Ethanol Production and Gasoline Prices: A Spurious Correlation

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ABSTRACT

Ethanol made from corn comprises 10% of U.S. gasoline, up from 3% in 2003. This dramatic increase was spurred by recent policy initiatives such as the Renewable Fuel Standard and state-level blend mandates and supported by direct subsidies such as the Volumetric Ethanol Excise Tax Credit. Some proponents of ethanol have argued that ethanol production greatly lowers gasoline prices, with one industry group claiming it reduced gasoline prices by 89 cents in 2010 and $1.09 in 2011. The 2010 figure has been cited in numerous speeches by Secretary of Agriculture Thomas Vilsack. We show that these estimates were generated by implausible economic assumptions and spurious statistical correlations. To support this last point, we use the same statistical models and find that ethanol production "decreases" natural gas prices, but "increases" unemployment in both the U.S. and Europe. We even show that ethanol production "increases" the ages of our children. Overall, we see no compelling reason to believe that the effect of ethanol use on gasoline prices has been more than $0.10 per gallon.

Keywords: Ethanol Production, Gasoline Prices, Renewable Fuel Standard, U.S. Policy

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"As a result of our biofuel industries, consumers across America are paying about $0.90, on average, less for gas than they would otherwise pay. So, it's a great opportunity for consumer choice, it's a job creator, and it improves income opportunities for farmers."

—Secretary of Agriculture Thomas Vilsack, 10/24/11.

1. INTRODUCTION

The median American household spent over 8 percent of its income on gasoline in 2011. Gasoline price fluctuations therefore significantly affect household budgets, and government policies that affect gasoline prices resonate widely. The most prominent recent policy has been to promote the use of ethanol as an ingredient in gasoline. This year, 10 percent of finished motor gasoline in the United States will be comprised of ethanol made from corn, up from 3 percent in 2003. The main forms of government support have been explicit subsidies through the Volumetric Ethanol Excise Tax Credit (VEETC) and even larger implicit subsidies through such policies as the Renewable Fuel Standard and state-level blend mandates.[1] The benefits of ethanol over gasoline are that it diversifies our fuel mix, can have lower emissions, and increases farmer and landowner

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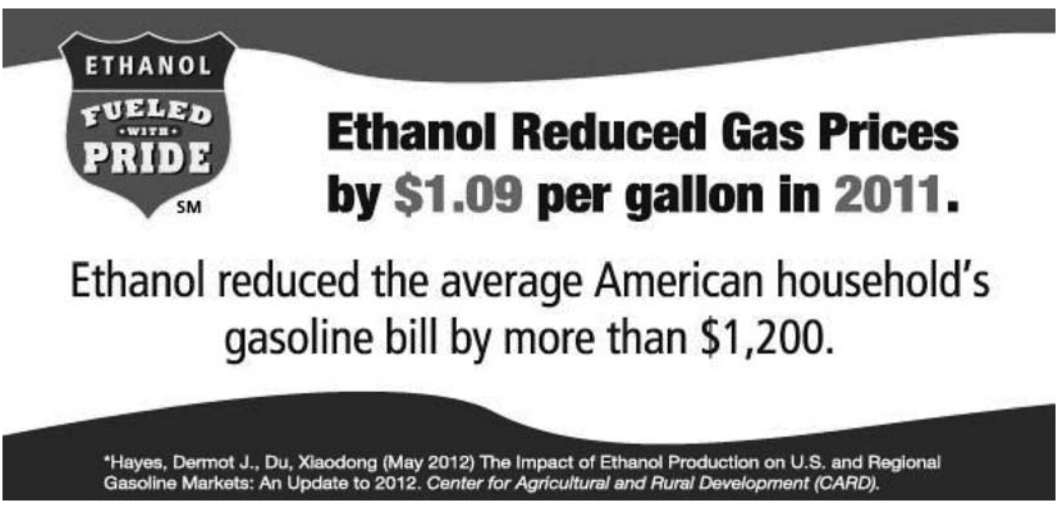
1. See Carter et al. (2012) for more on the growth of the ethanol industry and its effect on agricultural markets.

Figure 1: Renewable Fuel Association Ad Campaign, 2010

Note: http://www.zimmcomm.biz/images/rfa/rfa-dc-ad.jpg

Figure 2: Renewable Fuel Association Ad Campaign, 2011



Note: http://chooseethanol.com/page/-/ee/rfa-assoc/rotator/2011_Gas_Price_Ad.gif

wealth. An additional potential benefit is that it may relieve gasoline refining capacity constraints during peak demand periods; this would in turn lead to lower gasoline prices.

The national trade association for the U.S. ethanol industry, the Renewable Fuel Association (RFA), recently launched an advertising campaign claiming ethanol production lowered gasoline prices by 89 cents in 2010 and $1.09 in 2011 (see Figures 1 through 3). The U.S. Secretary

Figure 3: Renewable Fuel Association Metro Bus Billboard

Note: http://www.abengoa.es/htmlsites/boletines/en/octubre2011/images/produccion1.jpg

of Agriculture Thomas Vilsack has endorsed these claims in several speeches (see the opening quote of this paper for one example). These estimates are derived from regression models that use monthly regional data to estimate the relationship between ethanol production and the profit margin for oil refiners in text.[2] Thus, the effect comes not from a reduction in world crude oil prices, but rather from a decline in the relative price of gasoline to crude oil.

Given the importance of these estimates, we investigate their robustness. We show that they are driven by implausible economic assumptions and spurious statistical correlations. Put simply, the empirical results merely reflect the fact that ethanol production increased during the sample period whereas the ratio of gasoline to crude oil prices decreased. These trends make the empirical analysis extremely sensitive to model specification; however, we find that empirical models that are most consistent with economic theory suggest effects that are near zero and statistically insignificant.

Several other papers have addressed the effect of ethanol policy on gasoline prices. In contrast to Du and Hayes, none of them focused on the oil refining margin. McPhail (2011) estimates, using a structural VAR, that ethanol demand shocks have no effect on oil prices in the first few months, but a significant negative effect after a year. McPhail identifies this effect from ethanol price shocks by assuming that short-run (i.e., within-month) ethanol supply is perfectly inelastic. She does not report an effect on gasoline separately from that on crude oil. Serra et al. (2011) fit a smooth-transition vector error correction model to the U.S. corn-ethanol-oil-gasoline price system and find that ethanol price increases Granger cause oil price increases. Thus, the model predicts that a policy-induced increase in demand for ethanol would slightly increase gasoline prices. Drabik (2012) argues using a simulation model that the expansion of ethanol production has reduced

2. Du and Hayes (2009), Du and Hayes (2011), and Du and Hayes (2012).

gasoline prices by \$0.05–\$0.10 per gallon. Rajagopal et al. (2007) and DeGorter and Just (2009)) report similarly small effects using similar simulation methods.

