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THE PRICE TRANSMISSION RELATIONSHIP BETWEEN ETHANOL, WHOLESALE GASOLINE, AND BLENDED RETAIL GASOLINE

Daniel H. Morris
University of Tennessee, USA

Scott D. Parrott
University of Tennessee at Martin, Department of Agriculture, Geosciences & Natural Resources, 205 Brehm Hall, TN 38238, USA, Email:sparrott@utm.edu

Joey Mehlhorn
University of Tennessee at Martin, USA

Rachna Tewari
University of Tennessee at Martin, USA

Ross Pruitt
University of Tennessee at Martin, USA

Abstract

The volatile relationship between agricultural commodity prices and fuel prices has been a topic of interest in local and global economies over the past several years. For most applications, the price of retail gasoline in the United States is a function of the underlying price of crude oil and the price of ethanol (made from corn) that is part of the blended fuel. The typical retail-level blend of fuel in the United States consists of ninety percent gasoline and ten percent ethanol. We apply a polynomial distributed lag to a price transmission model that incorporates ethanol prices as well as wholesale and retail level gasoline prices. Our results indicate the existence of asymmetry between wholesale and retail gasoline prices. Our results also indicated the lack of asymmetry between ethanol and retail gasoline prices.
Key Words: *Asymmetry, energy, ethanol, polynomial, price transmission*
Jel Codes: *E37, Q11, Q13, Q16, and Q41*

1. Introduction

This study focused on the effects of changes in the prices of pure ethanol and wholesale gasoline on the price of retail gasoline. We are adding to the previous literature by developing a wholesale to retail price transmission model incorporating ethanol prices. The prices of gasoline and ethanol can be volatile and market price swings can be devastating to the agricultural industry. It is therefore imperative to better understand the relationship between ethanol and gasoline so policy may be crafted to minimize the negative impacts while simultaneously promoting the longer-term goals of cleaner fuels in the energy industry. As a better understanding of the relationship between ethanol and gasoline prices is developed, industry will be better equipped to reduce the risk associated with major swings in the price of one of the commodities. Ethanol is a vital part of the agricultural sector in the United States, as around forty percent of the corn harvest is processed into ethanol to be blended with gasoline as a fuel additive (U.S. Department of Agriculture, 2017). The existing government mandate that ethanol be blended with gasoline provides support to the ethanol industry within the United States. For the near term, it appears that the federal mandate will not be suspended and ethanol production will continue into the foreseeable future.

This focus of this study will be to estimate the impact of the price relationship between ethanol, wholesale gasoline and retail gasoline. We will examine whether the price relationship between the fuels at the wholesale level and at the retail level is symmetric or asymmetric in nature. This analysis will be determined by examining how changes in wholesale gasoline and ethanol prices are passed through to the retail level.

2. Literature Review

The literature review consists of two parts. The first part of the literature review will discuss ethanol and its inherent relationship to gasoline. This was done to provide insight as to why fluctuations in grain prices and ethanol prices are directly linked to the final price of gasoline. The second portion of the literature review will focus on relevant examples of asymmetrical price studies.

2.1 Ethanol Industry Analysis

Ethanol (ethyl alcohol) is an alcohol-based fuel that is created by fermenting grain and separating the alcohol from the coarse grains, typically by means of distillation. Ethanol has been used to power machinery for years and has numerous properties that make it a suitable fuel source for internal combustion engines (Frazier, 2009). Ethanol is also a reliable fuel additive that can be blended with gasoline to curb the total amount of crude oil needed to meet energy demands. Recent research estimates that half of the gasoline sold in the United States contains up to ten percent ethanol (E10) (Frazier, 2009). Ethanol helps boost the octane of gasoline by two to three points in an E10 blend (Frazier, 2009). When blended with gasoline, ethanol acts as a reformulating chemical agent and adds an additional oxygen atom to the emissions during the combustion process. The result is a reduction in the total amount of pollutants created from the fuel exhaust of a gasoline-powered vehicle, making ethanol-gas blends a more environmentally friendly fuel source compared to pure gasoline.

2.2 Asymmetrical Price Relationships

Asymmetrical pricing describes whether downstream prices rise and fall at the same rate when stimulated by changes in upstream markets. It has been a topic of interest for researchers across a variety of industries, including fuel and energy. Peltzman (2000) investigated a large and diverse array of consumer and producer goods and found output prices rise faster than they fall in two out of every three markets examined. Studies conducted by Bacon (1991), Karrenbrock (1991) and Borenstein, et al. (1992) all focused on some aspect of the asymmetrical relationship between crude oil and gasoline.

