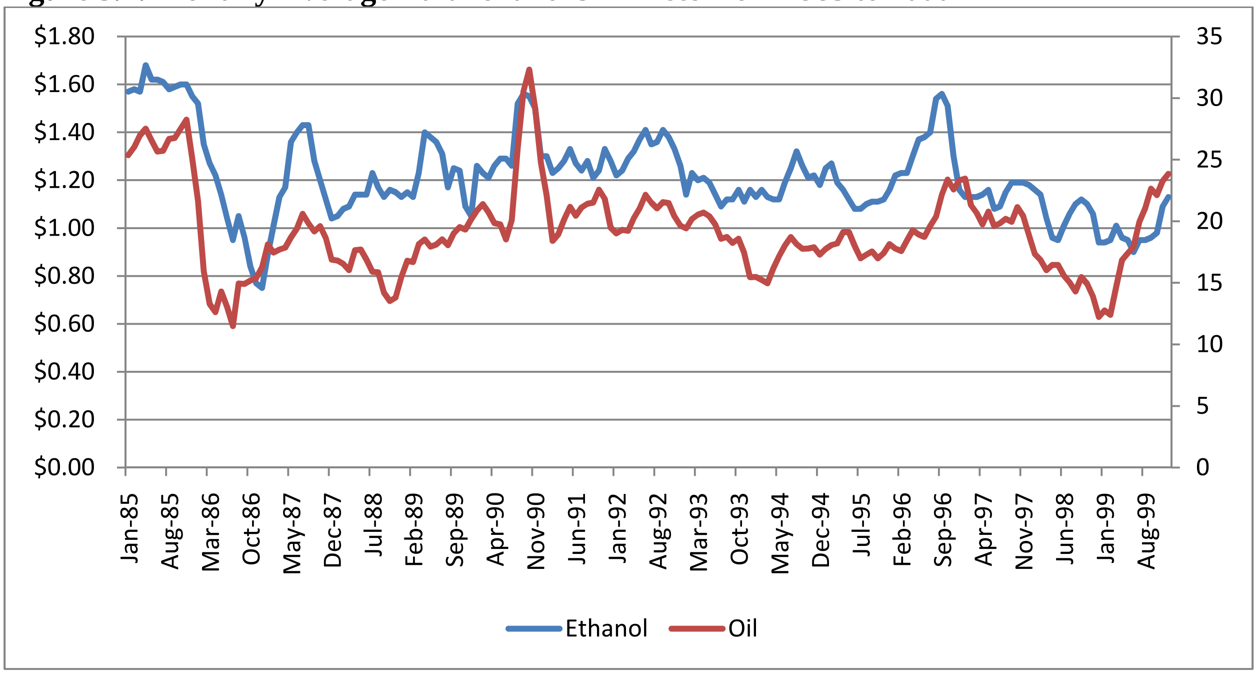
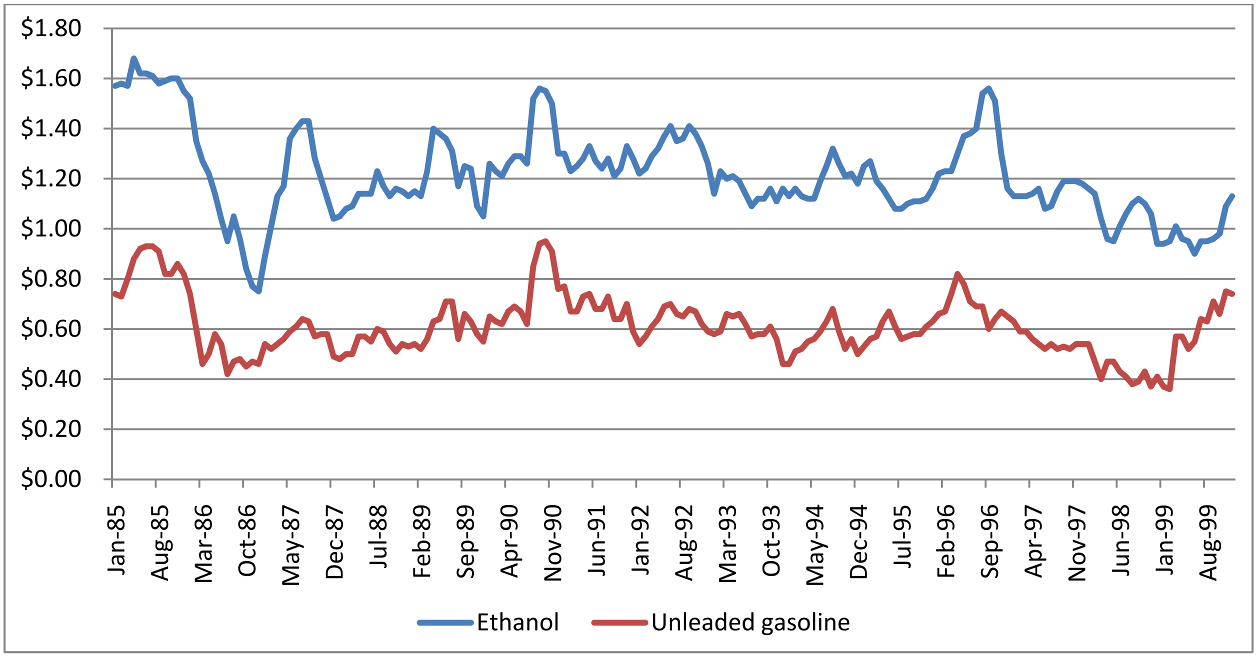


Figure 5.8: Monthly Average Ethanol and Unleaded Gasoline Prices from 1985 to 2000



5.8 Monthly Average Ethanol, Oil, and Unleaded Gasoline Prices from 2000 to 2005

Figure 5.9 depicts ethanol and oil prices from 2000 to 2005 and figure 5.10 depicts ethanol and unleaded gasoline prices from 2000 to 2005. The correlation coefficient for ethanol and oil prices from 2000 to 2005 is 0.68. The correlation coefficient for ethanol and unleaded gasoline prices from 2000 to 2005 is 0.72. The analysis reveals that ethanol prices often moved with oil and unleaded gasoline prices during the five years.

Figure 5.9: Monthly Average Ethanol and Oil Prices from 2000 to 2005

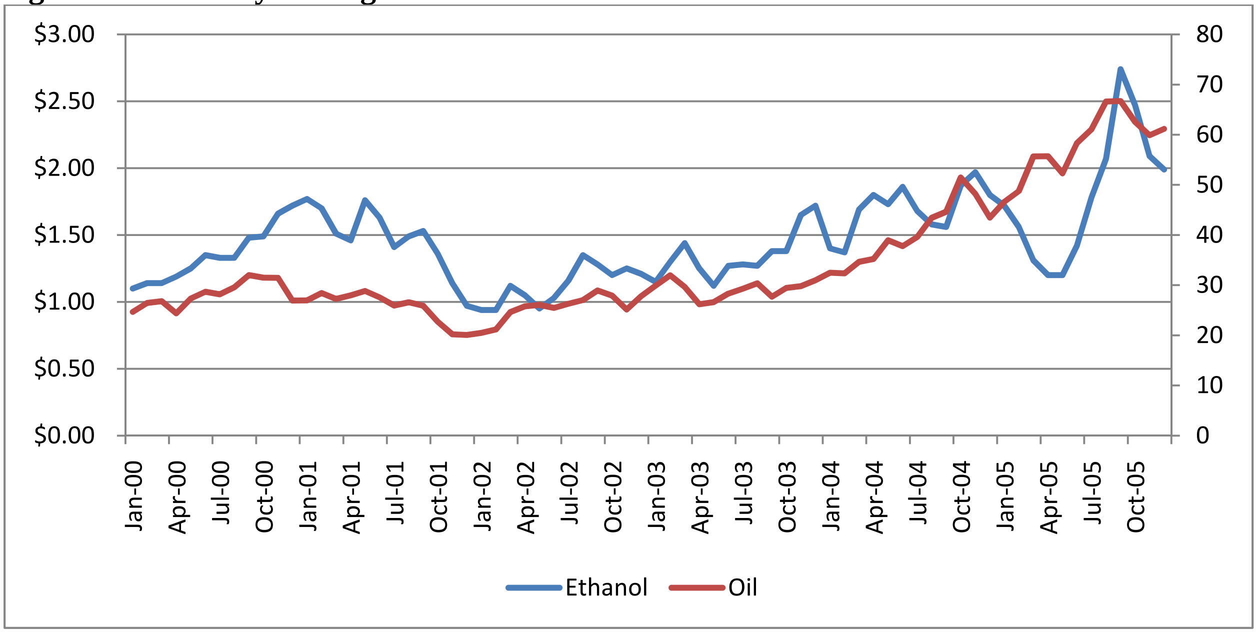
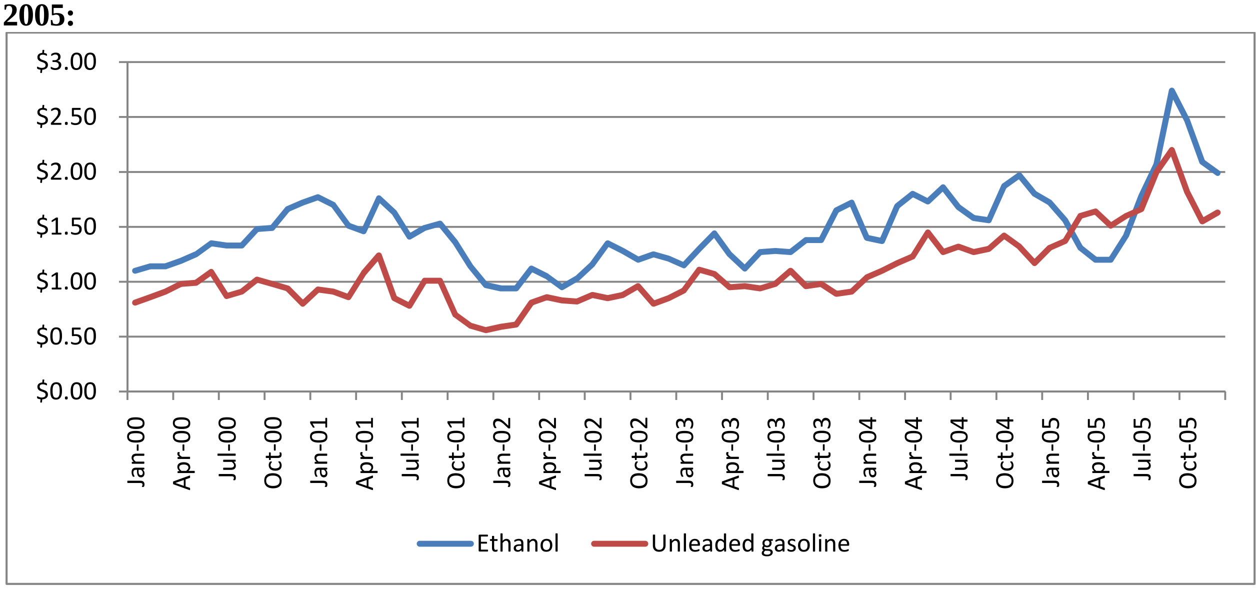


Figure 5.10: Monthly Average Ethanol and Unleaded Gasoline Prices from 2000 to 2005:



5.9 Monthly Average Ethanol, Oil, and Unleaded Gasoline Prices from 2006 to 2010

Figure 5.11 depicts ethanol and oil prices from 2006 to 2010 and figure 5.12 depicts ethanol and unleaded gasoline prices from 2006 to 2010. The correlation coefficient for ethanol and oil prices during the four year period is 0.43. The correlation coefficient for ethanol and unleaded gasoline prices during the four year period is 0.54. The analysis reveals that there has been a decrease in the correlation between ethanol and oil and between ethanol and unleaded gasoline. This decrease can be seen when you compare the correlation coefficient to the overall 25-year time period, the initial 15-year time period, and the five-year time period immediately preceding 2006 to 2010.