Because ethanol production increased smoothly during the sample period, statistical analysis with this variable is fraught with danger. It is strongly correlated with any trending variable. To illustrate this point, we take the same empirical models in Du and Hayes (2011) and Du and Hayes (2012) and use them to "explain" variables that have no material relationship to U.S. ethanol production: the U.S. price of natural gas and unemployment rates in the U.S. and the European Union. Our resulting estimates suggest that increases in ethanol production "cause" reductions in natural gas prices but increases in unemployment. The estimates imply that, had we eliminated ethanol in 2010, natural gas prices would have risen by 65 percent and unemployment would have dropped by 60 percent in the U.S., 12 percent in the EU, and 42 percent in the UK. To further underscore this point, we provide a silly example. Again, using the same empirical models in Du and Hayes (2011) and Du and Hayes (2012), we show that ethanol production "causes" our children to age. Obviously, anyone using these models to advocate eliminating ethanol production to end the Great Recession or make children age more slowly would be greeted by extreme skepticism. We encourage similar skepticism about the estimated effect of ethanol on gasoline prices generated from these models.

The remainder of the paper is organized as follows. Section 2 discusses the economics of how ethanol production may influence gasoline prices. Understanding these basic economic concepts puts useful bounds on the effect. Section 3 discusses how these basic concepts can guide the choice of the empirical model. In Section 4 we discuss the empirical models we employ. The data are discussed in Section 5. Section 6 reports the estimated results from the models used in Du and Hayes and alternative specifications. Section 7 offers some concluding remarks.

2. BASIC ECONOMICS OF OIL REFINING

We begin with a basic discussion of how ethanol production might influence gasoline prices. In doing so we discuss the channels through which this is possible and stress the difference between short-run effects—those that might last one or two months—and long-run effects—those price effects that can be sustained in the industry. Simple economic calculations allow us to place loose bounds on the impact ethanol production has on the price of gasoline in both the short and long run.

The largest component of the price of gasoline is the cost associated with crude oil. Oil refineries produce numerous products from each barrel of crude, but we can obtain a rough approximation to the contribution of the cost of crude to the price of gasoline by allocating it proportionally to each product. For example, when oil is \$100 per barrel (i.e., \$2.40 per gallon), approximately \$2.40 of the price of a gallon of gasoline could be assigned to the cost of the crude in that gallon.[3] Ethanol production has a minimal impact on the price of crude oil. In the world market for crude oil, an individual country's supply and demand decisions are small relative to the market as a whole—even for a country the size of the U.S. To put this into perspective, the U.S. consumes roughly 20 percent of world oil. Roughly half of the U.S. oil consumption goes toward gasoline, and ethanol comprises roughly 10 percent of our gasoline-blend fuel. Thus, on a volu-

3. It takes approximately two gallons of crude oil to make a gallon of gasoline. The remaining gallon of crude becomes other refined products such as diesel and heating oil. Allocating the \$4.80 equally by volume implies \$2.40 to gasoline and \$2.40 to the other refined products.

metric basis, U.S. ethanol constitutes about 1 percent of world oil use. However, ethanol has 33.3 percent less energy than gasoline and thus engines require more ethanol than gasoline to go the same distance. So, U.S. ethanol replaces just 0.67 percent of world oil. Crude-oil supply and demand would need to be very inelastic before such a quantity had a noticeable effect on price (see Rajagopal et al. (2007) and DeGorter and Just (2009)).

In analyzing the oil price spike of 2007–08, Hamilton (2009) argues that a short-run demand elasticity of -0.06 and a short-run supply elasticity of zero fit the observed price patterns. This demand parameter is consistent with that estimated by Hughes et al. (2008) using regressions with time series data. However, the demand elasticity is much larger over longer horizons because consumers adapt to high prices by driving less and buying more fuel-efficient vehicles. For example, Hamilton notes a large switch in consumer's purchases from SUVs to smaller cars when oil prices peaked in summer 2008. This adaptation was followed by a steep decline in prices, a decline that accelerated when the financial crisis hit world markets several months later. Thus, although a -0.06 demand elasticity implies that removing 0.67% of global crude oil demand would decrease oil prices by 11%, this effect only applies in the short run. Over a year or longer the demand elasticity is much greater and suppliers would respond by changing production. It is difficult to estimate reliable long-run elasticities, and we are unaware of such estimates, but some introspection is useful. If the long-run supply elasticity were 0.25 and the long-run demand elasticity -0.25, then the effect of U.S. ethanol production on world crude oil prices would be $0.67/(0.25 - -0.25) = 1.33\%$ or about \$0.03 per gallon on \$100 oil. We see these elasticities as likely to be too small and so we view 1.33% as an upper bound of the effect.

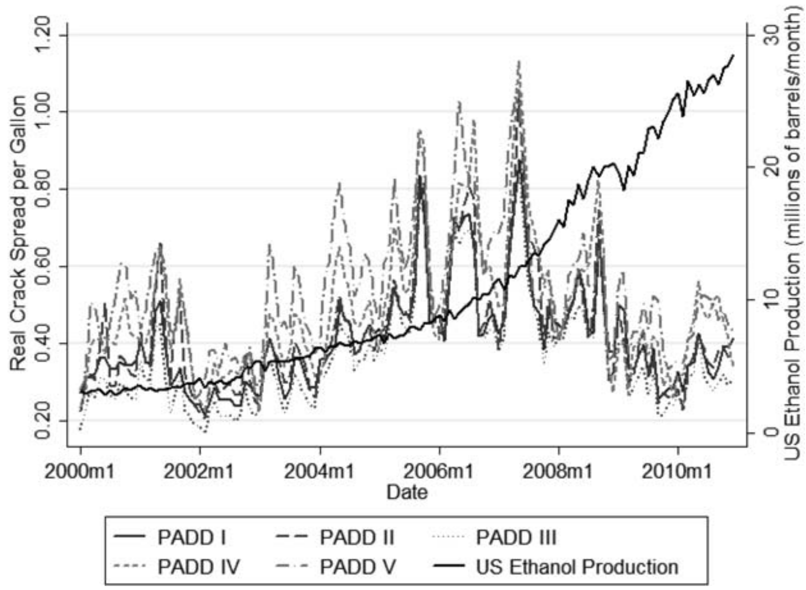
Ethanol production may affect gasoline prices through other channels, however. Retail gasoline prices typically exceed crude oil prices by \$0.70–\$1.20 per gallon, although this price spread can spike much higher for short periods of time. About 45 cents of this premium represents state and federal taxes and the remainder is the margin associated with the refining and transportation of gasoline. Du and Hayes focus on the refining margin. They estimate the relationship between ethanol production and two measures of the refining margin: the crack spread and crack ratio. The crack spread equals the weighted average price of the two main refined products (gasoline and distillate fuel oil) minus the price of crude oil. Du and Hayes define the crack ratio as the price of gasoline divided by the price of oil. Based on their crack-ratio models, they conclude that the refining margin would have expanded by \$0.89 if ethanol had been removed from the market in 2010 and \$1.09 if it had been removed in 2011.