An analysis of asymmetric pricing research has revealed several different conclusions about the direction and extent of price shocks as they move through pricing systems, but the general consensus is that there is indeed an asymmetric price relationship between crude oil and gasoline prices. The evidence of such a relationship is most apparent when crude oil prices are rising. Typically, gasoline prices rise as a direct response to higher crude oil prices. This relationship is not as clear when crude oil prices are declining. Bacon (1991) indicated that there was an asymmetrical price relationship between crude oil and gasoline prices in the

United Kingdom. Further studies conducted by Karrenbrock (1991) emphasized that there tends to be a stronger relationship between crude oil and gasoline prices under the conditions of rising prices. Borenstein, Cameron, and Gilbert (1992) suggested that gasoline prices do in fact respond asymmetrically to rising crude oil prices. They indicated that there is strong and ubiquitous evidence of asymmetry between crude oil and gasoline prices. Their research employed a bivariate error correction models that tested for asymmetry in price movements in gasoline and crude oil at various stages of the production and distribution process. Research conducted by Balke, Brown, and Yucel (1998) suggested that the relationship between crude oil and gasoline could be seen all the way from the refinery to the retail pump.

Other research is not so clear on the evidence of price asymmetry in price and output. Tinsley and Krieger (1997) concluded that negative asymmetry was more apparent in a manufacturing setting and positive asymmetry was seen more when producer pricing occurs. This result could be applied to the relationship between crude oil and gasoline as refiners act as manufacturers of gasoline since it is a byproduct of the refining process. The refiners price the gasoline, and other fuels, to vendors, which is an example of producer pricing. Tinsley and Krieger (1997) further conclude that the asymmetry in pricing may possibly be attributed to asymmetric movements in output and the sign of price responses were due to the utilization rate of the output, which in this case is fuel. Asymmetric pricing is more than an "econometric curiosity" as it provides details in regard to variations in average response time of prices within a certain industry (Tinsley and Krieger, 1997).

Researchers have completed numerous studies that tested for the symmetry between crude oil, fuel, and the overall price of energy. An example of this type of research can be found in a study conducted by Huntingdon (1998), who found that energy prices respond symmetrically to petroleum product prices. Huntingdon also discovered that the majority of asymmetry in the economy's reaction to crude oil price fluctuations occurred within the energy industry, and more specifically, within oil markets. Huntingdon's research was an attempt to answer the question as to whether changes in oil prices have a direct impact on macroeconomic activities or not. Huntingdon's work utilized vector autoregressive techniques to try to explain the impact that oil price shocks have on the overall economy. Chang, et al. (2012) suggest asymmetry and price adjustments in the ethanol industry may be affected by government regulations. Acquah and Ofosuhene (2013) tried to develop a model that would provide a better fit when testing for complete asymmetrical price relationships. This particular study noted various statistical methods that are used to test for asymmetrical pricing with most emphasis being placed on which asymmetric price model is the most reliable. They concluded that the accuracy of the asymmetric price model was dependent upon the size of the data set and the overall complexity of the model.

3. Data

The data used in this research was obtained from Oil Price Information Service (OPIS). We chose a market in the Southeastern United States that had readily available daily prices of each fuel component. To analyze the relationships between gasoline and ethanol prices, daily price data for the time period of March 2011 through September 2012 were used. The retail level regular unleaded gasoline blend price consisted of ninety percent conventional gasoline and ten percent ethanol and was calculated as the average daily price at local retail service stations in our test market. The daily wholesale price (unblended with ethanol) used in this study was also calculated as the average daily price of regular unleaded.

4. Methods of Analysis

Our first step of analysis included performing data correlations to determine the strength and magnitude of relationships among the price data in our analysis. After the data were examined using correlations and initial regressions, they were transformed using the Houck (1977) procedure in order to test for the presence of asymmetry. Additionally, the Granger Causality test was used to determine the direction of causality between retail prices and wholesale gasoline and ethanol prices. Finally, pair-wise and summary coefficient comparisons were then used to test for asymmetry within the data set.

The test for asymmetry begins with specifying both upstream and downstream variables. The upstream variable typically represents the price of a main input or a price at a lower market level compared to retail. The upstream prices used in this study are the prices of wholesale ethanol and regular unblended gasoline. A downstream variable is usually an output price or a price at a lower market level such as the retail price of a product. For this study, the downstream variable is hypothesized to be the retail price of gasoline. The Granger Causality test metric was used to specify the appropriate upstream and downstream relationship.

5. Results and Discussion

Table 1 contains the descriptive statistics for the major variables used in this analysis. The values are expressed as dollars per United States gallon. During the period of analysis, the range of variation in the variables was fairly stable relative to their averages as indicated by the coefficient of variation.