Figure 5.11: Monthly Average Ethanol and Oil Prices from 2006 to 2010

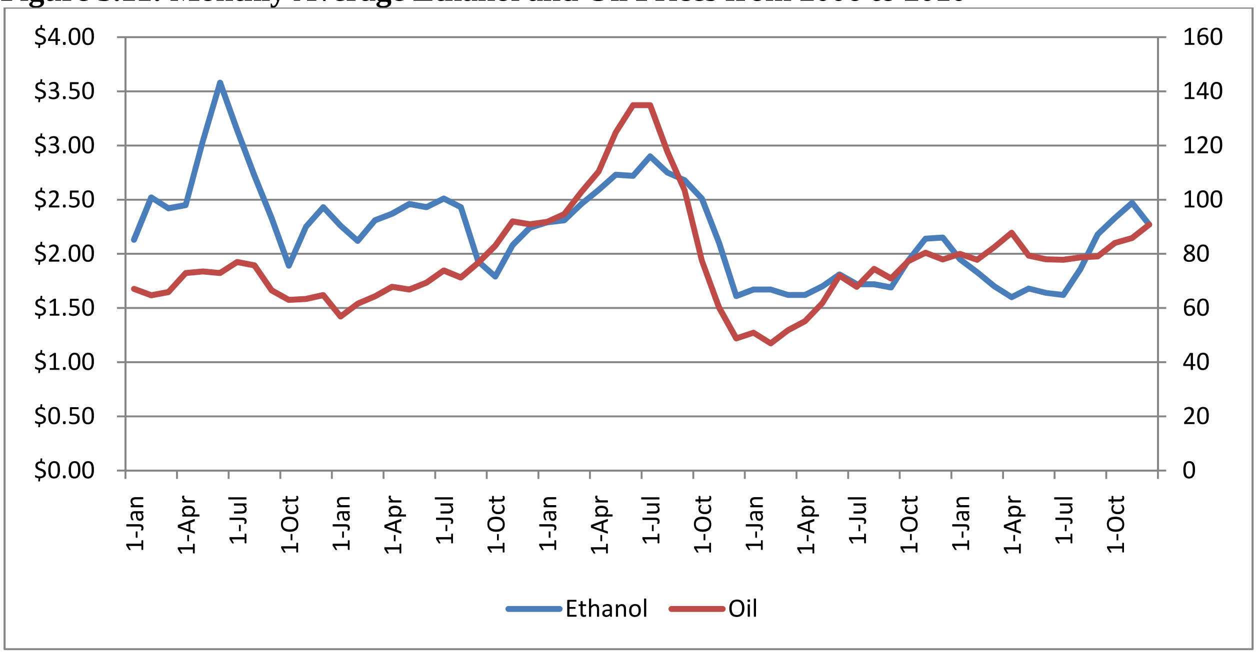
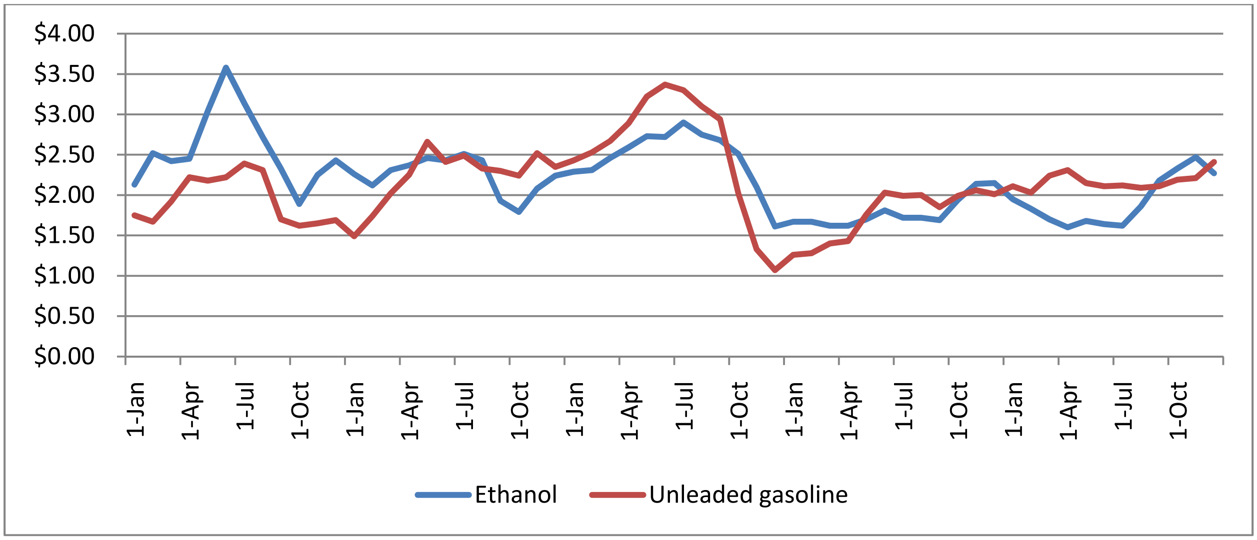


Figure 5.12: Monthly Average Ethanol and Unleaded Gasoline Prices from 2006 to 2010



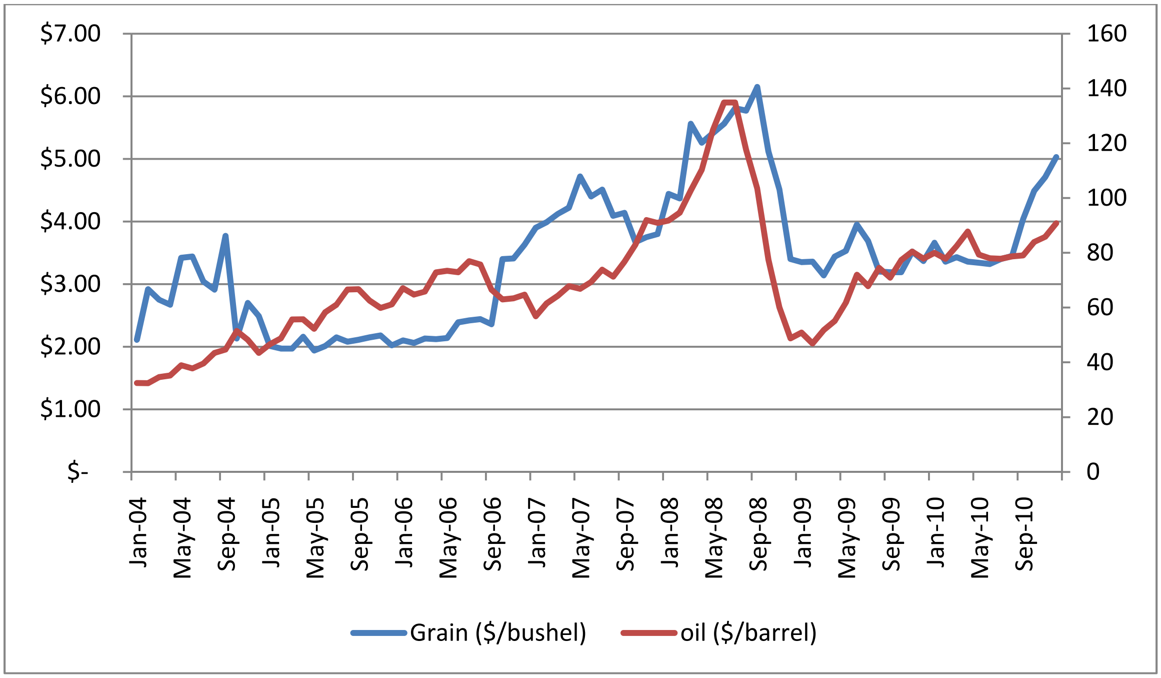
5.10 Analysis of Oil, Unleaded Gasoline, and Ethanol Correlation

There is a much higher degree of correlation over the overall 25 year period than there is in the five years after the passage of the RFS. During all of the time periods examined, the degree of correlation was the weakest during the five year period after the enactment of the RFS.

5.11 Western Plains Grain Prices and National Oil Prices from January 2004 to December 2010

Figure 5.13 depicts the average monthly price that Western Plains paid for corn and milo used to produce ethanol from January 2004 until December 2010 and the average monthly price for a barrel of oil from January 2004 until December 2010. The correlation coefficient between the two prices for these years is 0.67. This correlation coefficient reveals that there has been a strong relationship between grain prices that Western Plains paid and the price of a barrel of oil during the full six year period.

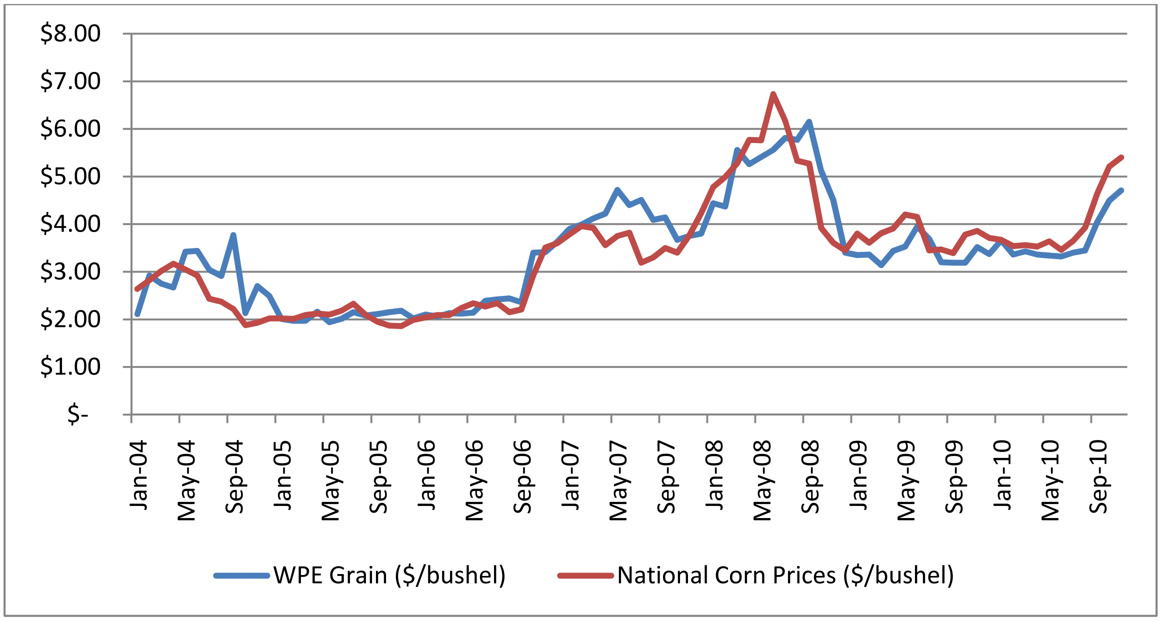
Figure 5.13: Monthly Western Plain Grain Prices and National Oil Prices from 2004 to 2010



5.12 Western Plains Grain Prices and National Corn Prices from January 2004 to December 2010

Figure 5.14 depicts the average monthly price that Western Plains paid for corn and milo used to produce ethanol from January 2004 until December 2010 and the average monthly price for a gallon of ethanol. From January 2004 until December 2010 there is a high degree of correlation between the price that Western Plains paid for grain that it used to produce ethanol and national corn prices. From 2004 to 2010 the correlation coefficient between the local grain price and the national corn price was 0.90.

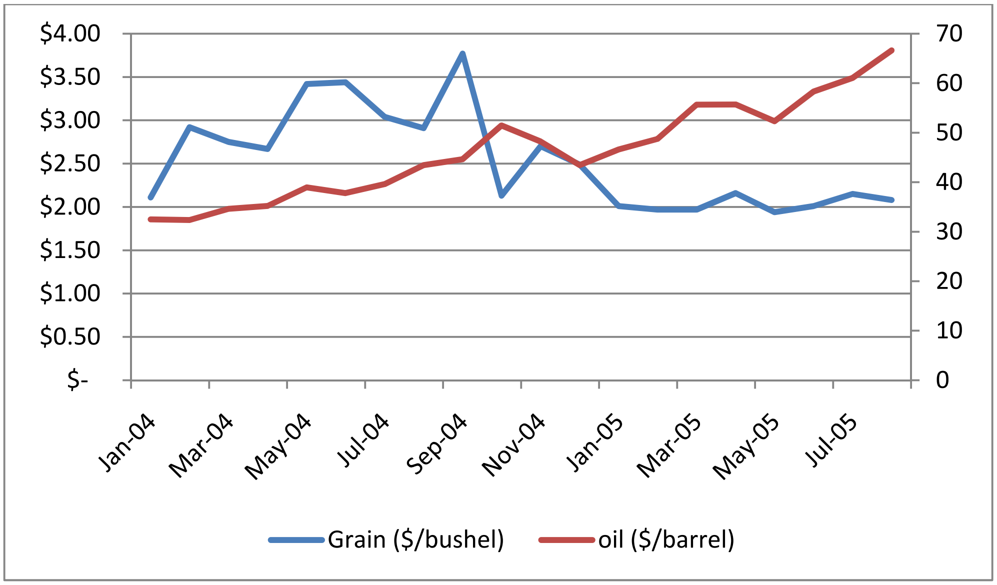
Figure 5.14: Monthly Average Western Plains Ethanol Grain Prices and National Corn Prices from January 2004 to December 2010



5.13 Western Plains Grain Prices and National Oil Prices from January 2004 to July 2005

Figure 5.15 depicts the prices Western Plains paid for grain that it used to produce ethanol from January 2004 to July 2005 and the price of a barrel of oil. The correlation coefficient between the prices for these years is -0.57. Even though over the full six-year period the price that Western Plains paid for grain and the oil prices moved together, during this 19 month period the prices tend to move in the opposite direction.

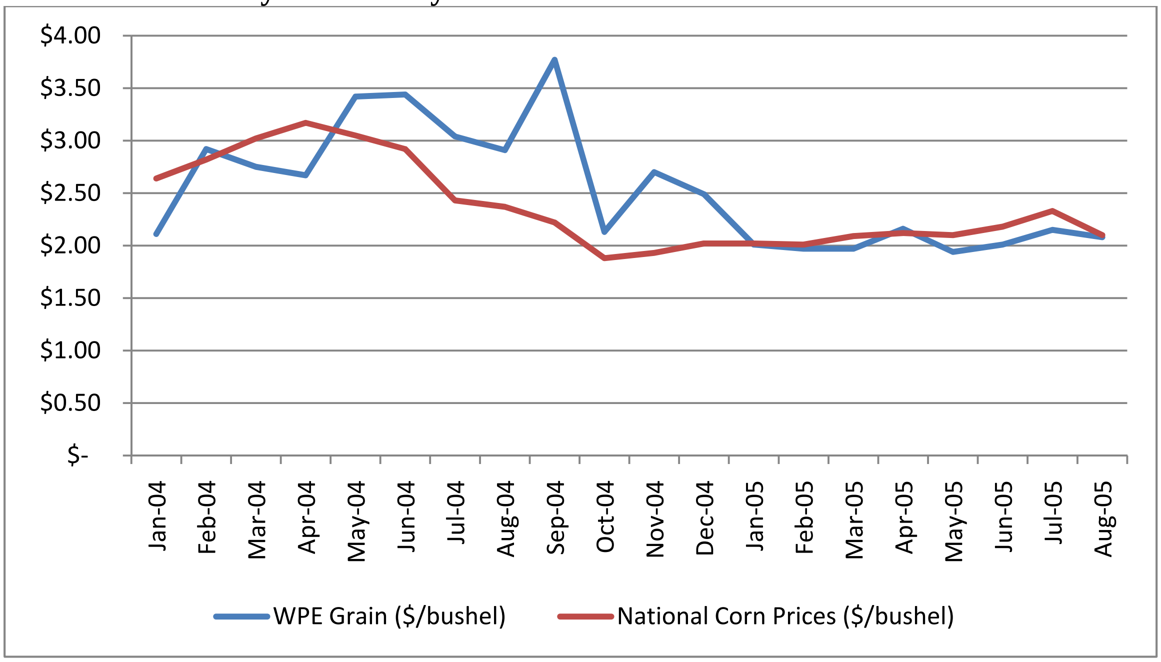
Figure 5.15: Monthly Western Plain Grain Prices and National Oil Prices from January 2004 to July 2005



5.14 Western Plains Grain Prices and National Corn Prices from January 2004 to July 2005

Compared to the degree of correlation during the entire six year period, the degree of correlation between the price Western Plains Energy paid for grain and the national price of corn before the RFS was enacted is relatively low. The correlation coefficient from January 2004 to July 2005 is 0.54.