From every 100 gallons of crude oil, the typical oil refinery produces 46 gallons of gasoline and 28 gallons of distillate, which is used mostly for diesel fuel and heating oil. In addition, it produces 6 gallons of still gas and petroleum coke that is re-used as fuel in the refining process and about 27 gallons of other products such as jet fuel, kerosene, feedstock for petrochemical use, petroleum coke for sale, and liquefied refinery gases.[4] The sum of refinery outputs equals 107 gallons because the refined products are less dense than crude oil, so they have greater volume. Based on this output mix, the most common approximation to the profit margin for oil refiners is the 3:2:1 crack spread, which is:

$$crack\ spread = \frac{2}{3} price_{gas} + \frac{1}{3} price_{dist} - price_{oil}, \tag{1}$$

4. These quantities are based on data from the Energy Information Administration. Specifically, we use the Refinery Yield (http://www.eia.gov/dnav/pet/pet_pnp_pct_dc_nus_pct_m.htm) and Fuel Consumed (http://www.eia.gov/dnav/pet/pet_pnp_capfuel_dcu_nus_a.htm) tables.

Figure 4: Real Crack Spread over Time (per gallon)



where each price is measured in dollars per gallon.

Although it is often referred to as a measure of profit, the crack spread also includes refining costs. The largest single cost of operating a refinery is energy, which makes up about half of operating costs.[5] Most of this energy is generated by burning by-products of the refining process, but a typical refinery also uses quantities of natural gas and electricity with energy equivalent to 3% of the crude oil processed.[6] In addition, the refining industry uses 3 gallons of natural gas plant liquids (NGPL) as a raw material for every 100 gallons of crude oil. NGPLs are hydocarbons in natural gas that are lighter than most crude oil and produce feedstocks for petrochemical products as well as some gasoline and distillates. Thus, we expect the crack spread to expand when the prices of crude oil and natural gas increase and to contract when these prices decrease.

Figure 4 plots the crack spread for each Petroleum Administration for Defense Districts (PADD) over time.[7] PADDs are regions of the country represented in Figure 13. The average crack spread, in 2011 dollars, from 1995 to 2011 was 41 cents per gallon; the crack spread is also below 48 cents 75 percent of the time. During this time period the lowest crack spread was 15 cents in February of 1999 in PADD III, and the highest was $1.17 in PADD IV in May of 2007. The high crack spread of $1.17 was very short lived, falling by 20 cents in June and then another 20 cents in July.

5. See http://www.eia.gov/cfapps/frs/frstables.cfm?tableNumber = 28.

6. We convert all quantities to energy equivalent terms using the assumptions that one gallon of crude oil equals 114,000 BTU, one cubic foot of natural gas equals 319 BTU, and one kilowatt hour of electricity equals 3,413 BTU.

7. For the refined products, we use the total gasoline wholesale/resale price by refiners and the wholesale price of no.2 distillate fuel (diesel), and for the input price we use the national average refiner acquisition cost of crude oil. PADD-specific crude oil acquisition costs exist only back to 2004, which is why we use the national series. The gasoline prices exclude taxes. According to their description, these are the same series used by Du and Hayes. We deflate by the urban consumer price index (CPI).

There is an economic reason why the crack spread has not exceeded 60 cents for more than a few brief periods in the last 30 years.[8] When the crack spread is high, large profits encourage entry into the refining industry, which in turns puts downward pressure on the crack spread. Similarly, when the crack spread is too low, refineries will no longer be profitable, and exit must occur. This will in turn put upward pressure on the crack spread. For the industry to be in a long-run equilibrium, the crack spread must be high enough for refineries to cover operating costs and recuperate their investments in capital, but low enough not to encourage entry. Figure 4 illustrates that the crack spread is currently very low and refineries are exiting; the number of operating refineries fell from 146 in 2008 to 137 in 2011. The exit of refineries will, in time, put upward pressure on gasoline prices and increase the profitability of remaining refineries. Thus, even if ethanol contributed to a low recent refining margin, this effect will not persist.

The long-run bounds on the refining margin do not necessarily hold for short-term fluctuations in profitability. In the short run, for example within a given month or two, gasoline prices can rise considerably and not attract entry if the rise is believed to be temporary; similarly, gasoline prices might fall considerably and not lead to exit. This is, perhaps, best illustrated by the seasonal fluctuations of gasoline prices. Figure 4 illustrates that each summer the crack spread increases as capacity constraints for refined products are more likely to bind. From 1995 to 2011, the average December crack spread in real terms was 34 cents, but the average May crack spread was 49 cents.

Crack spreads still have a lower bound in the short run, however. There is a short-run lower bound driven by the profit maximizing condition that the value of refined products must exceed short-run average variable costs, which include the price of crude oil. If prices for refined products fall too low, refineries will temporarily close. There is also a short-run upper bound driven by the cost of importing refined product from outside of the geographical area.

Ethanol production could have affected the refining margin in the short run if it had arrived when refineries were producing at capacity. High gasoline demand can cause refineries to hit capacity constraints, which in turn increases the refining margin. If more ethanol were made available to the market at such a time, then capacity constraints would be relieved, the refining margin would decrease and gasoline prices would decline. Gasoline prices would have declined in the longer run even without ethanol because more refining capacity would be built or gasoline imports would increase. The effect of ethanol in this scenario is only to speed up the price decline. Alternatively, if the refining industry has market power, then ethanol production can increase the elasticity of the residual-demand curve faced by refiners. This would, in turn, reduce market power and gasoline prices.

Du and Hayes estimate regression models that control for some factors that may affect refinery profitability in the short-run, such as inventories and capacity utilization, but they do not address the length of run in their discussion of the effects of ethanol production. As an example, suppose their regression results are true—ethanol production decreased gasoline prices by \$1.09 per gallon in 2011. Eliminating all ethanol would have increased the average difference between wholesale gasoline and oil prices from 44 cents to \$1.53 in 2011. This is 41 cents larger than the largest spread observed in a single month and more than twice as large as the highest average spread observed over a full year during the sample period. Such a dramatic price shock may be feasible in a single month if all ethanol production were surprisingly and immediately removed from the market. However, for the estimated reduction in gasoline prices to last for a full year or longer—

8. In the 12 years leading up to the period shown in Figure 4, the national average real crack spread was quite similar to its values between 1995 and 2004; it ranged between 30 and 50 cents and averaged 35 cents.

which is the implicit assumption in the RFA's claims—we would have to expect that these historic high spreads would not increase capacity utilization. According to the EIA, refinery capacity utilization averaged 86.3% in 2011, which is lower than every year from 1992–2007.[9] Even if this idle capacity could not be utilized for gasoline production, new refining capacity or import sources would quickly be attracted by such massive profit margins.