Table 1. Descriptive Statistics for Wholesale Gasoline, Ethanol and Retail Gasoline Prices from March 2011 to September 2012

	Descriptive Statistics		
Item	Retail	Wholesale	Ethanol
Mean ($)	3.41	2.98	2.75
Range ($)	2.99-3.84	2.55-3.47	2.29-3.19
Coefficient of Variation	0.06	0.07	0.09

To begin testing for price asymmetry between pure ethanol, wholesale gasoline, and retail gasoline, correlation coefficients were computed. The correlation coefficients were calculated to determine the length of lag in price response. As illustrated in Table 2, the value of the lagged correlation between wholesale gasoline and retail gasoline prices peaks at day five. This result indicates that the effect of a wholesale price change has the greatest impact five days later at the retail level and then begins to decline. The correlation tests revealed the lack of a lag relationship between ethanol and retail gasoline prices.

Table 2. Lagged Price Correlations of Wholesale Gasoline Prices With Respect to Retail Gasoline Prices

Wholesale Gasoline Price Periods (Lagged Days)								
	t	t-1	t-2	t-3	t-4	t-5	t-6	t-7
Retail Series_t	0.90312	0.91598	0.92251	0.93323	0.93714	0.93907	0.93774	0.93471

We then proceeded to develop a structural model that would allow the asymmetry tests to be carried out appropriately. The model assumes the following structural components:

$$P_{rg} = f\ (\text{Rising/Falling } P_{cg;}\ \text{Rising/Falling } P_{pe}) \quad (1)$$

where P_{rg} is the retail price of gasoline and is a function of rising/falling price of conventional (regular unblended) gasoline (P_{cg}) and the rising/falling price of pure ethanol (P_{pe}).

The next step involved testing for model specification using a Granger Causality test. The Granger Causality test determines the direction of causality between two potentially related variables. If wholesale gasoline prices are a function of retail gasoline prices, then the inclusion of wholesale gasoline prices as an explanatory variable could possibly create simultaneity bias (Kesselring, 2009).

Granger Causality tests were conducted in this study to ensure that the causality is unidirectional. The results indicated a causality flow from the wholesale gasoline and ethanol prices to the retail price of gasoline.

The next step in the statistical analysis was to identify the appropriate lag lengths for rising and falling prices by means of Generalized Least Squares (GLS) regressions. The lag lengths were determined by eliminating statistically insignificant parameters from the initial model and re-estimating. Results from this iterative procedure indicated an optimal lag length of 8 days for rising prices and a lag length of 11 days for falling prices. The lag length of 8 days for rising prices indicates a price increase takes 8 days to completely pass through the retail level while a price decrease takes 11 days to pass through.

The data were then converted into a format suitable to test for asymmetry. The Houck procedure was used to alter the price data into a form necessary to conduct asymmetrical testing. The Houck procedure tests for nonreversibilities in a particular data set. Nonreversibilities are most commonly expressed in terms of asymmetrical changes from a previous position in time, which makes the initial observation vital to the test.

The next step was to develop a polynomial distributed lag regression in order to estimate the lag distribution parameters. The equation for this procedure is defined as:

$$RP_t = \sum_{m=0}^{r} \beta_{1,m}\, WPR_{t-m} + \sum_{m=0}^{f} \beta_{2,m}\, WPF_{t-m} + \beta_3 EPR_t + \beta_4 EPF_t + e_t \qquad (2)$$

where RP is the daily retail gasoline price change from period 0 to period *t*, *WPR* is the sum of all daily increases in the wholesale gasoline price from period 0 to period *t*, *WPF* is the sum of all daily decreases in the wholesale gasoline price from period 0 to period *t*, *EPR* is the sum of all daily increases in the ethanol price from period 0 to period *t*, *EPF* is the sum of all daily decreases in the ethanol price from period 0 to period *t*, *r* is the lag length for rising wholesale gasoline prices, *f* is the lag length for falling wholesale gasoline prices and e_t is an error term.

In this study, we imposed a 5^{th} degree polynomial on the wholesale gasoline rising and falling model parameters based on the correlation relationships observed between retail and wholesale gasoline prices as illustrated in Table 2. The results of the polynomial lag regression are illustrated in Table 3. The parameter estimates for rising wholesale prices revealed the time period of 0 (immediate) and the lag periods of 3, 4, 5, 6, and 8 were all statistically significant at the 0.10 level. The parameter estimates for the falling wholesale price time lag periods of 1, 2, 3, 6, 7, 8, 10, and 11 were found to be significant at the 0.10 level.