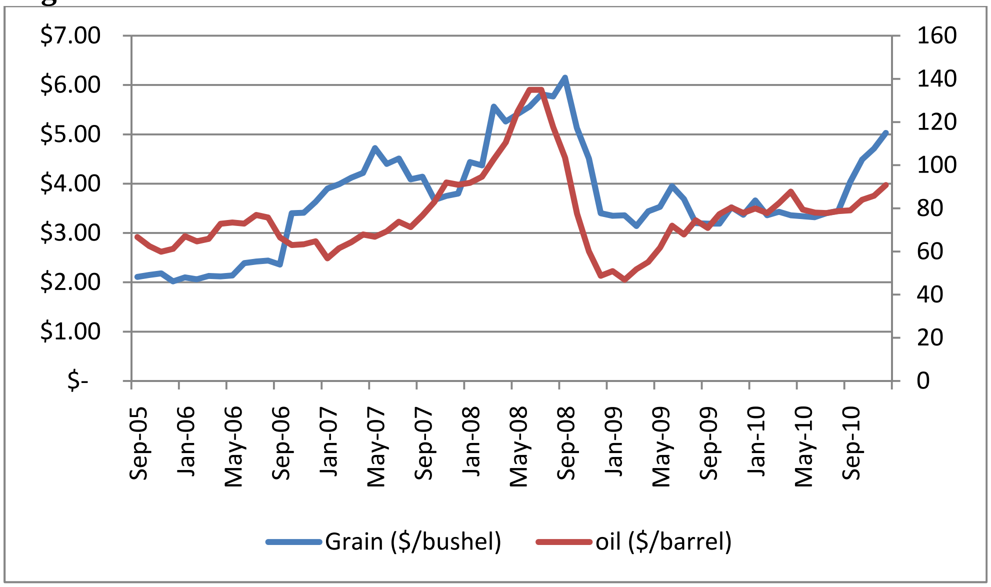
Figure 5.16: Monthly Average Western Plains Ethanol Prices and National Ethanol Prices from January 2004 to July 2005



5.15 Western Plains Grain Prices and National Oil Prices from August 2005 to December 2010

Figure 5.17 depicts the prices that Western Plains paid for grain used in ethanol production from after the RFS was signed into law in August 2005 through December 2010. The correlation coefficient between the prices for these years is 0.65. This correlation coefficient reveals a strong relationship between the grain prices that Western Plains was paying and national oil prices.

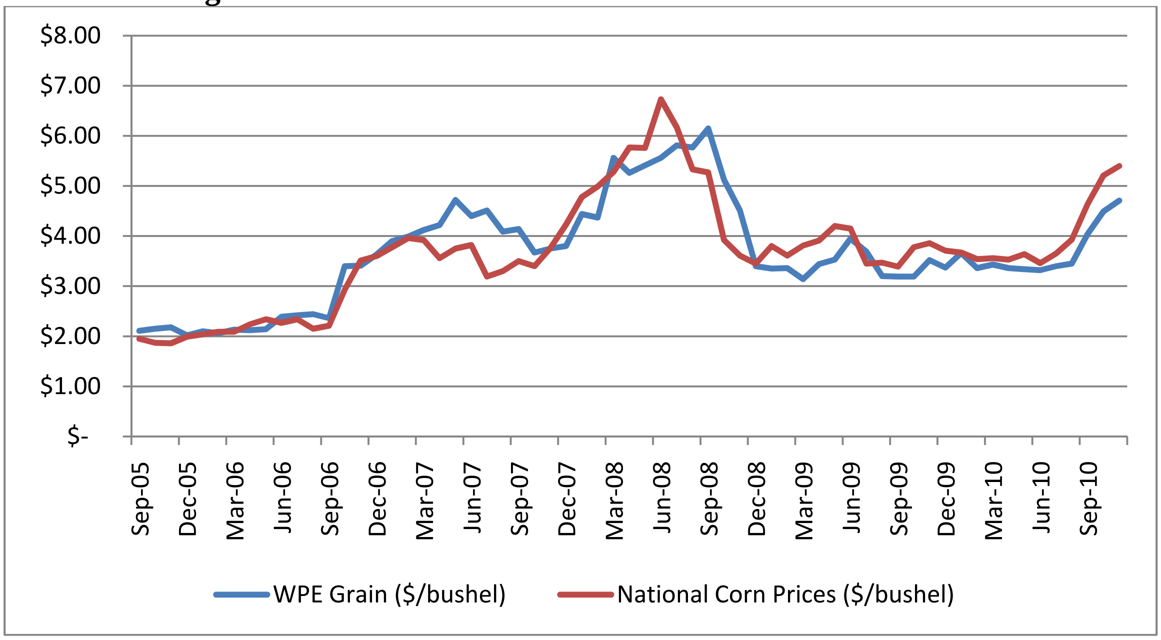
Figure 5.17: Monthly Western Plain Grain Prices and National Oil Prices from August 2005 to December 2010



5.16 Western Plains Grain Prices and National Corn Prices from August 2005 to December 2010

Figure 5.18 depicts the price that Western Plains Energy's paid for grain used to produce ethanol and the national price of corn from after the RFS was signed into law in July 2005 to December 2010. There is a high degree of correlation between the local grain prices and the national corn prices after the enactment of the RFS. The correlation coefficient between the two prices is 0.90.

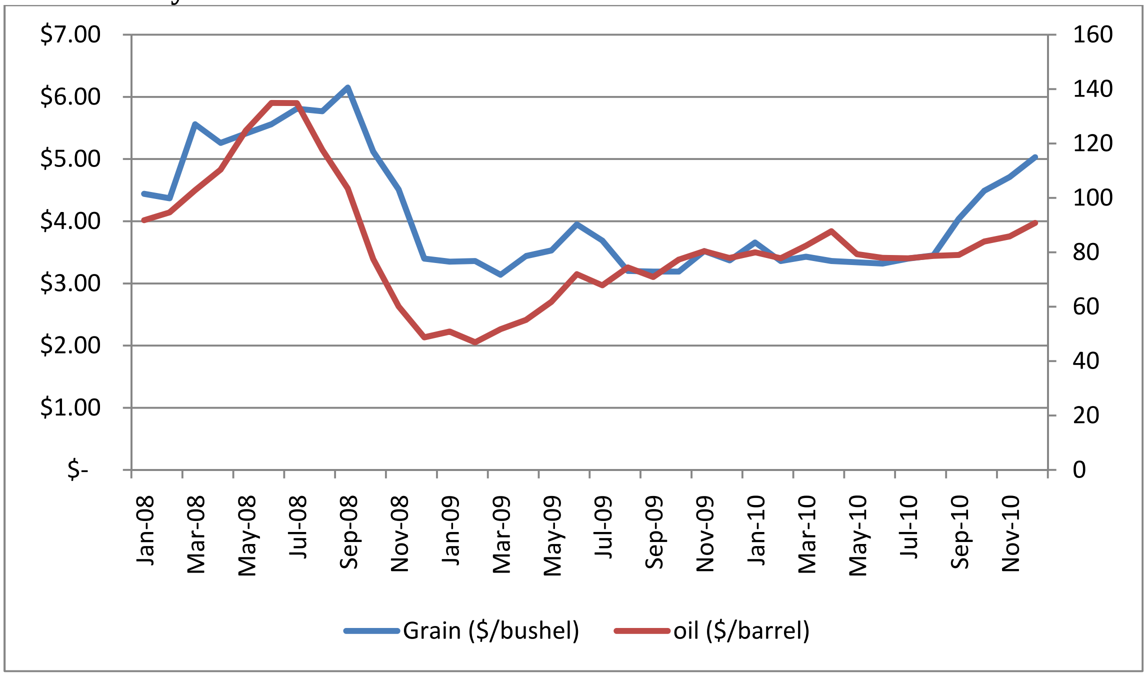
Figure 5.18: Monthly Average Western Plains Ethanol Prices and National Ethanol Prices from August 2005 to December 2010



5.17 Western Plains Grain Prices and National Oil Prices from January 2008 to December 2010

Figure 5.19 depicts the average monthly price Western Plains paid for grain used in the ethanol process and the national average monthly price for a barrel of oil from January 2008 through December 2010. This time period was analyzed because the RFS was significantly expanded in the 2007 energy bill, which President Bush signed into law on December 19, 2007. The correlation coefficient between these prices for the two year period is 0.78. This correlation coefficient reveals that after the RFS was expanded in the 2007 energy law, the prices that Western Plains paid for grain for ethanol production and national oil prices moved more in conjunction with each other than in other time period since Western Plains began producing ethanol in January 2004.

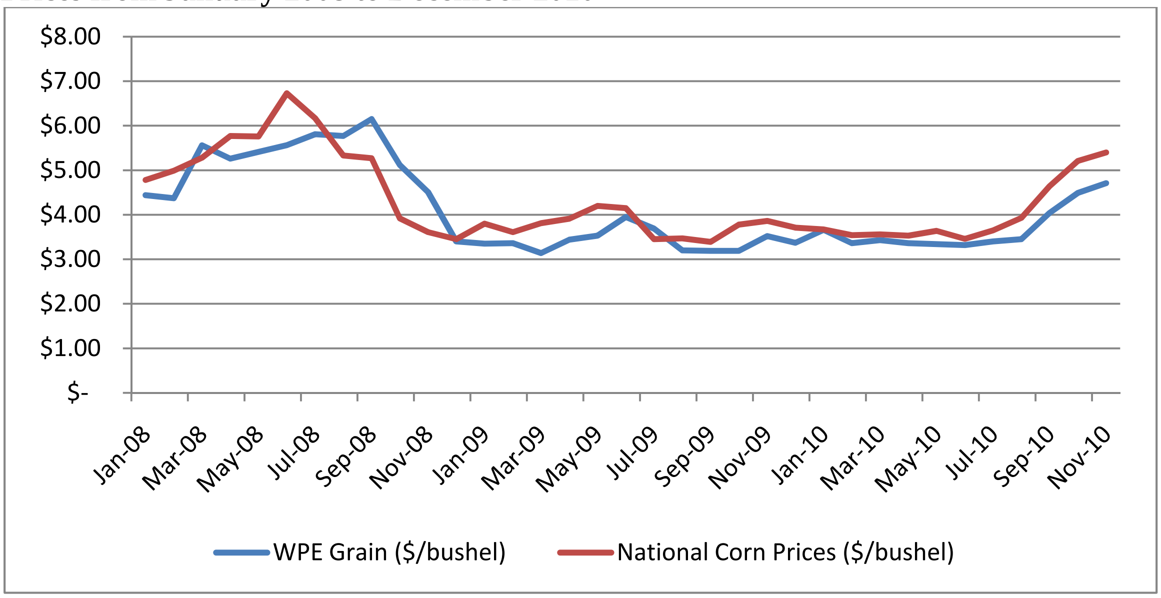
Figure 5.19: Monthly Average Western Plains Grain Prices and National Oil Prices from January 2008 to December 2010



5.18 Western Plains Grain Prices and National Corn Prices from January 2008 to December 2010

Figure 5.20 depicts the price that Western Plains Energy's paid for grain used to produce ethanol and the national price of corn from after the RFS was increased in December 2007 to December 2010. There is a high degree of correlation between the local grain prices and the national corn prices after the expansion of the RFS. The correlation coefficient between the two prices is 0.86.

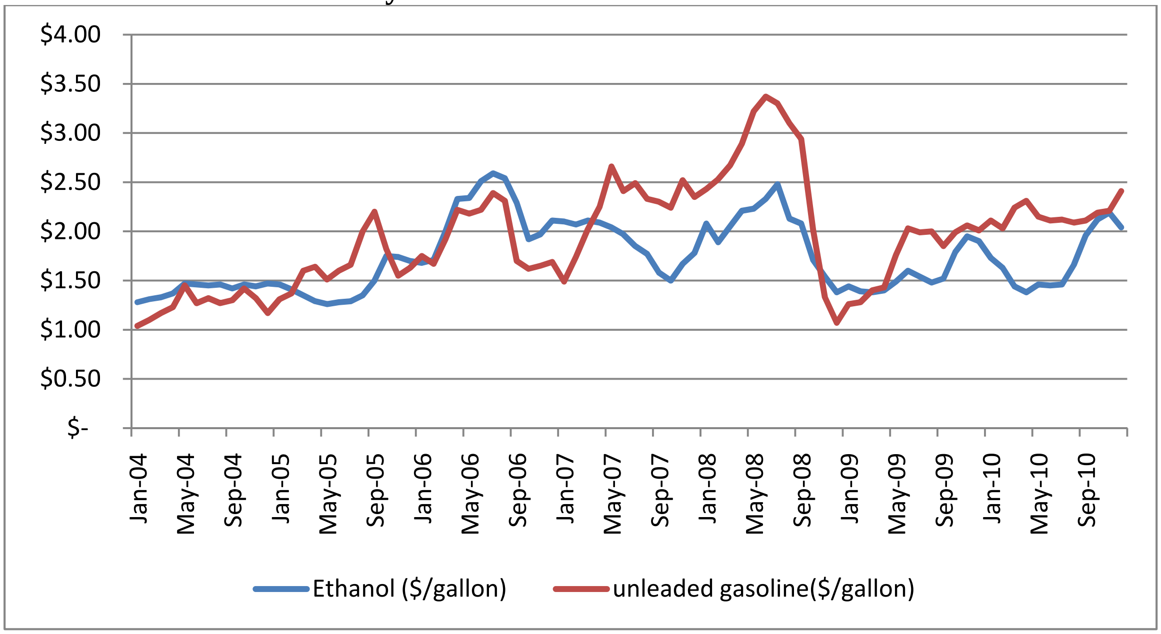
Figure 5.20: Monthly Average Western Plains Ethanol Prices and National Ethanol Prices from January 2008 to December 2010



5.19 Western Plains' Ethanol Prices and Unleaded Gasoline Prices from January 2004 to December 2010

Figure 5.21 depicts the average monthly price that Western Plains received for its ethanol and the average price of unleaded gasoline from January 2004 through December 2010. The correlation coefficient between the two prices during the six year period is 0.65. This correlation coefficient reveals that during the time period analyzed, ethanol and unleaded gasoline prices have generally moved together. They have not moved together perfectly, but they have clearly moved together.