Ethanol is not a perfect substitute for gasoline, which implies additional channels through which it could affect retail motor fuel prices. Ethanol contains two-thirds the energy of gasoline, and it has higher octane content. In recent years, ethanol has made up about 10% of finished gasoline, so the energy content in each gallon of gasoline has been about 3% less than it would have been if there was no ethanol. If energy content were the only difference between ethanol and gasoline, then refiners would be willing to buy ethanol at prices up to two-thirds the price of gasoline. However, the high octane content of ethanol increases its value above this threshold. If refiners were to use less ethanol, they would use more of octane enhancers such as reformate and alkylates, which are refined petroleum products with higher value than regular gasoline blendstock.

Between 2006 and 2011, the relative price of ethanol to gasoline averaged 0.9. It is difficult to ascertain the extent to which this price exceeds marginal willingness to pay because liquid markets for reformate and alkylates do not exist. As such, it is unclear whether ethanol mandates increase gasoline prices through these channels because the price of ethanol exceeds marginal willingness to pay, or whether ethanol prices are below willingness to pay, in which case ethanol use decreases gasoline prices. However, although these details are critically important for real-world oil refiners trying to maximize profit, they affect fuel prices by only a few cents and thus have small effects on refining margins relative to factors such as capacity constraints and the cost of energy used in refining.

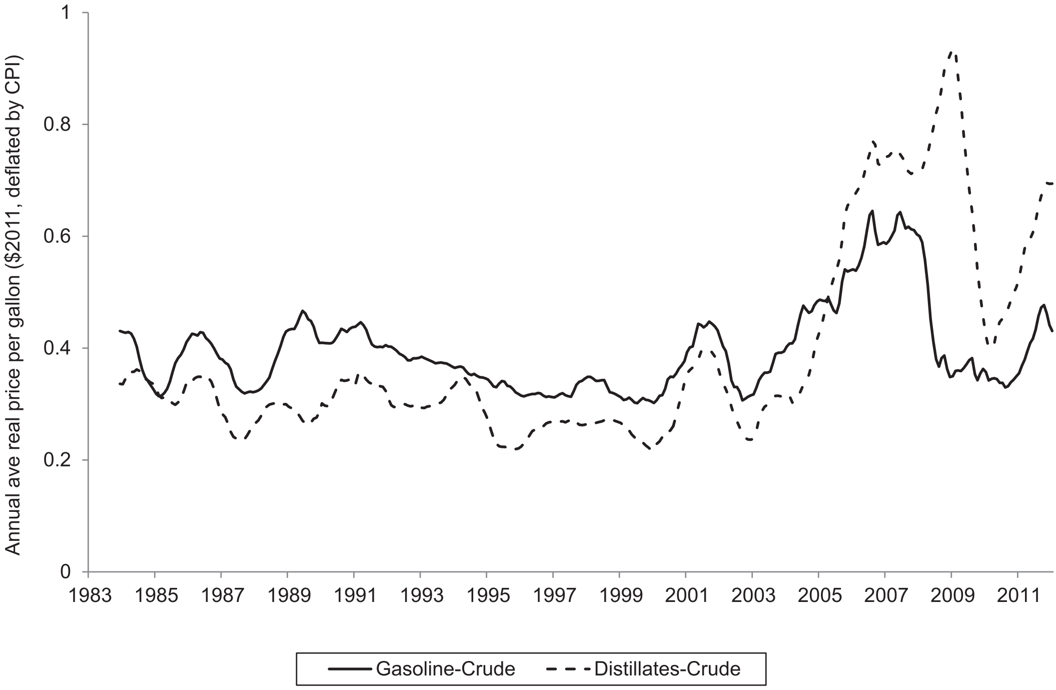
The preceding discussion assumes that distillate prices do not change in response to ethanol use. Specifically, if removing ethanol were to cause more crude oil to be refined, then production of distillates would increase and distillate prices would decline.[10] We investigate the extent to which this mechanism could accommodate a large gasoline-price effect but a small effect on the crack spread. Figure 5 shows the annual real price spread between each of the two main refined products and crude oil, i.e., it shows the two components of the crack spread. According to the results of Du and Hayes, removing ethanol production in 2011 would have increased the gasoline-oil price spread from \$0.44 to \$1.53 per gallon, which is more than double the largest price spread observed in any 12-month period in the data. Suppose that removing ethanol would have decreased the price spread for distillates by \$0.47 from its 2011 level to its lowest observed level in the sample, which was \$0.22 in 1999. Then the net result would be an increase in the crack spread of $(2/3)*1.09-(1/3)*0.47=\$0.57$. This increase would generate the highest crack spread observed in the past 30 years and cause it to be more than twice its average in the pre-ethanol period. It seems implausible that removing ethanol would have a greater than \$0.47 effect on distillate prices.

Figure 5 shows that distillate prices were less than gasoline prices before 2006 and have exceeded gasoline prices since that time. At first blush, this pattern suggests that ethanol may have significantly affected distillate prices. However, three additional factors have placed upward pressure on distillate prices and together these factors dominate the possible effect of ethanol. First, in 2006 the U.S. EPA adopted an Ultra-Low-Sulfur standard for diesel fuel. This standard required

9. See http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm

10. Refiners have some capacity to respond to relative price changes by changing the mix of outputs produced from each barrel of oil.

Figure 5: Real Price Spread between Refined Products and Crude Oil



substantial capital investment by refineries and increased refining costs. A 2001 Department of Energy report estimated that these costs would be about $0.07 per gallon,[11] but crude oil prices in 2011 were triple those projected in 2002 so the realized incremental cost of the standard likely exceeded $0.07. Second, diesel-powered cars have gained significant market share around the world, especially in Europe. In 1997, diesel cars made up 23% of new car registrations in Europe, but this proportion increased to 50% by 2010.[12] This change caused an increase in demand for diesel, and is one reason that U.S. distillate exports increased sixfold between 2004 and 2010.[13] Third, the price of distillates varies more strongly with the price of crude oil than does the price of gasoline, which may reflect differential production costs as well as a lower elasticity of demand for distillates than gasoline. In the U.S., distillates are used primarily for home heating and commercial transportation, whereas gasoline is used mostly for individual transportation. A smaller demand elasticity for distillates would cause the price of distillates to increase relatively more than the price of gasoline when oil prices increase.

Distillate prices were $0.10 below gasoline in 2004 but exceeded gasoline by $0.60 in 2008 and $0.20 in 2011. Although factors other than ethanol can explain this pattern, it is worth asking how much ethanol could explain. The effect of ethanol production on distillate prices depends on the elasticity of demand for diesel and heating oil, the extent to which refiners can change their product mix, and the marginal cost of changing the product mix. Distillate production in U.S. refineries increased from 23.2% of refinery output in 2002 to 28.9% in 2011. About half of this increase came from reduced gasoline output, which went from 47.3% of output in 2002 to 44.9% in 2011.[14]

11. http://www.eia.gov/oiaf/servicerpt/ulsd/index.html

12. Source: European Automobile Manufacturers Association. http://www.acea.be/collection/statistics

13. See http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid = 5&pid = 54&aid = 4.

14. See http://www.eia.gov/dnav/pet/pet_pnp_pct_dc_nus_pct_a.htm.

If refiners had no capacity to change their product mix, then an ethanol-induced decrease in gasoline production would cause an equal reduction in distillate production. However, the observed change in product mix suggests that refiners do have the ability to increase distillate production and thereby mitigate any effect of ethanol on distillate prices. Thus, we expect the response of distillate prices to ethanol production to be small.