To test for the presence of asymmetry, we imposed restrictions on the wholesale gasoline independent variables in the regression. The restrictions were then evaluated using an F-test. Pairwise comparisons can be made if both the estimates of the lag distribution for rising and falling wholesale prices are statistically significant at the same lag period. For example, a pairwise comparison cannot be made between WPR_t and WPF_t as the coefficient WPF_t is not statistically significant. However, WPR_t is statistically significant, which leads to the inference that a portion of an increase in wholesale gasoline prices was passed along immediately with remainder of the price increase passed along through the lag relationship. In the event of a price decrease, the current period wholesale price is not transmitted instantaneously because its coefficient was not significant. Research conducted by Borenstein et al. (1992) support the findings that changes in wholesale prices are not passed through immediately to the retail level. Their research findings indicated that changes in wholesale gasoline prices are not fully realized at the retail level until seven to fourteen days later. Pairwise comparisons also could not be made between the estimates of the lag distribution for WPR_{t-1} and WPF_{t-1}, WPR_{t-2} and WPF_{t-2}, WPR_{t-4} and WPF_{t-4}, WPR_{t-5} and WPF_{t-5}, and WPR_{t-7} and WPF_{t-7}.

Table 3. Regression Estimates of the Polynomial Lag Relationship Between Ethanol, Wholesale Gasoline and Retail Gasoline

Variable	Estimate
WPR_t	0.1520**
WPR_{t-1}	0.0795
WPR_{t-2}	0.0620
WPR_{t-3}	0.1005**
WPR_{t-4}	0.1476***
WPR_{t-5}	0.1495***
WPR_{t-6}	0.0880**
WPR_{t-7}	0.0234
WPR_{t-8}	0.1363**
WPF_t	0.0444
WPF_{t-1}	0.1530***
WPF_{t-2}	0.1142***
WPF_{t-3}	0.0495**
WPF_{t-4}	0.0148
WPF_{t-5}	0.0192
WPF_{t-6}	0.0443**
WPF_{t-7}	0.0628**
WPF_{t-8}	0.0580**
WPF_{t-9}	0.0421
WPF_{t-10}	0.0755*
WPF_{t-11}	0.2859***
EPR_t	0.2880
EPF_t	0.0108

Notes: *** = 0.01 level of significance; ** = 0.05 level of significance; * = 0.10 level of significance

A pair wise comparison could be assessed for WPR_{t-3} and WPF_{t-3}, WPR_{t-6} and WPF_{t-6}, and WPR_{t-8} and WPF_{t-8} as the coefficients for those prices were found to be statistically significant. These results are illustrated in Table 4. The pair-wise comparisons for these coefficients were not statistically significant as we failed to reject the null hypothesis in the F-test. The F-test results from the evaluation of the current period rising and falling ethanol prices were also not statistically significant which leads to the inference that there was no difference in retail pricing behavior under current period changes in ethanol prices.

The overall asymmetry test for the rising and falling wholesale gasoline prices dictated that only the first eight days can be evaluated as this was the end point of the rising lag. The overall asymmetry test results are also contained in Table 4. The null hypothesis in the F-test for overall asymmetry was rejected, indicating that when all time periods were considered together there was a difference in the way retailers transfer wholesale gasoline price increases to the customer versus wholesale gasoline price decreases. The F-test results lead to the inference that when comparing the first eight days after a change in wholesale gasoline prices, the price increases are transferred quicker than wholesale gasoline price decreases.

Table 4. Pairwise Comparison and Overall Asymmetry Results

Pairwise Comparison	P-Value of F-Test
Wholesale Gasoline Price Rise and Fall Time Period 3	0.3458
Wholesale Gasoline Price Rise and Fall Time Period 6	0.3560
Wholesale Gasoline Price Rise and Fall Time Period 8	0.2747
Overall Asymmetry (all time periods together)	<0.0001

The difference in the treatment of ethanol price changes versus wholesale gasoline price changes by retailers may be explained by the composition of gasoline. For this study, the retail gasoline mix consisted of ninety percent wholesale gasoline and ten percent pure ethanol. Therefore, a change in wholesale gasoline prices should have a larger impact on the retail price of gasoline due to the inherent relationship between the two. Ethanol price changes seem to have been absorbed in the transfer from the wholesale level to the retail level as it only represented a small portion of the retail gasoline blend.

6. Conclusions

The results of our study indicate retail gasoline prices respond with a lag to wholesale gasoline price changes and that there was no evidence of asymmetry with respect to the retail gasoline and ethanol relationship. Our results indicated retail gasoline prices respond faster to increases in wholesale gasoline than to decreases at the summary level (all time periods together). This result was illustrated by the test for asymmetry being both positive and significant when comparing the first eight days following a change in wholesale gasoline prices.