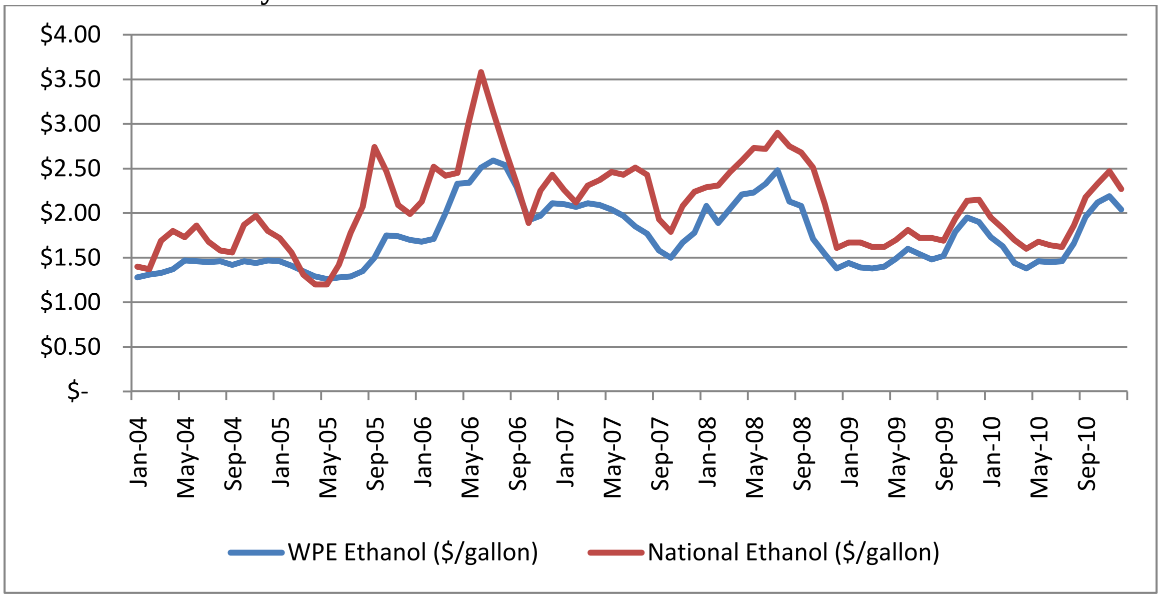
Figure 5.21: Monthly Average Western Plains Ethanol Prices and National Unleaded Gasoline Prices from January 2004 to December 2010



5.20 Western Plains' Ethanol Prices and Unleaded Gasoline Prices from January 2004 to December 2010

Figure 5.22 depicts the average monthly price that Western Plains received for its ethanol and the average national price for ethanol from January 2004 to December 2010. The correlation coefficient between the two prices during the six year period is 0.87. This correlation coefficient reveals that during the time period analyzed, the price Western Plains received for its ethanol and the national ethanol price have generally moved together.

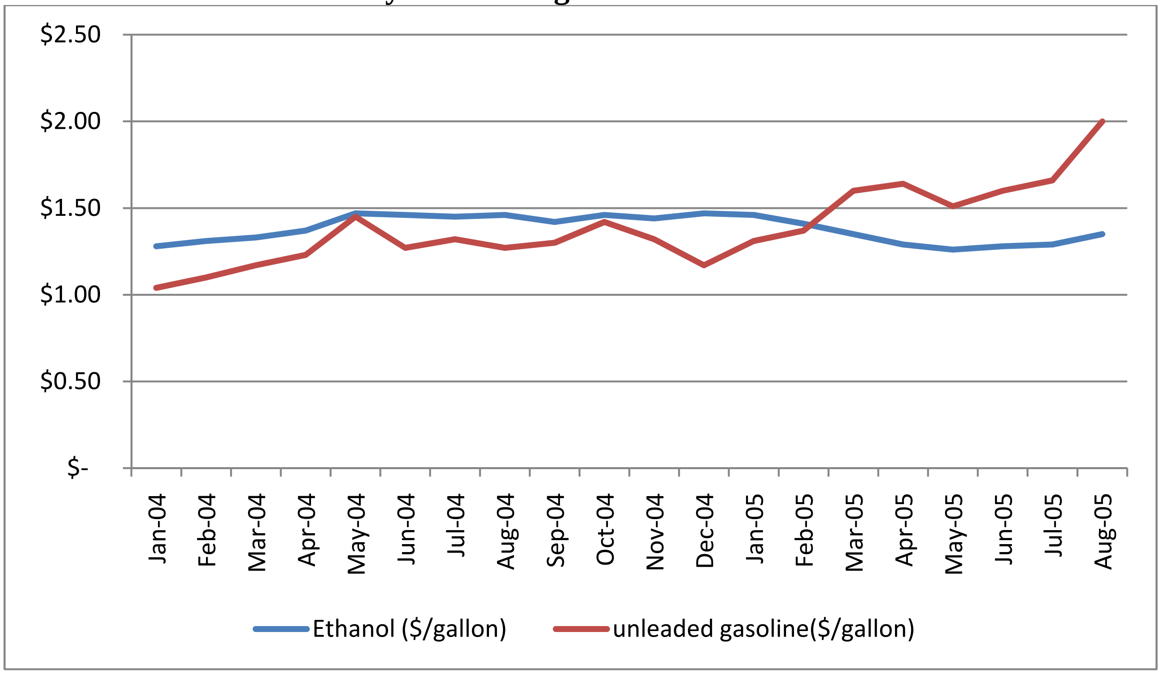
Figure 5.22: Monthly Average Western Plains Ethanol Prices and National Ethanol Prices from January 2004 to December 2010



5.21 Western Plains' Ethanol Prices and Unleaded Gasoline Prices from January 2004 to August 2005

Figure 5.23 depicts the average monthly price Western Plains received for its ethanol and the average monthly price of unleaded gasoline from January 2004 through August 2005, when the RFS was signed into law. The correlation coefficient for the price of Western Plains' ethanol and unleaded gasoline for this 18 month time period is -0.27. Even though over the full six year time period Western Plains' ethanol and unleaded gasoline move together, during this 18 month period they do not move together.

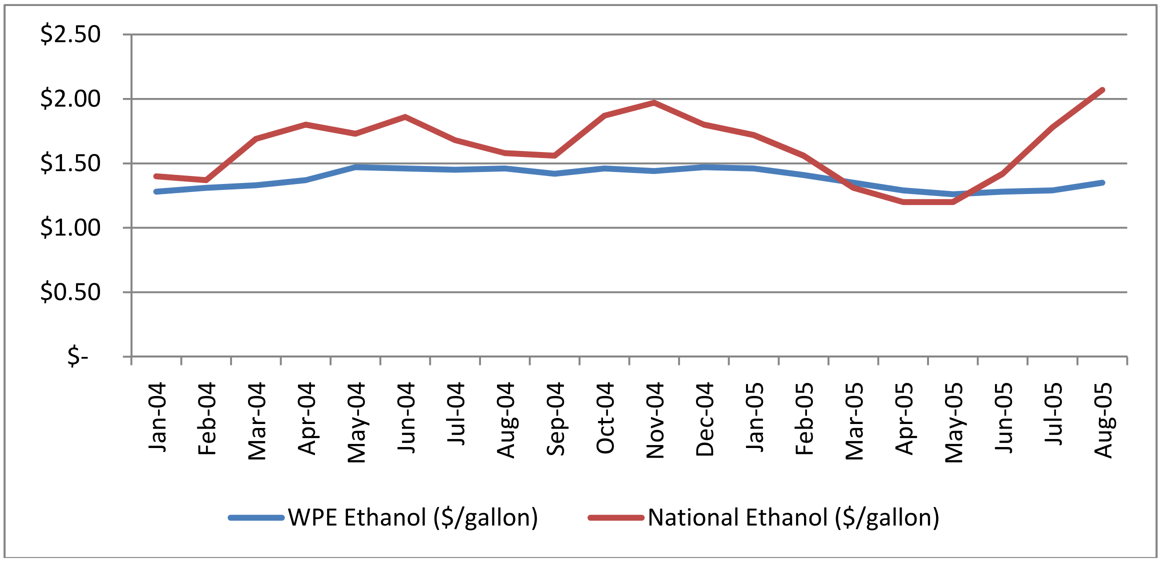
Figure 5.23: Monthly Average Western Plains Ethanol Prices and National Unleaded Gasoline Prices from January 2004 to August 2005



5.22 Western Plains' Ethanol Prices and National Ethanol Prices from January 2004 to August 2005

Figure 5.24 depicts the average monthly price that Western Plains received for its ethanol and the average national price for ethanol from January 2004 to August 2005. The correlation coefficient between the two prices during the 20 month period is 0.59. This correlation coefficient reveals that during the time period analyzed, the price Western Plains received for its ethanol and the national ethanol price have generally moved together. They have not moved as closely together as they have during the overall six year time period that Western Plains Energy has been producing ethanol.

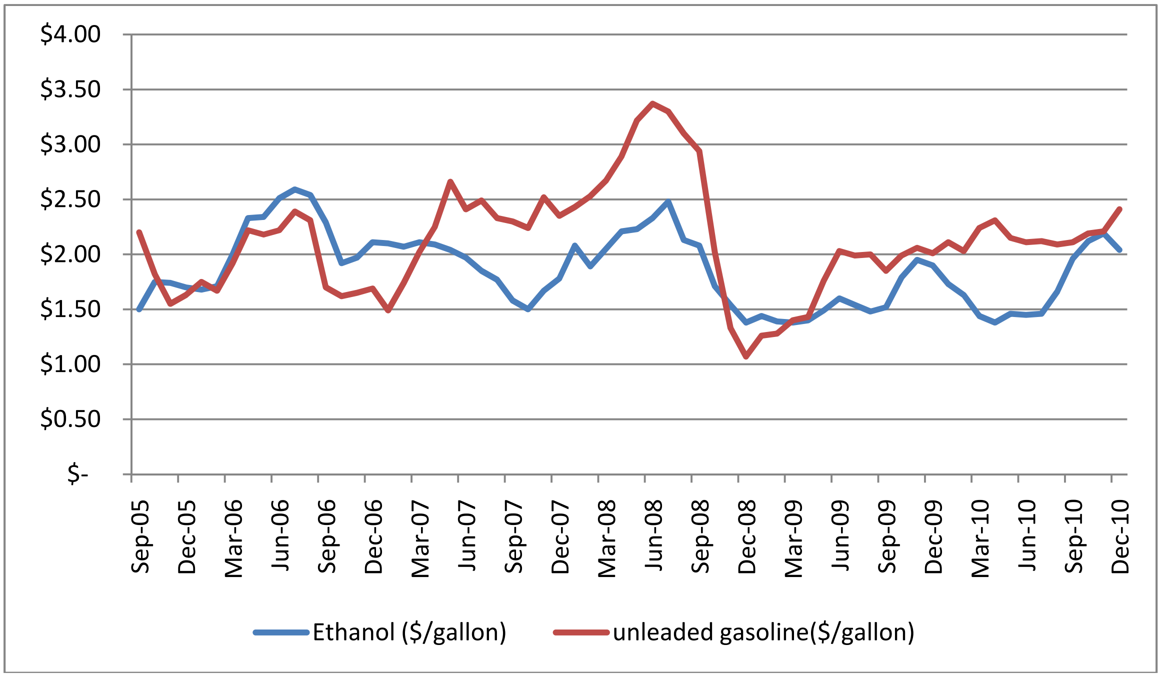
Figure 5.24: Monthly Average Western Plains Ethanol Prices and National Ethanol Prices from January 2004 to August 2005



5.23 Western Plains' Ethanol Prices and Unleaded Gasoline Prices from September 2005 to December 2010

Figure 5.25 depicts the prices that Western Plains received for its ethanol and the price of unleaded gasoline from September 2005—after the RFS was signed into law—through December 2010. The correlation coefficient between the two prices during the time period analyzed is 0.51. This correlation coefficient shows that the prices generally moved together during the time period analyzed.