In summary, the basic economics of oil refining suggest that removing ethanol production would increase crude oil prices by less than \$0.03 per gallon over a time horizon of a year, increase refining margins in the short-run if oil refiners were producing at close to capacity, and possibly have additional effects of a few cents per gallon depending on the price of ethanol and the indirect effects on distillate production. These calculations suggest that the \$0.89 and \$1.09 numbers are an order of magnitude too large. We next discuss several choices a researcher must make in order to estimate the relationship between gasoline prices and ethanol production and how they relate to the discussion above.

3. ISSUES RELATED TO MODEL SPECIFICATION

We start with the empirical models of Du and Hayes, who use monthly PADD-level data on either the crack ratio or the crack spread and include a number of covariates. The key covariate is the monthly production of ethanol in the U.S. The other covariates are: the PADD-level stock of oil and gasoline reserves; PADD-level refining capacity; PADD-level gasoline imports; PADD-level Hirschman-Herfindahl Index for refining concentration; a dummy variable for supply disruptions; and a set of month and PADD fixed effects. They include all dependent and independent variables in levels in an ordinary least squares regression.[15]

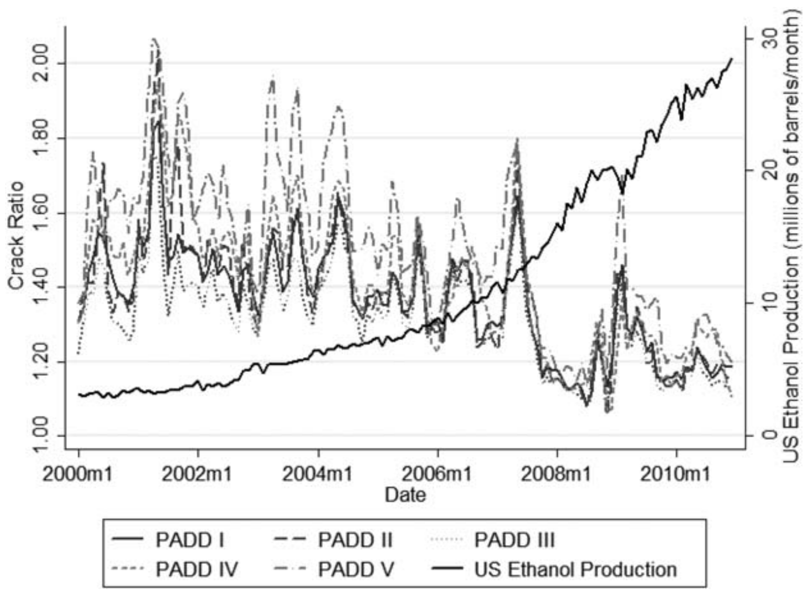
3.1 Time Horizon and Trend

The first decision a researcher must make if she is interested in estimating the impact of ethanol production on gasoline prices is: "what time horizon am I interested in"? For example, she could ask what would happen to gasoline prices over the course of the next month if ethanol suddenly vanished from the market. This horizon, however, is of very little policy relevance. Policies seek to increase ethanol production over the course of years, having very little impact in any one month. For example, the Renewable Fuel Standard slowly increases ethanol requirements over a 10-year period and says little about what should happen in any one month.

Figure 4 shows that ethanol production increased smoothly during the 11-year sample period, with the exception of a downward blip during the financial crisis in the fall of 2008. This trend causes ethanol production to be strongly correlated with any variable that increased or decreased during the same period, especially if that variable also experienced a blip during the financial crisis. These patterns present an empirical challenge. To rule out omitted variables bias due to coincidental trends, the researcher must control for the trend or, equivalently, detrend the data. However, once the data are detrended, only short-run fluctuations remain, so the researcher is locked into studying the short run.

15. Du and Hayes (2009) uses an instrumental variables approach for gasoline imports. However, the numbers cited by the RFA and Secretary Vilsack are based on Du and Hayes (2011) and Du and Hayes (2012) which explicitly say the authors estimate the model using ordinary least squares (page 3 in both papers).

Figure 6: Crack Ratio and Ethanol Production over Time



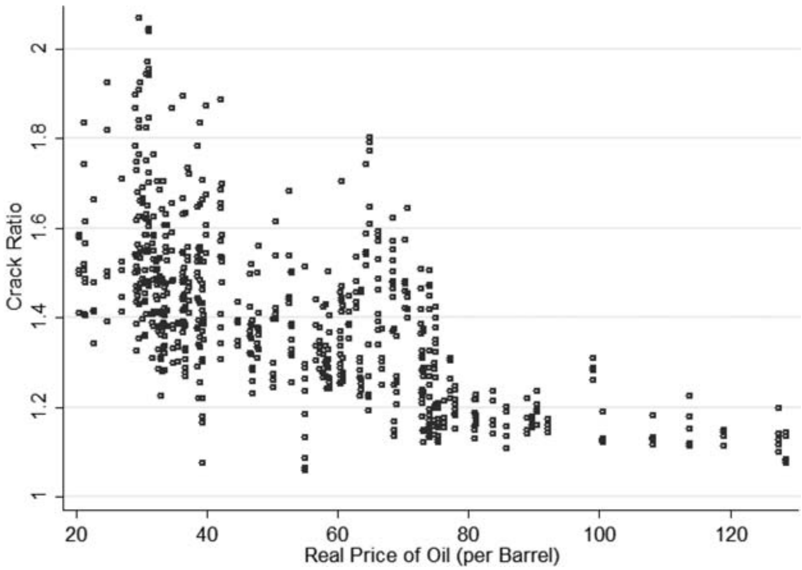
The discussion in Section 2 can help resolve these issues. In the long run, the crack spread is driven by changes in oil refining technology, the cost of capital, and average operating costs. Controlling for these factors reduces the chance of obtaining spurious results due to coincident trends. In particular, we show in Section 6 that using the prices of crude oil and natural gas to control for the energy cost of refining dramatically reduces the estimated effect of ethanol on the crack spread and crack ratio. Figure 6 plots the crack ratio in each PADD over time, along with U.S. ethanol production. It shows that the crack ratio has steadily fallen, which suggests that the crack ratio may be particularly susceptible to generating spurious results due to coincident trends.

3.2 Choice of Dependent Variable

Profitability of a refinery depends on the difference between the prices of the various refined products and the costs of production, which are dominated by the price of crude oil. Therefore if ethanol production reduces refinery margins, then it will operate through a reduction in the difference between gasoline and oil prices, not a proportional change in gasoline prices relative to oil prices, as a crack ratio model requires.