Based on the results of the model, it can be concluded that there was a statistically significant amount of price asymmetry between wholesale gasoline and retail gasoline in our test market. The fact that the level of asymmetry in our study is not as severe when compared to previous studies could be attributed to use of daily price data. Many of the previous studies of gasoline price asymmetry used yearly price data, but the findings of each study often varied greatly. Daily price data will have an advantage versus other aggregated forms of data in that they will more realistically capture the decision-making methods that retail firms evaluate when making price decisions at the final consumer level.

The asymmetrical relationship between retail gasoline and pure ethanol was more difficult to determine due to the lack of a significant lag relationship between retail gasoline prices and ethanol prices. Serra, et al. (2011) found that increases in ethanol prices are followed by increases in gasoline prices. However, their results were not based on the use of daily data nor did they employ a price transmission model similar to the methodology used in this paper.

The lack of asymmetry between retail gasoline and ethanol may be due to the fact that ethanol makes up a small percentage of the retail gasoline blend. Also, industries that produce and blend ethanol and wholesale gasoline for use at the retail level use hedging and forward contracting methods of acquiring their inputs, especially corn for ethanol production. These business strategies help produce the effect of smoothing price swings in ethanol as the corn used for current processing may have been purchased months in advance in order to help ethanol producers determine their costs of production. Also, as indicated in previous studies outlined in this paper, the level and magnitude of clean energy government support policies will no doubt continue to have an effect on the responsiveness of ethanol prices to real market fluctuations in corn and energy prices. In light of these findings, further research needs to be conducted to investigate the asymmetrical relationship between pure ethanol and retail gasoline prices over a longer period of time as well as an analysis of different ethanol and gas blends.

References

Acquah, H.D. and Ofosuhene, P. (2013). The Role of Model Complexity and the Performance of the Selection Criteria in Asymmetric Price Transmission Models. *Journal of Economics and Behavioral Studies*, 5(3), 157-163.

Bacon, R. W. (1991). Rockets and feathers: the asymmetric speed of adjustment of UK retail gasoline prices to cost changes. *Energy Economics*, 13(3), 211-218.

Balke, N.S., Brown, S.P.A., and Yucel, M.K. (1998). Crude Oil and Gasoline Prices: An Asymmetric Relationship? *Federal Reserve Bank of Dallas Economic Review,* First Quarter 1998, 2-11.

Borenstein, S., Cameron, A.C., and Gilbert, R. (1992). Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes? *National Bureau of Economic Research,* August, NPER Paper No. 4138.

Chang, C., L. Chen, S. Hammoudeh, and M. McAleer (2012). Asymmetric adjustments in the ethanol and grains markets. *Energy Economics*, 34, 1990-2002.

First Research. (2013). *Industry Profile: Biofuel Manufacturing.* Austin, TX. First Research Staff.

Frazier, R. S. (2009). Ethanol Gasoline Blends-Problems or Benefits for Customers? *Energy Engineering,* 106(1), 62-70.

Granger, C.W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica* 37(3), 424-438.

Houck, J.P. (1977). An Approach to Specifying and Estimating Nonreversible Functions. *American Journal of Agricultural Economics,* 59(3), 570-572.

Huntingdon, H.G. (1998). Crude Oil Prices and U.S. Economic Performance: Where Does the Asymmetry Reside? *The Energy Journal*, 19(41), 107-132.

Karrenbrock, J. D. (1991). The Behavior of Retail Gasoline Prices: Symmetric or Not? *Federal Reserve Bank of St. Louis Review,* July/August, 19-29.

Kesselring, R.G. and Bremmer, D.S. (2009). Presentation from 51st Annual Meeting of the Western Social Science Association: *Gasoline and Crude Oil: Evidence of Asymmetric Price Changes during 2008?* Albuquerque, NM.

Oil Price Information Service (OPIS). www.opisnet.com/about/opis.aspx.

Peltzman, S. (2000). Prices Rise Faster than They Fall. *Journal of Political Economy,* 108(3), 466-502.

Serra, T., D. Zilberman, J.M. Gil, and B.K. Goodwin (2011). Nonlinearities in the U.S. corn ethanol-oil-gasoline price system. *Agricultural Economics,* 42, 35-45.

Tinsley, P.A. and Krieger, R. (1997). Asymmetric Adjustments of Price and Output. *Economic Inquiry,* July, 35(3), 631-652.

U. S. Department of Agriculture (2017). Economic Research Service. *Bioenergy Statistics*. Washington, DC.