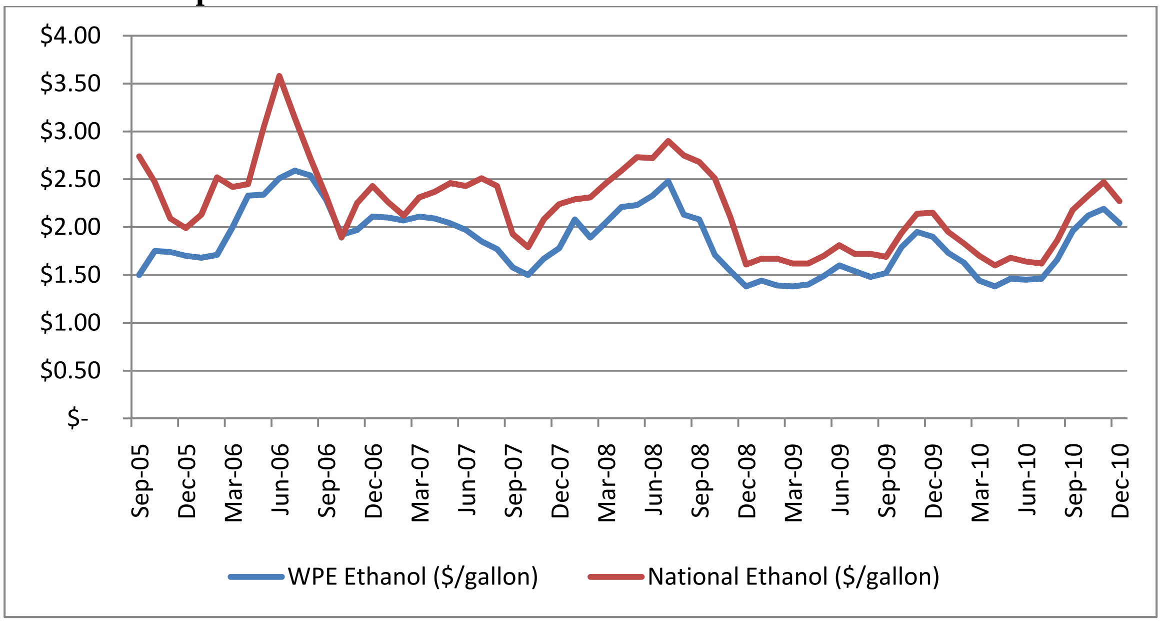
Figure 5.25: Monthly Average Western Plains Ethanol Prices and National Unleaded Gasoline Prices from September 2005 to December 2010



5.24 Western Plains' Ethanol Prices and National Ethanol Prices from September 2005 to December 2010

Figure 5.26 depicts the average monthly price that Western Plains received for its ethanol and the average national price for ethanol from January 2004 to December 2010. The correlation coefficient between the two prices during the 5 year period is 0.84. This correlation coefficient reveals that during the time period analyzed, the price Western Plains received for its ethanol and the national ethanol price have moved together.

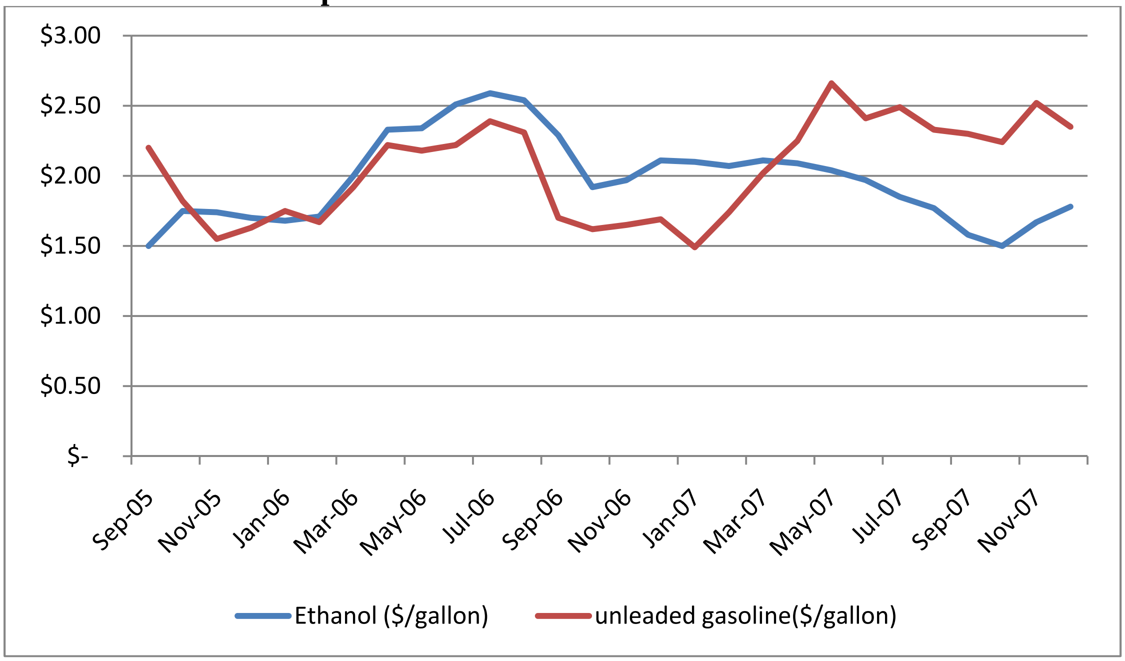
Figure 5.26: Monthly Average Western Plains Ethanol Prices and National Ethanol Prices from September 2005 to December 2010



5.25 Western Plains' Ethanol Prices and Unleaded Gasoline Prices from September 2005 to December 2007

Figure 5.20 depicts prices the average monthly price that Western Plains received for its ethanol from September 2005 after the RFS was signed into law through December 2007 when the RFS was expanded. It also depicts the average monthly unleaded gasoline prices for the same time period. The correlation coefficient between the price Western Plains received for its ethanol and unleaded gasoline prices during this time period is 0.10. The two prices move in the same direction, but the relationship is very week.

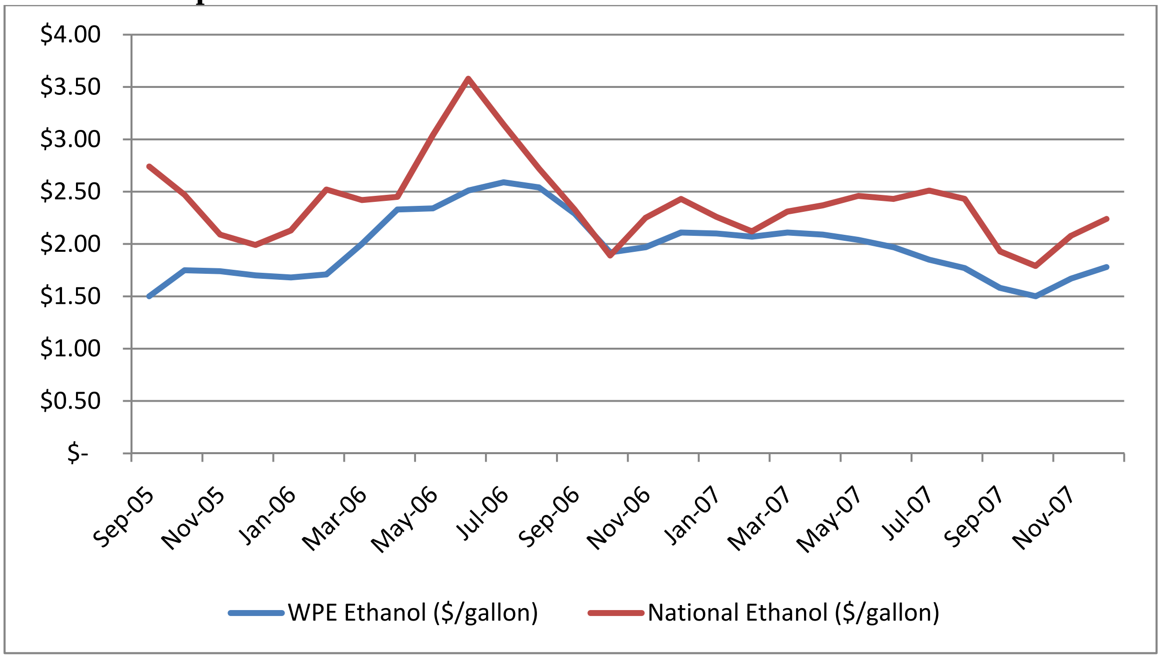
Figure 5.27: Monthly Average Western Plains Ethanol Prices and National Unleaded Gasoline Prices from September 2005 to December 2007



5.26 Western Plains' Ethanol Prices and National Ethanol Prices from September 2005 to December 2007

Figure 5.28 depicts the average monthly price that Western Plains received for its ethanol and the average national price for ethanol from September 2007 to December 2007. The correlation coefficient between the two prices during the 5 year period is 0.66. This correlation coefficient reveals that during the time period analyzed, the price Western Plains received for its ethanol and the national ethanol price have moved together.

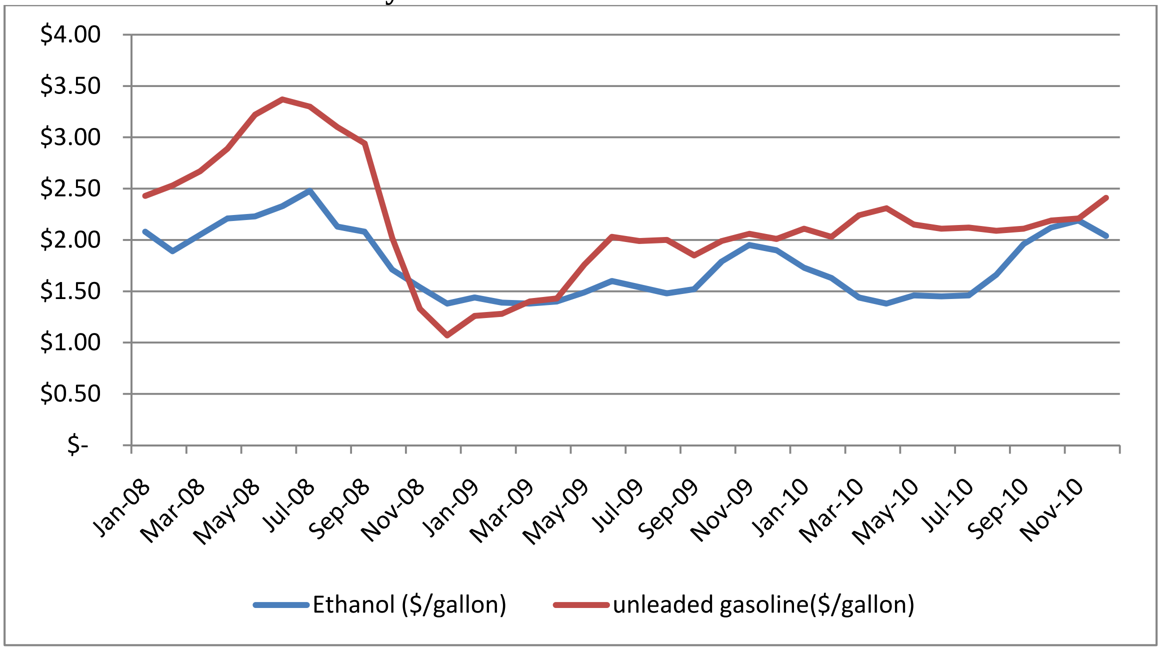
Figure 5.28: Monthly Average Western Plains Ethanol Prices and National Ethanol Prices from September 2005 to December 2007



5.27 Western Plains' Ethanol Prices and Unleaded Gasoline Prices from January 2008 to December 2010

Figure 5.29 depicts the average monthly price that Western Plains received for its ethanol from after the RFS was expanded in January 2008 through December 2010. It also depicts the average monthly price of unleaded gasoline for the same two year period. The correlation coefficient of the prices during the time period analyzed is 0.81. This reveals that the prices moved in the same direction and that there is a very strong relationship between them during this time period.

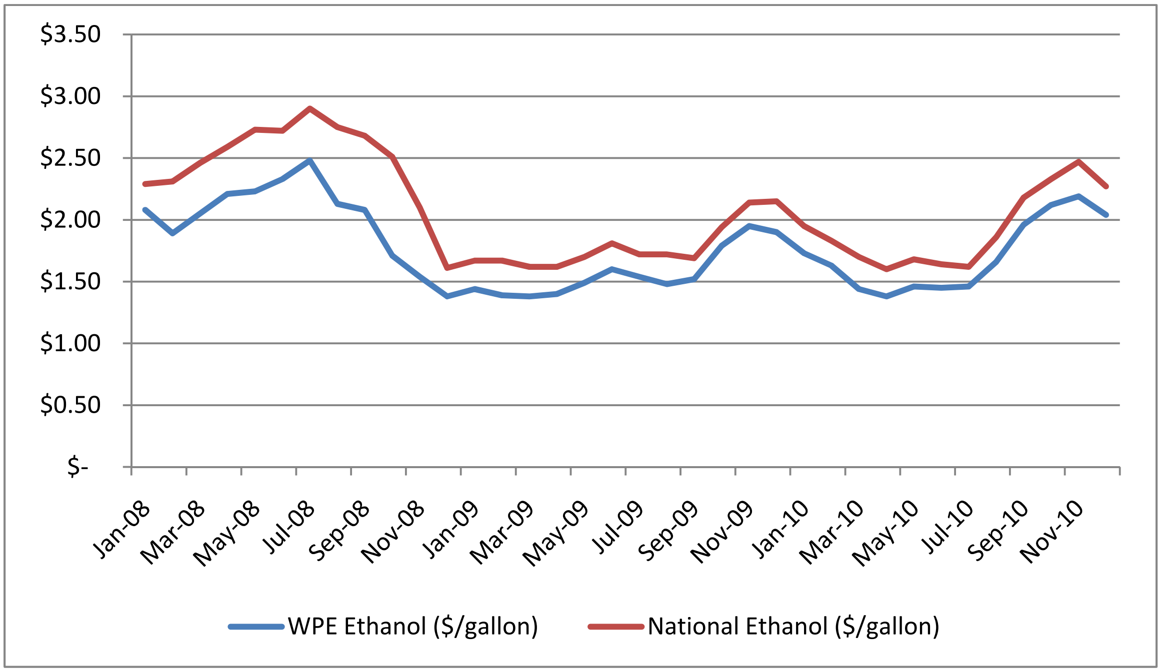
Figure 5.29: Monthly Average Western Plains Ethanol Prices and National Unleaded Gasoline Prices from January 2008 to December 2010



5.28 Western Plains' Ethanol Prices and National Ethanol Prices from January 2008 to December 2010

Figure 5.30 depicts the average monthly price that Western Plains received for its ethanol and the average national price for ethanol from January 2008 to December 2010. The correlation coefficient between the two prices during the 2 year period is 0.94. This correlation coefficient reveals that during the time period analyzed, the price Western Plains received for its ethanol and the national ethanol price have moved together. The prices move more closely together during this two year time period than at any other point during the overall six year period.