Put differently, the crack ratio model requires that if oil prices increase by 20 percent, all else equal, gasoline prices should also increase by 20 percent. If this were true, however, the profitability of refineries would increase. To see this, suppose the price of oil is \$2.00 per gallon and the price of gasoline is \$2.40 implying a crack spread of 40 cents and a crack ratio of 1.2. Suppose the energy-cost of refining is \$0.10 per gallon. Ignoring the non-energy and non-raw-material costs of refining, refineries earn 30 cents per gallon of producer surplus. Now suppose the price of oil increases to \$4.00 and the energy-cost of refining to \$0.20 per gallon. If nothing else changes, the crack ratio model would imply that the price of gasoline would increase to \$4.80. Refineries would now earn 60 cents per gallon in producer surplus (again ignoring other costs). However, if the marginal refinery was just breaking even when oil prices were \$2.00, we would

Figure 7: Crack Ratio versus the Real Price of Oil (per barrel)



now expect to see entry, because this marginal refinery would now be earning a positive economic profit.

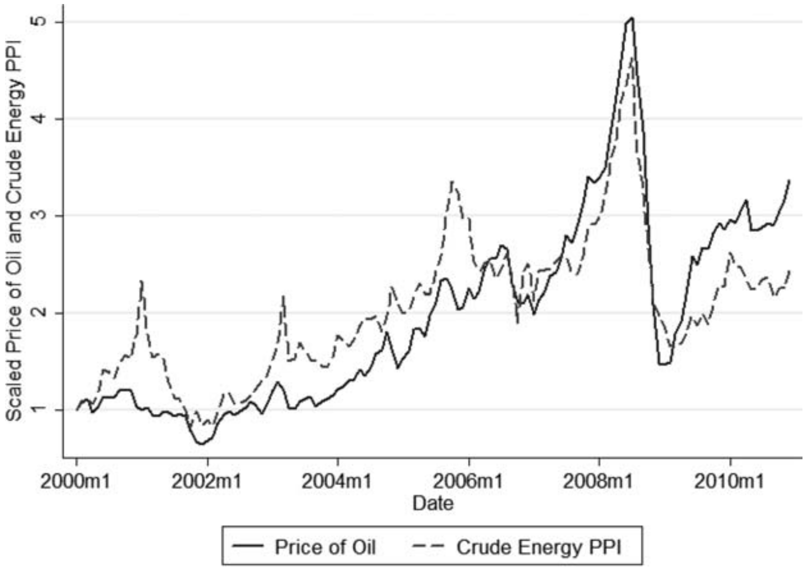
This discussion suggests a negative relationship between the crack ratio and oil prices, all else equal. Thus, crack-ratio models that exclude crude oil as a regressor make the implicit assumption that the crack-ratio ratio is independent of the price of oil. The above discussion and the data contradict this. Figure 7 is a scatter plot of the crack ratio and oil prices. There is a strong negative relationship; when oil prices increase, the crack ratio falls.[16] By not controlling for the price of oil in their crack ratio empirical models, Du and Hayes likely overstate the impact of ethanol on gasoline prices. Over their sample, both oil prices and ethanol production increased; the simple correlation between the two variables is 0.73. In a model of the crack ratio that omits the price of oil, the estimated ethanol effect captures both a portion of the oil-price effect and any ethanol effect that may or may not exist.

We report results for models both with the crack ratio and the crack spread as dependent variables and we control for the real prices of oil and natural gas to partially capture refining costs. Following Du and Hayes, we treat the price of crude oil as exogenous in these regressions.[17] We also treat natural gas prices as exogenous as changes in refining margins are unlikely to have large effects on the price of natural gas. The crack spread models produce estimates of the effect of ethanol production on refinery profit margins. As discussed in Section 2, it is possible that such

16. The simple correlation is -0.67.

17. It could be argued that the crude oil price is endogenous in this regression because this price is in the denominator of the dependent variable. Does using the crude oil price as a right hand side variable entail putting the same thing on the left and right hand side of the model? This endogeneity argument only holds if the refining margin in the U.S. feeds back to world oil prices. The magnitude of any such feedback is likely to be negligible. Put another way, arguing that an endogenous oil price confounds the estimated ethanol effect in these models requires making the implausible argument that increased ethanol production reduces refining margins by *increasing* the price of oil rather than by *decreasing* the price of gasoline.

Figure 8: The Price of Oil and the Energy Sector PPI over Time



models under-estimate the magnitude of the effect on gasoline prices because ethanol could cause an increase in the price of other refined products such as distillates. We explore this possibility when presenting our results.

3.3 Controlling for Inflation

Because the data used in the analysis cover at least 10 years, the crack spread should be deflated to control for inflation—the overall change in prices over the time period. Deflating prices is important because \$100 in 2000 is worth less than \$100 in 2010 because it is able to buy less of a given basket of goods. Du and Hayes deflate prices by the producer price index (PPI) for crude energy material, which measures changes in energy prices over time. Deflating by the PPI for crude energy material does not account for inflation and makes the crack spread measure very close to the crack ratio.

Figure 8 plots both the crude energy PPI and the price of oil both scaled so that they begin at one and reveals their close relationship. Therefore, by deflating the crack spread by the crude energy PPI essentially divides the crack spread by the price of oil. This leads to the following:

$$\frac{price_{gas}-price_{oil}}{Energy\ PPI} \approx \frac{price_{gss}-price_{oil}}{price_{oil}} = \frac{price_{gas}}{price_{oil}} - 1 = crack\ ratio - 1 \qquad (2)$$

We show in Section 6 that this assumption increases the estimated effect of ethanol on gasoline prices. The foundation underlying this result can be seen in two simple scatter plots. Figure 9 is a scatterplot of the PADD-level monthly crack spread, deflated by the PPI for crude energy material, and U.S. ethanol production. Also plotted are three fitted bivariate relationships: a linear model, a quadratic model, and a log-log model. When deflating by essentially the price of oil, there is a consistent negative relationship between the crack spread and ethanol production. Figure 10,

Figure 9: Scatterplot of the Monthly Crack Spread versus Monthly Ethanol Production deflating by the Energy Sector PPI

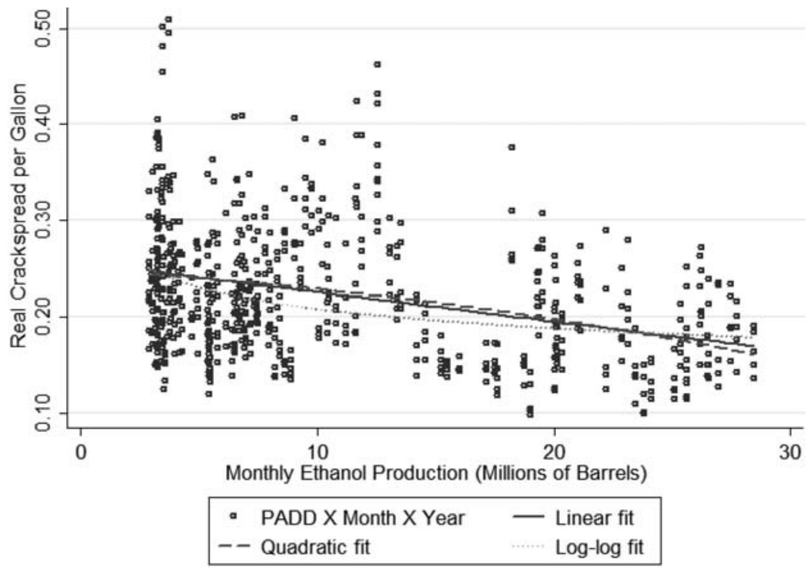
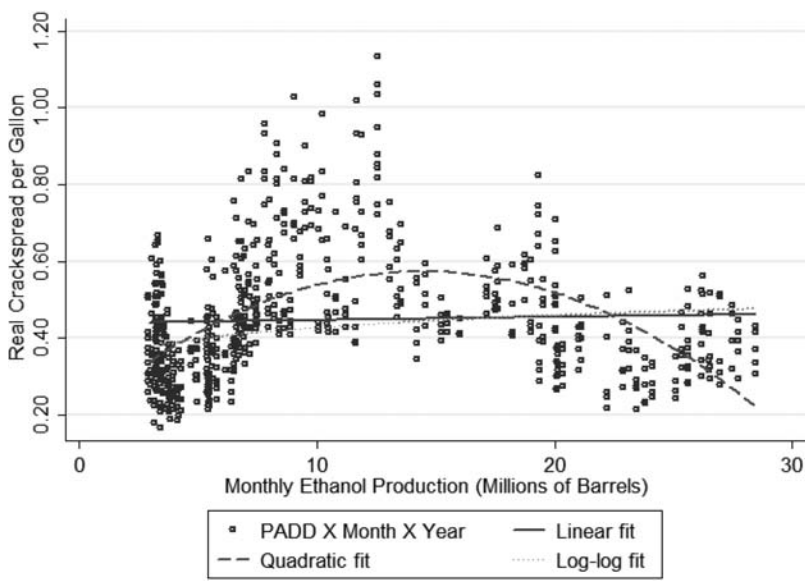


Figure 10: Scatterplot of the Monthly Deflated Crack Spread versus Monthly Ethanol Production Deflating by the Urban CPI



in contrast, deflates by a general urban consumer price index (CPI). The negative relationship breaks down. Indeed, for the linear and log-log bivariate models, there is a positive relationship.

3.4 Linearity Assumption

We follow Du and Hayes by specifying a linear model, which implies that a one million barrel increase in ethanol production has the same effect on either the crack ratio or crack spread regardless of whether current ethanol production is 3 million barrels or 28 million barrels per month (roughly the range in the data) and regardless of the current level of the dependent variable. While we do not investigate the robustness of the results to this assumption, we note that because of both short- and long-run constraints on the profitability of refineries, such a linear assumption could not hold forever.

3.5 Dynamics

The crack ratio and crack spread display significant autocorrelation. For example, the first-order autocorrelation in the CPI-deflated real crack spread ranges from 0.77 to 0.83 across the five PADDs. Much of this autocorrelation remains in the residuals after estimating the various models, which implies that the models do not capture the dynamics of the refining margin. Adding a lag of the dependent variable to the models would absorb this autocorrelation and could be motivated by adjustment costs. Borenstein and Shepard (2002) show that gasoline prices take several weeks to adjust to oil price shocks due to the cost of adjusting refinery production and the cost of gasoline storage.

A dynamic analysis of the effects of ethanol production and the refining margin would require a model of expectations. The industry anticipated the rate of expansion of ethanol capacity, because it was published in the RFS. Coupled with an anticipated effect of ethanol on gasoline prices, this expectation would lead refiners to reduce the amount of gasoline in storage, which would cause the refining margin to decline before ethanol production increased. We see a full dynamic analysis of this problem as beyond the scope of these data. Nonetheless, we report results from models that include a lagged dependent variable.

Including a dynamic component such as a lagged dependent variable in the regression model, implies that the effect of ethanol production is also dynamic. The coefficient on ethanol production represents the contemporaneous response of the refining margin to an unanticipated ethanol production increase. Because of the adjustment costs, the margin would respond more in the next period and each period thereafter as it asymptotes to the new long-run equilibrium. This narrative contradicts the basic economics outlined in Section 2, namely that ethanol production would not have a long-run effect on the refining margin. We would expect any short-run effect to dissipate over time. Thus, although one could interpret the coefficient on the lagged dependent variable as capturing partial adjustment to oil price shocks, we would not assert that ethanol production increases should have the same dynamic effect.

3.6 Standard Errors

Following Du and Hayes, we estimate some models using a panel that includes monthly time series data for each of the five PADDs, and we also estimate separate models for each PADD. These data are not distributed independently across observations, so correct inference requires the use of robust standard errors. Two dimensions of dependence exist in the data. First, as noted in Sections 3.1 and 3.5, ethanol production and the regression errors are strongly autocorrelated. If these variables exceed their mean in one month, they are likely to exceed their mean in the next month. Second, gasoline prices are strongly correlated across PADDs in the same month. Figures 4 and 6 show that, if the crack ratio or spread exceeds its mean in one PADD this month, then it is likely to exceed its mean in all PADDs this month.

These correlations imply that the data cannot be treated as though each observation brings independent information. It is particularly important to use robust standard errors when both the regression residuals and the covariates exhibit strong correlation. In the cross-sectional dimension, ethanol production is identical across PADDs because Du and Hayes use national ethanol production as the explanatory variable. In the time series dimension, ethanol production appears to have a unit root. Using the Dickey Fuller, Dickey Fuller GLS, and the Phillips-Perron unit root tests, both including and not including a trend, we are unable to reject the unit-root null hypothesis. The results with respect to the crack ratio and crack spread are more mixed; some tests reject the null of a unit root, but others do not.

Extreme correlations in ethanol production in both of time-series and cross-sectional dimensions imply that correct standard errors are likely much larger than the default estimates produced by a standard regression package (Moulton (1990)). We use the Newey-West estimator with 12 lags and cluster across PADDs.[18] Each of these steps approximately doubles the standard error. Put another way, each of these steps doubles the width of confidence intervals on the effect of ethanol on gasoline production. Du and Hayes appear to recognize the need to account for time series dependence; they report using the "bw" option in STATA to construct Newey-West standard error estimates. They do not state how many lags they use, nor do they appear to cluster across PADDs.

4. MODEL SPECIFICATIONS

We begin with the empirical specifications reported in Du and Hayes (2011) and Du and Hayes (2012) for both the crack ratio and the deflated crack spread. The full results are reported in the Appendix. We replicate their results quite well; differences may be the result of minor differences in the data collection methods and how missing data are treated (discussed in more detail below). We then present the results from several alternative empirical specifications that address the issues discussed above.