Figure 5.30: Monthly Average Western Plains Ethanol Prices and National Ethanol Prices from January 2008 to December 2010



5.29 Overall Assessment of Comparison of Western Plain Energy Prices to National Market Prices

The prices that Western Plains Energy paid for grain that it used to produce ethanol and national oil prices are more closely correlated after the passage of the RFS. In the time period before the creation of the RFS, the prices are not correlated. Following creation and then expansion of the law, there is a high degree of correlation between the price Western Plains Energy paid for grain to produce ethanol and national oil prices. The pre-law correlation coefficient is -0.57. The post-expansion correlation coefficient is 0.78.

The prices that Western Plains Energy paid for grain that it used to produce ethanol and the prices that the company received for the ethanol that it produced are more closely correlated after the creation of the RFS. The prices are even more closely correlated after the RFS levels were increased and extended from 2012 to 2022. The pre-RFS correlation coefficient is 0.54 and the post-expansion of RFS correlation coefficient is 0.86.

The price that Western Plains Energy received for the ethanol it produced and national unleaded gasoline prices are more closely correlated following the creation and expansion of the RFS. The pre-RFS correlation coefficient is -0.27. The post-expansion of the law correlation coefficient is 0.81.

The prices that Western Plains Energy received for the ethanol it produced and national ethanol prices are more closely correlated following the creation and expansion of the RFS. The price that Western Plains Energy received for the ethanol it sold and the national prices are correlated throughout the time period studied, but the degree of correlation increases significantly following creation and expansion of the RFS. The pre-RFS correlation coefficient is 0.59, while the post-RFS expansion correlation coefficient is 0.94.

Regressions

5.30 Regression Analysis of National Corn Prices and Western Plains Energy's Grain Prices

Regression analysis is used to determine the relationship between the national corn price and the price that Western Plains Energy paid for the grain that it used to produce ethanol.

Estimated Model:

Western Plains Price of Grain= 0.56 + 0.84*(National Price of Corn)
t-statistic (3.56) (19.01)

The coefficient of the price of corn of 0.84 reveals that the national price of corn and the price that Western Plains Energy paid for grain move together. If the intercept was 1, that would mean that they move together exactly.

The t-statistic is 3.56 on the intercept and 19.01 on the slope coefficient. Since the t-statistic is more than 19, it is statistically likely that national corn prices have a significant impact on Western Plains Energy's grain prices.

5.31 Regression Analysis of National Ethanol Prices and Western Plains Energy's Ethanol Prices

Regression analysis is used to determine the relationship between the national ethanol price and the price that Western Plains Energy received for the ethanol that it produced.

Estimated Model:

Western Plains Energy Price of Ethanol= 0.36 + 0.66*(National Price of Ethanol)

t-statistic (4.16) (16.31)

The coefficient of the national price of ethanol of 0.66 reveals that the national price of ethanol and the price that Western Plains Energy paid for ethanol move together. If the intercept was 1, that would mean that they move together exactly.

The t-statistic on the slope coefficient is more than 16. Since the t-statistic is more than 2, it is likely that national ethanol prices have a significant impact on the price that Western Plains Energy receives for the ethanol that it produces.

5.32 Vector Autoregression Results

This section will discuss the vector autoregression model, the impulse response functions, and the forecast error variance decomposition analysis. Tables 5.1, 5.2, 5.3, and 5.4 present the regression results for equation 1 through 4 in Chapter 4.

Table 5.1: Vector Autoregression Oil Equation

	Estimate	Standard Error	t-value
Oil Lag 1	1.36	0.08	16.00
Unleaded Gasoline Lag 1	-0.56	2.28	-0.25
Ethanol Lag 1	2.30	1.48	-1.55
Corn Lag 1	2.21	0.88	2.51
Oil Lag 2	-0.10	0.13	-0.75
Unleaded Gasoline Lag 2	-6.07	2.92	-2.08
Ethanol Lag 2	3.97	2.10	1.90
Corn Lag 2	-0.81	1.40	-0.58
Oil Lag 3	-0.37	0.08	-4.44
Unleaded Gasoline Lag 3	9.08	2.28	3.98
Ethanol Lag 3	-1.80	1.40	-1.29
Corn Lag 3	-1.28	0.90	-1.43
Const	-0.45	1.04	-0.43
Trend	0.01	0.00	3.23

The residual standard of error for the oil equation estimates is 2.92 (Table 5.1). This indicates that the standard deviation from the $34 per barrel mean price of oil is plus or minus $2.92. The adjusted R-squared is 98.6% indicating there is a high level of explanatory power in these results.

Table 5.2: Vector Autoregression Unleaded Gasoline Equation

	Estimate	Standard Error	t-value
Oil Lag 1	0.01	0.00	4.37
Unleaded Gasoline Lag 1	0.82	0.09	9.57
Ethanol Lag 1	-0.03	0.06	-0.49
Corn Lag 1	0.04	0.03	1.32
Oil Lag 2	0.00	0.00	0.68
Unleaded Gasoline Lag 2	-0.42	0.11	-3.79
Ethanol Lag 2	0.14	0.08	1.80
Corn Lag 2	0.04	0.05	0.85
Oil Lag 3	-0.01	0.00	-4.15
Unleaded Gasoline Lag 3	0.34	0.09	3.94
Ethanol Lag 3	0.08	0.05	-1.45
Corn Lag 3	-0.09	0.03	-2.59
Const	-0.00	0.04	-0.10
Trend	0.01	0.00	3.35

The residual standard of error for the unleaded gasoline equation is 0.11 (Table 5.2). This means that the standard deviation from the mean price of $1.01 per gallon for unleaded gasoline is plus or minus 11 cents. The adjusted R-squared is 97.1%, which means that there is a high level of explanatory power in these results.

Table 5.3: Vector Autoregression Ethanol Equation

	Estimate	Standard Error	t-value
Oil Lag 1	6.17e-03	3.41e-03	1.81
Unleaded Gasoline Lag 1	2.12e-01	9.15e-02	2.32
Ethanol Lag 1	1.13e+00	5.95e-02	18.98
Corn Lag 1	3.79e-02	3.53e-02	1.07
Oil Lag 2	-5.46e-03	5.10e-03	-1.07
Unleaded Gasoline Lag 2	-2.71e-01	1.17e-01	-2.32
Ethanol Lag 2	-4.58e-01	8.39e-02	-5.46
Corn Lag 2	4.36e-02	5.63e-02	0.77
Oil Lag 3	2.59e-04	3.34e-03	0.08
Unleaded Gasoline Lag 3	1.57e-01	9.15e-02	1.71
Ethanol Lag 3	1.43e-01	5.60e-02	2.55
Corn Lag 3	-9.36e-02	3.60e-02	-2.60
Const	-1.84e-01	4.18e-02	4.40
Trend	-8.16e-05	1.20e-04	-0.68

The residual standard of error for the ethanol equation is 0.118 (Table 5.3). This means that the standard deviation from the mean price of $1.46 per gallon for ethanol is plus or minus 11.8 cents. The adjusted R-squared is 93.9%, which means that there is a high level of explanatory power in these results.

Table 5.4: Vector Autoregression Corn Equation

	Estimate	Standard Error	t-value
Oil Lag 1	0.00	0.01	0.57
Unleaded Gasoline Lag 1	-0.20	0.15	-1.31
Ethanol Lag 1	-0.14	0.10	-1.37
Corn Lag 1	1.29	0.06	21.69
Oil Lag 2	0.01	0.01	1.63
Unleaded Gasoline Lag 2	-0.29	0.20	-1.45
Ethanol Lag 2	0.18	0.14	1.26
Corn Lag 2	-0.24	0.10	-2.47
Oil Lag 3	-0.01	0.01	-2.41
Unleaded Gasoline Lag 3	0.42	0.15	2.70
Ethanol Lag 3	-0.09	0.09	-0.96
Corn Lag 3	-0.12	0.06	-2.05
Const	0.18	0.07	2.54
Trend	0.00	0.00	0.80

The residual standard of error for the corn equation is 0.199 (Table 5.4). This means that the standard deviation from the mean price of $2.69 per bushel for corn is plus or minus 19.9 cents. The adjusted R-squared is 94.8%, which means that there is a high level of explanatory power in these results.

5.33 Correlation Matrix of Residuals

There is a strong correlation between the contemporaneous residuals from the oil and unleaded gasoline equations. If they moved together exactly, the correlation would be

1. The correlation between oil and unleaded gasoline is 0.723. The other commodities are not as highly correlated. Instantaneous correlations measure the degree to which an error in one estimated equation is correlated with the error in another estimated equation.

Table 5.5: Instantaneous Residual Correlation Matrix for the VAR System

	Oil	Unleaded Gasoline	Ethanol	Corn
Oil	1.000	0.723	0.198	0.242
Unleaded Gasoline	0.723	1.000	0.315	0.184
Ethanol	0.198	0.315	1.000	0.026
Corn	0.242	0.184	0.026	1.000

Table 5.6: Eigenvalues of the VAR System

0.8996	0.8996	0.8735	0.6609	0.6609	0.5156	0.5156	0.4164	0.4164	0.2757	.02757	0.1264

The eigenvalues of the VAR is used to check the stability of the system (Table 5.6). Because all of the numbers are less than one, the system is stable. The estimated VAR system must be converted to a moving average representation to analyze the dynamics of the system. This is done using Choleski decomposition. However the system will only be stable if the eigenvalues reported in Table 5.6 are all less than one, indicating stability in the system.

5.34 Impulse Response

The impulse response is used to measure the interrelationships between the price of oil, unleaded gasoline, ethanol, and corn. The impulse response measures the response of the variables to a shock in one variable. For example, a one standard deviation shock in oil is examined to determine the effect on the corn markets.

5.35 Impulse Response Coefficients for Oil

Figure 5.31 shows that when there is a shock to the price of oil, it has a significant impact on unleaded gasoline and ethanol prices. The X axis is the number of months after the shock. The chart shows that a shock to the price of oil has a limited impact on the price of corn. Unleaded gasoline and ethanol respond dramatically to an oil shock and the impact is still pronounced for three years after the shock.

Figure 5.31: Impulse Response Coefficients for Oil

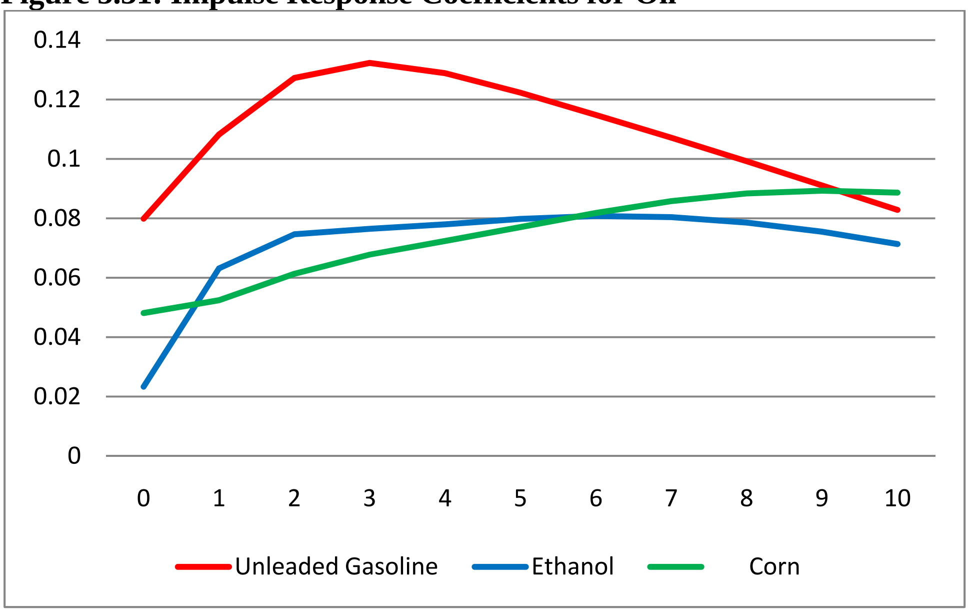
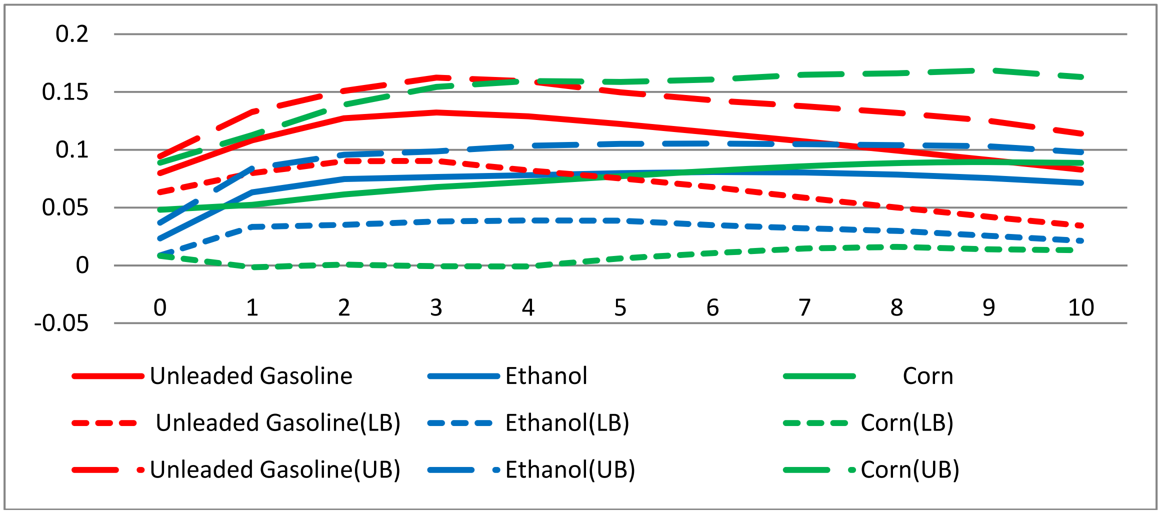


Figure 5.32 illustrates the 95% confidence intervals for the impulse response functions in Figure 5.31. If the lower and upper bounds are of the opposite signs, the response is statistically significant at the 5% level.

Figure 5.32: Impulse Response Coefficients for Oil with Lower and Upper Bands



5.36 Impulse Response Coefficients for Unleaded Gasoline

Figure 5.33 illustrates a shock to the price of unleaded gasoline and the impact it has an impact on oil, ethanol, and corn prices. Oil prices do not return to their previous levels for five years. The chart shows that a shock in unleaded gasoline prices has virtually no effect on ethanol and corn prices.

Figure 5.33: Impulse Response Coefficients for Unleaded Gasoline

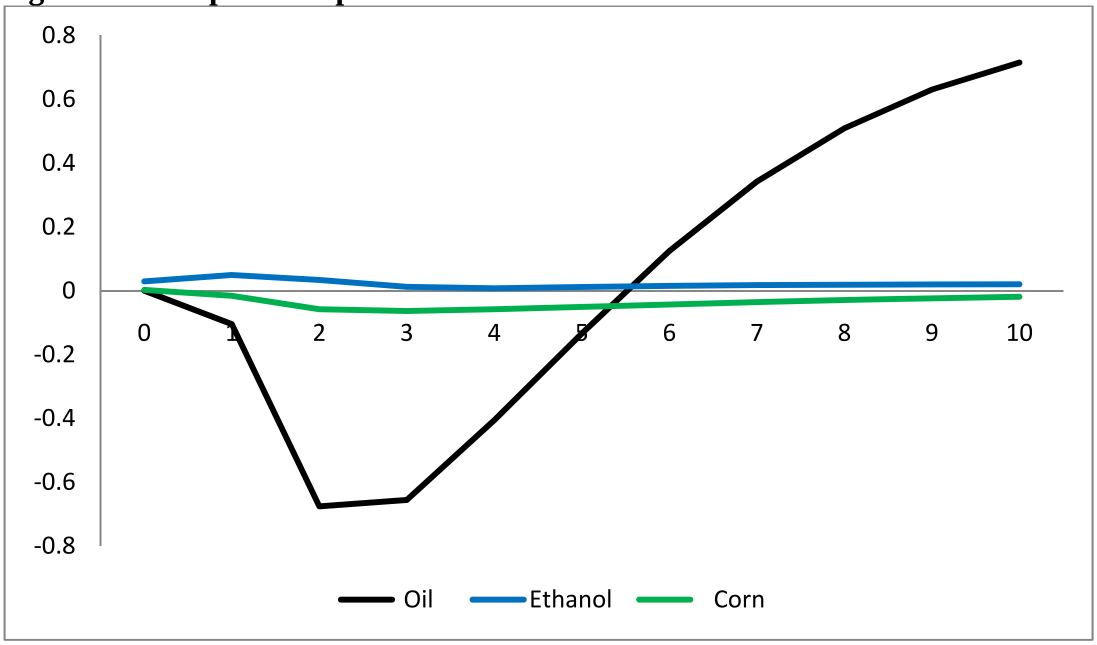
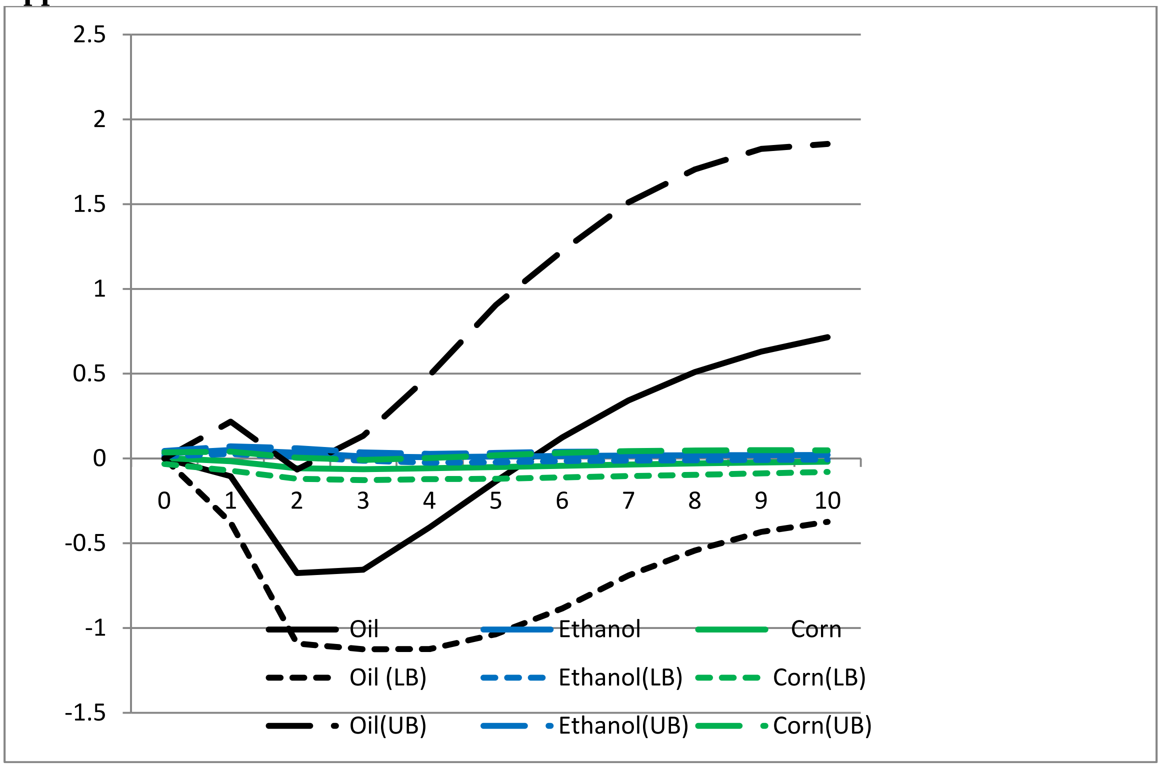


Figure 5.34 illustrates the 95% confidence intervals for the impulse response functions in Figure 5.33. If the lower and upper bounds are of the opposite signs, the response is statistically significant at the 5% level.

Figure 5.34: Impulse Response Coefficients for Unleaded Gasoline with Lower and Upper Bands



5.37 Impulse Response Coefficients for Ethanol

Figure 5.35 shows when there is a shock to the price of ethanol, it has an impact on oil, unleaded gas, and corn prices. Oil prices do not return to their previous levels for five years. The chart shows that a shock in ethanol prices has virtually no effect on unleaded gasoline and corn prices.

Figure 5.35: Impulse Response Coefficients for Ethanol

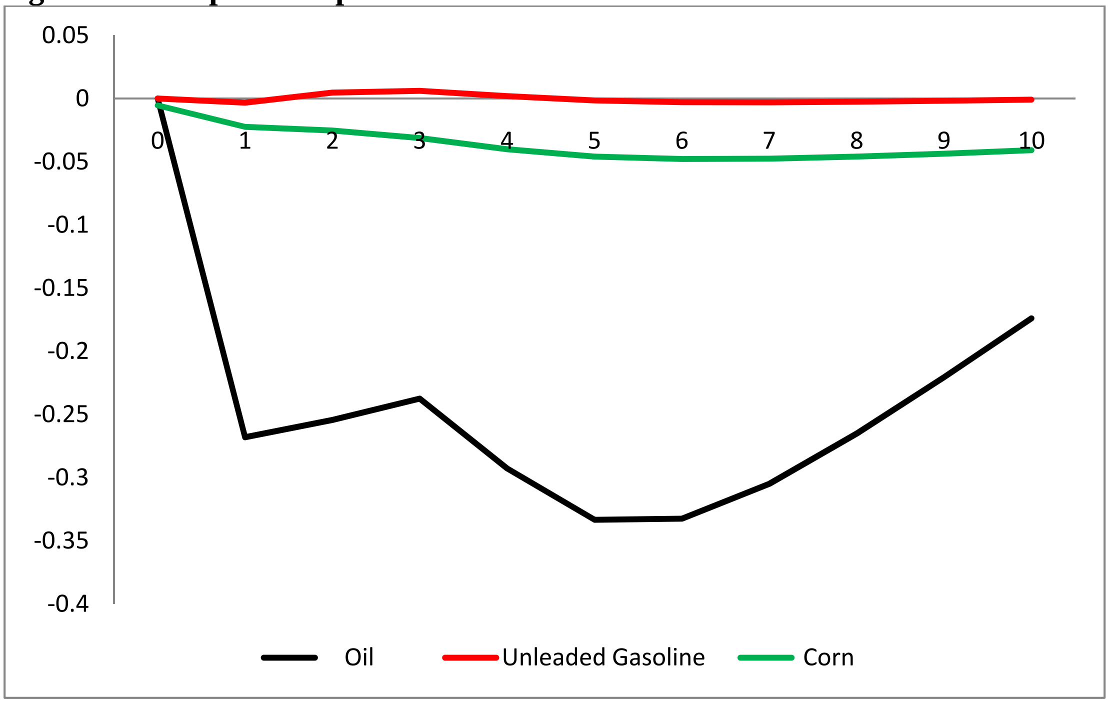
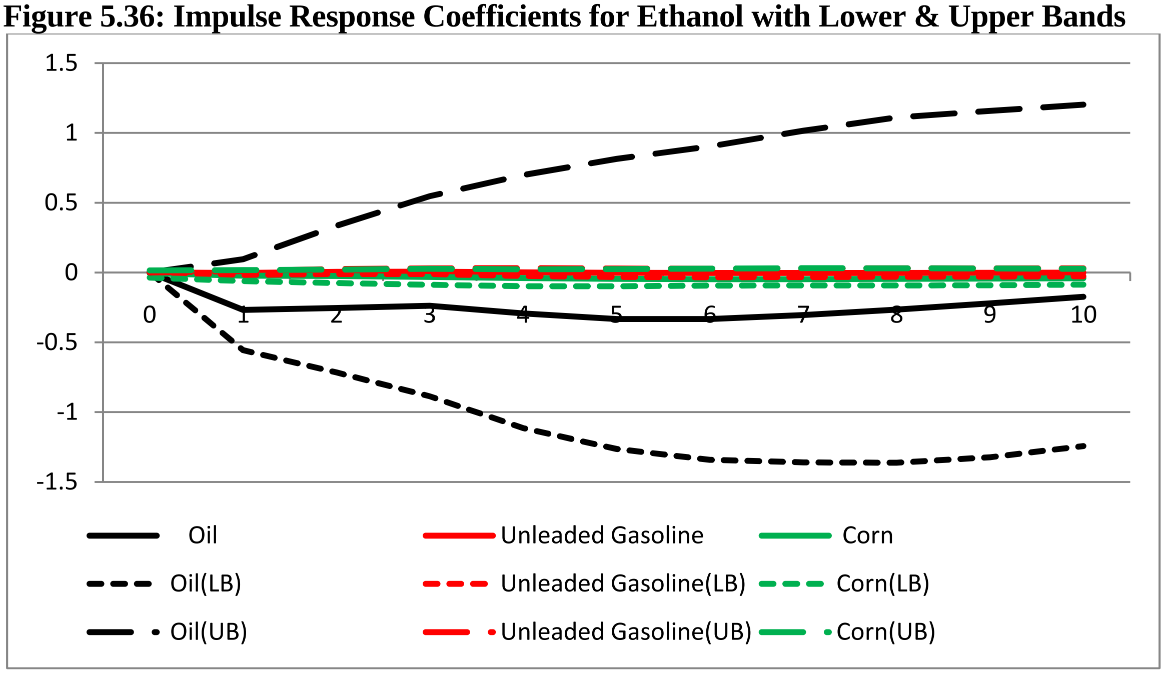


Figure 5.36 illustrates the 95% confidence intervals for the impulse response functions in Figure 5.35. If the lower and upper bounds are of the opposite signs, the response is statistically significant at the 5% level.

Figure 5.36: Impulse Response Coefficients for Ethanol with Lower & Upper Bands



5.38 Impulse Response Coefficients for Corn

Figure 5.37 shows when there is a shock to the price of corn, it has a significant impact on oil prices. Oil prices do not return to their previous levels for five years. The chart shows that a shock in unleaded gasoline prices has virtually no effect on unleaded gasoline and ethanol prices.

Figure 5.37: Impulse Response Coefficients for Corn

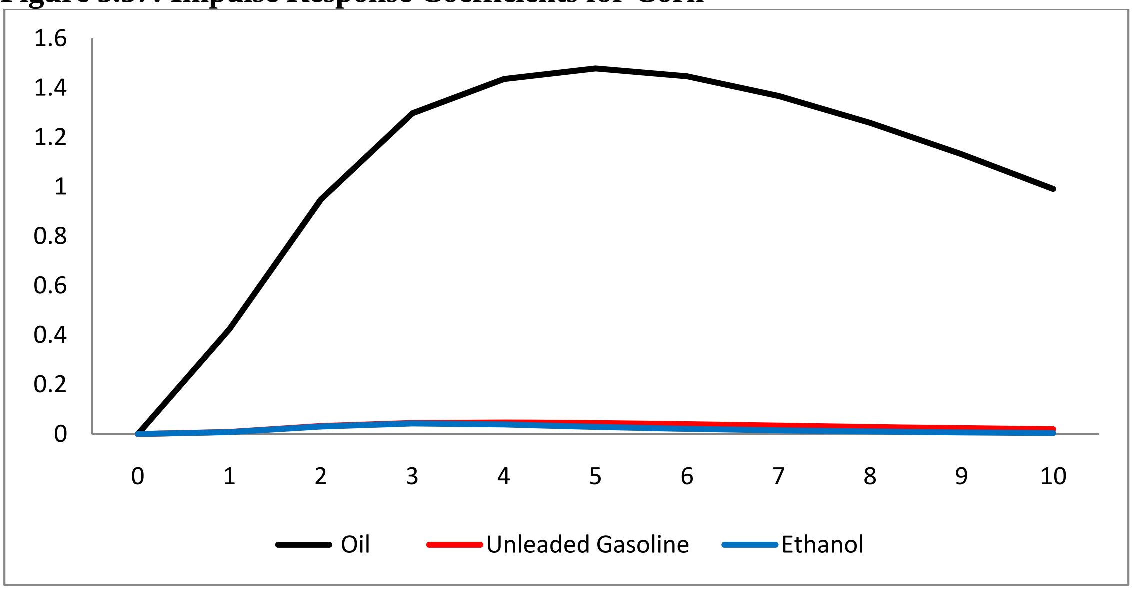
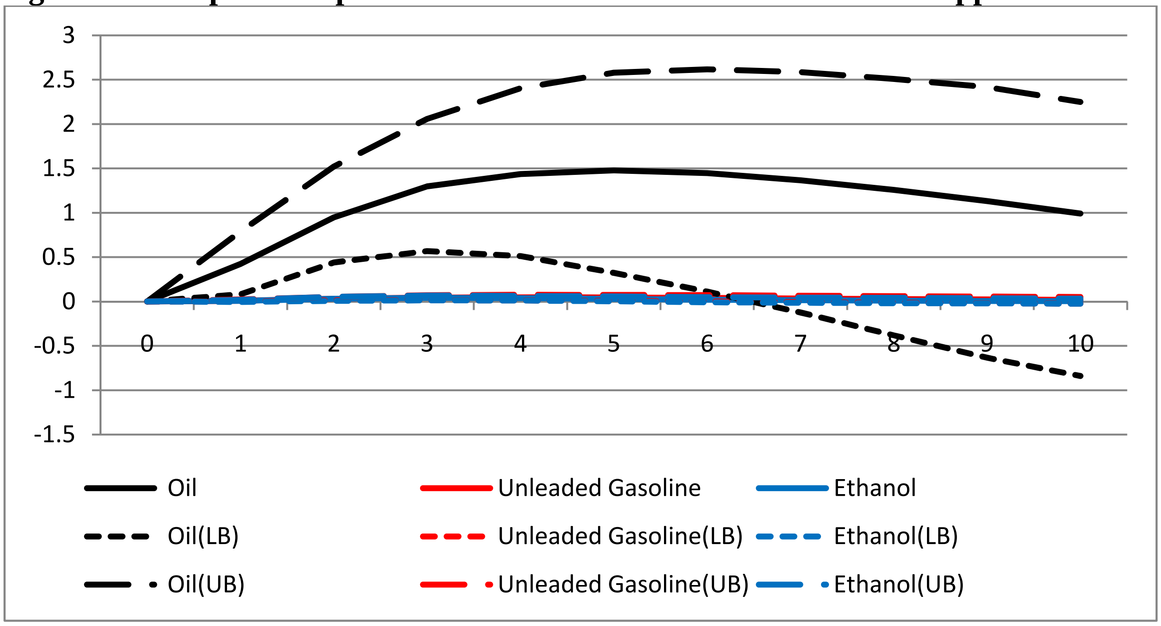


Figure 5.38 illustrates the 95% confidence intervals for the impulse response functions in Figure 5.37. If the lower and upper bounds are of the opposite signs, the response is statistically significant at the 5% level.

Figure 5.38: Impulse Response Coefficients for Corn with Lower and Upper Band



5.39 Forecast Error Variance Decomposition (FEVD) for Oil

Variance decomposition measures the amount of information each variable contributes to the other variables in the vector autoregression models. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. Table 5.7 reveals the impact that a shock on oil prices has on oil, unleaded gasoline, ethanol, and corn prices. Actual oil prices are used with forecasted unleaded gasoline, ethanol and corn prices. Actual oil prices account for 90% of the error at the end of the period. Corn prices account for 6.8% of the error at one year. A shock on oil prices has an impact on oil prices, a slight impact on corn prices and virtually no impact on unleaded gasoline and ethanol prices. The results for the forecast error decomposition suggest oil is exogenous to the system.

Table 5.7: Oil Forecast Error Variance Decomposition

Months	Oil	Unleaded Gas	Ethanol	Corn
1	**100%**	**0%**	**0%**	**0%**
2	**98.9%**	**0%**	**0.3%**	**0.7%**
3	**96.5%**	**1.0%**	**0.3%**	**2.3%**
4	**94.8%**	**1.2%**	**0.3%**	**3.8%**
5	**93.8%**	**1.1%**	**0.3%**	**4.8%**
6	**93.2%**	**0.9%**	**0.3%**	**5.6%**
7	**92.8%**	**0.7%**	**0.3%**	**6.1%**
8	**92.4%**	**0.7%**	**0.4%**	**6.5%**
9	**92.3%**	**0.8%**	**0.4%**	**6.7%**
10	**91.9%**	**0.9%**	**0.3%**	**6.8%**
11	**91.7%**	**1.1%**	**0.3%**	**6.8%**
12	**91.6%**	**1.3%**	**0.3%**	**6.8%**

5.40 FEVD for Unleaded Gasoline

Table 5.8 reveals the impact that a shock on unleaded gasoline prices has on oil, unleaded gasoline, ethanol, and corn prices. The impact of the shock on oil prices increases from 52.3% in the first month to 84.9% in the twelfth month. The impact of the shock on unleaded gasoline prices decreases from 47.7% in the first month to 7.7% in the twelfth month. A shock on unleaded gasoline prices has a very limited effect on corn prices and virtually no impact on ethanol prices.

Table 5.8: Unleaded Gas Forecast Error Variance Decomposition

Months	Oil	Unleaded Gas	Ethanol	Corn
1	**52.3%**	**47.7%**	**0%**	**0%**
2	**64.9%**	**34.8%**	**0%**	**0.3%**
3	**75.3%**	**22.2%**	**0.1%**	**2.4%**
4	**79.6%**	**15.6%**	**0.1%**	**4.7%**
5	**81.6%**	**12.1%**	**0.1%**	**6.2%**
6	**82.7%**	**10.1%**	**0.1%**	**7.1%**
7	**83.4%**	**9.0%**	**0.1%**	**7.6%**
8	**83.9%**	**8.3%**	**0.1%**	**7.7%**
9	**84.3%**	**7.9%**	**0.1%**	**7.7%**
10	**84.6%**	**7.7%**	**0.1%**	**7.6%**
11	**84.8%**	**7.7%**	**0.1%**	**7.4%**
12	**84.9%**	**7.7%**	**0.1%**	**7.3%**

5.41 FEVD for Ethanol

Table 5.9 reveals that a shock in ethanol prices has an impact on ethanol prices, a lesser impact on oil prices, and a limited impact on unleaded gasoline and corn prices. The impact of the shock on ethanol prices declines from 89.9% in the first month to 36.5% in the twelfth month. The impact of the shock on oil prices increases from 3.9% in the first month to 52.7% in the twelfth month.

Table 5.9: Ethanol Forecast Error Variance Decomposition

Months	Oil	Unleaded Gas	Ethanol	Corn
1	**3.9%**	**6.2%**	**89.9%**	**0**
2	**12.6%**	**9.1%**	**78.2%**	**0.1%**
3	**19.7%**	**8.6%**	**69.8%**	**1.9%**
4	**25.5%**	**7.3%**	**62.7%**	**4.4%**
5	**30.6%**	**6.4%**	**57.0%**	**6.0%**
6	**35.4%**	**5.9%**	**52.3%**	**6.4%**
7	**39.7%**	**5.7%**	**48.4%**	**6.3%**
8	**43.4%**	**5.5%**	**45.0%**	**6.0%**
9	**46.5%**	**5.5%**	**42.2%**	**5.7%**
10	**49.1%**	**5.5%**	**39.9%**	**5.4%**
11	**51.1%**	**5.6%**	**38.0%**	**5.1%**
12	**52.7%**	**5.8%**	**36.5%**	**5.0%**

5.42 FEVD for Corn

Table 5.10 reveals that a shock in corn prices only has a significant impact on corn prices. The impact of a shock on corn prices decreases from 94.0% in the first month to 82.8% in the twelfth month. A shock on corn prices has a limited impact on oil prices. The shock is 5.9% in the first month and increases to 11.3% in the twelfth month. This reveals that the price of corn is independent from the price of oil. Corn, like oil, is exogenous to the system.

Table 5.10: Corn Forecast Error Variance Decomposition

Months	Oil	Unleaded Gas	Ethanol	Corn
1	**5.9%**	**0%**	**0%**	**94.0%**
2	**4.8%**	**0.3%**	**0.5%**	**94.4%**
3	**4.7%**	**1.9%**	**0.6%**	**92.8%**
4	**5%**	**2.8%**	**0.8%**	**91.4%**
5	**5.4%**	**3.2%**	**1.1%**	**90.3%**
6	**6.1%**	**3.4%**	**1.4%**	**89.0%**
7	**6.9%**	**3.4%**	**1.8%**	**88.0%**
8	**7.7%**	**3.4%**	**2.1%**	**87.0%**
9	**8.7%**	**3.3%**	**2.3%**	**85.7%**
10	**9.6%**	**3.2%**	**2.5%**	**84.7%**
11	**10.5%**	**3.1%**	**2.7%**	**83.7%**
12	**11.3%**	**3.0%**	**2.8%**	**82.8%**

CHAPTER VI: CONCLUSIONS

U.S. ethanol production has increased dramatically since 2000. While there was significant growth in production from 2000 to 2005, there was a fundamental shift in ethanol production from 2005 to 2010. Ethanol production increased from 1.6 billion gallons in 2000 to 3.9 billion gallons in 2005 and to 13.2 billion gallons in 2010. The objective was to analyze whether the Renewable Fuels Standard (RFS) that was implemented in 2005 and expanded in 2007, has changed the relationship between corn prices and oil prices. The Renewable Fuels Standard mandates the use of specified amounts of renewable fuels, such as ethanol.

This study analyzed both national prices and the prices that an ethanol plant in western Kansas received for the ethanol that it produced to examine the impact that the creation and expansion of the RFS has had on prices. An analysis of these prices would provide insight into if the creation and expansion of the RFS has caused corn prices and oil prices to move together and ethanol and unleaded gasoline prices to move together.

The prices were analyzed to see if there was an increase in the degree of correlation after the creation and expansion of the RFS. Regression analysis of the national corn prices and the prices that Western Plains Energy paid for the grain that it used to produce ethanol; and regression analysis of the national price of ethanol and the price that Western Plains Energy sold its ethanol for were also used to study the impact of the RFS. Finally, the vector autoregression (VAR) model is used to analyze the dynamic relationships between the variables in the system: corn price, oil prices, ethanol prices, and unleaded gasoline prices.

A review of the correlations reveals that the creation and expansion of the RFS has resulted in corn and oil prices moving more closely together. This applies to both the national prices and the local prices for the Western Plains Energy ethanol plant in Oakley, Kansas.

The national average monthly corn and oil prices from 1985 to 2000 barely move together and from 2000 to 2005, when the RFS was created, they actually move in opposite directions. Following the passage and expansion of the RFS, corn and oil prices track closely together.

The national average monthly ethanol, unleaded gasoline and oil prices moved together throughout the 25-year period. The degree to which they moved together, decreased after creation of the RFS in 2005.

The prices that Western Plains Energy paid for the grain that it used to produce ethanol and oil prices moved in opposite directions from the time Western Plains Energy began producing ethanol in January 2004 and the creation of the RFS. Once the RFS was created, the price that Western Plains Energy paid for the grain that it used to produce ethanol and oil prices moved closely together. When the time period is further broken down to examine prices after the RFS was expanded, it reveals that Western Plains Energy's grain prices and oil prices tracked more closely together following the expansion of the RFS in 2007.

The prices that Western Plains Energy received for the ethanol it produced and national ethanol prices moved more closely together following the creation and expansion of the RFS. The price that Western Plains Energy received for the ethanol it produced and national unleaded gasoline prices also moved more closely together following the creation and expansion of the RFS. These relationships between the prices contradict the national trends.

The vector autoregression that was done on the national prices reveals that there is a weak relationship between corn and oil prices. The correlation matrix of residuals reveals that there is not a strong contemporaneous correlation between national corn and oil prices. The forecast error variance decomposition test reveals that both corn and oil are exogenous. The weak relationship between corn and oil prices in the vector autoregression may reflect the limited amount of time that has passed since the creation and expansion of the RFS.

The contradictory results suggest that more analysis needs to be done to clarify the relationship between corn and oil prices and determine if creation and expansion of the RFS has imported instability from the oil markets into the corn markets.

Further study of the relationship between ethanol and unleaded gasoline prices and ethanol and oil prices would be valuable. Greater analysis of the relationship between these prices could provide insight on the impact of the RFS.

Another area of further study that could help explain the relationship between the prices studies would be to examine if there has been a change in the type of investors who are purchasing the commodities whose prices are examined. An increase in the number of investors who are buying corn and oil as an investment, rather than as a product may explain some of the changes in the relationships between the prices studied.

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