For the models using the crack ratio as the dependent variable, we estimate the following specifications:

1. The Du and Hayes specification.
2. Adding the real price of oil as an explanatory variable.
3. Adding the real prices of oil and natural gas as explanatory variables.
4. Adding the real prices of oil and natural gas and the lagged dependent variable as explanatory variables.

For the models using the deflated crack spread as the dependent variable, we estimate the following specifications:

1. Deflating using the Producer Price Index for crude energy material (the Du and Hayes specification).
2. Deflating using the Consumer Price Index.
3. Deflating using the Consumer Price Index and adding the price of oil.
4. Deflating using the Consumer Price Index and adding the price of oil and the price of natural gas.

18. We implement this using the ivreg2 command in STATA with the "bw" and "cluster" options. Increasing the number of lags to 24 makes no difference to the estimates.

5. Deflating using the Consumer Price Index and adding the price of oil, the price of natural gas, and the lagged dependent variable.

5. DATA

We followed Du and Hayes (2009), Du and Hayes (2011), and Du and Hayes (2012) in the collection of the data used in our analysis. See our respective websites for the data, links to websites where the data were collected, information on how certain variables were constructed, and the computer code to generate the results. We rescale our data so that the first four digits after the decimal points of the regression coefficients are informative.

The gasoline price variable is the total gasoline wholesale/resale price by refiners, which excludes taxes and is mostly reflects gasoline prior to blending with ethanol. The crude oil price is the national average refiner acquisition cost of crude oil. PADD-specific crude oil acquisition costs exist only back to 2004, which presumably is why Du and Hayes use the national series.

Our data go through the end of 2010. One of the covariates that Du and Hayes employs is PADD-level gasoline imports. These data are collected from the Energy Information Administration website and are missing for a number of time periods. Du and Hayes do not discuss what they do with these missing observations, but we suspect that they impute the missing observations in some way. In what follows, we replace the missing observations with the PADD-level average for that month of year. We have found that omitting these observations from the analysis can have large effects on the estimated coefficients. However, omitting these observations does not alter our conclusion that the effect of ethanol production on gasoline prices is not robust.

6. RESULTS

Figure 11 presents the estimated effects from eliminating ethanol for 2010 using the pooled-sample estimates, which we also show in Table 1. We discuss the PADD-level results in Section 6.1. The large square in Figure 11 shows the estimate from the model favored by Du and Hayes. This model uses the crack ratio as the dependent variable and produces an estimated price effect $0.86 per gallon. We argue in Section 2 that the crack ratio specification is flawed because it imposes that the long-run refining margin is constant as a proportion of oil prices. Therefore, we focus on models that use the crack spread as the dependent variable.[19]

We calculate the ethanol effect from the crack spread models as the implied increase in the crack spread from eliminating all ethanol production. We then assume that gasoline prices rise by this amount, based on the notion expressed in Section 2 that ethanol reduces the refining margin by relaxing capacity constraints and thereby reduces the prices of the refined products.

Figure 11 shows that the Du-Hayes crack-spread model produces an estimated 2010 ethanol effect of just $0.12 per gallon, a small fraction of the $0.89 estimate. The estimate drops further to $0.09 per gallon and becomes statistically insignificant when we deflate by the CPI, which is much more defensible than the PPI for crude energy material deflator that Du and Hayes use. When we control for the energy costs of refining using oil and natural gas prices, the estimated effect is

19. The results for the expanded set of crack ratio models are presented in Table 1. These expanded crack ratio models suggest that once oil and natural gas prices and the lagged crack ratio are controlled for the effect of ethanol is statistically insignificant. We note that including higher order terms for oil and natural gas prices further decreases the estimated effects when using the crack ratio models. Because we put little weight on the crack ratio models, we omit these results.

Figure 11: Implied Gasoline Price Effects from Elimination of Ethanol for 2010

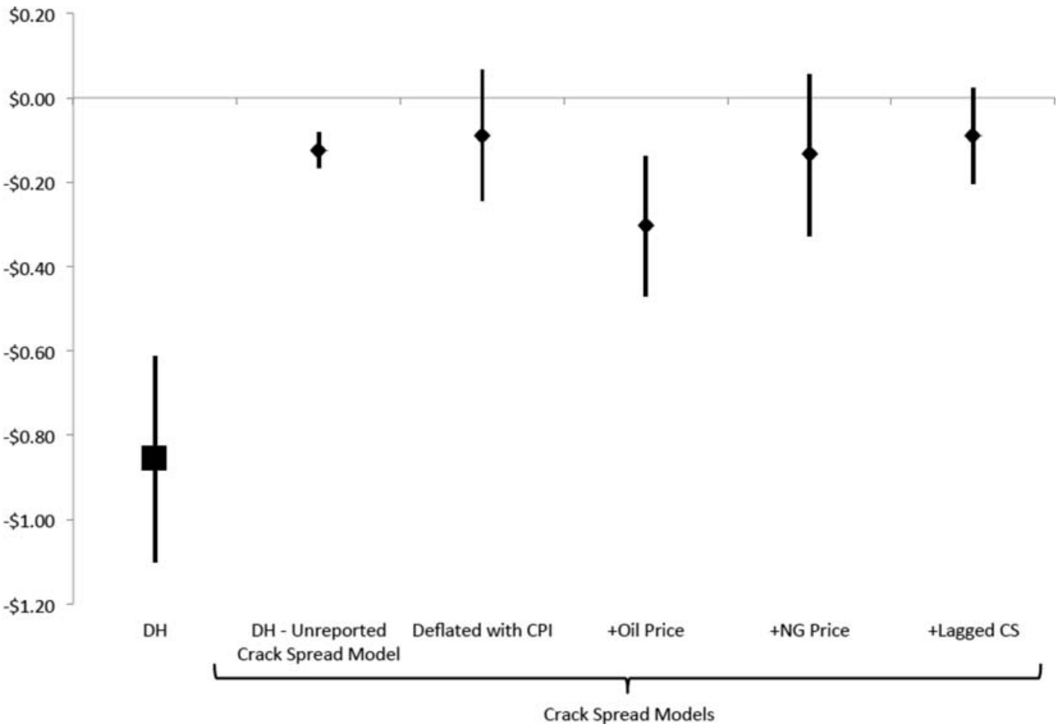


Table 1: Implied Gasoline Price Effects from Elimination of Ethanol for 2010

Model	Reduction in Gasoline Prices from Eliminating All Ethanol	Statistically Significant?
Crack Spread		
Du and Hayes Model (unreported)	*−$0.12*	*Yes*
Du and Hayes Model using CPI to Deflate	−$0.09	No
CPI to Deflate and Price of Oil	−$0.30	Yes
CPI to Deflate, Price of Oil, and Price of NG	−$0.13	No
CPI to Deflate, Price of Oil, Price of NG, and Lagged Dependent Variable	−$0.09	No
Crack Ratio		
Du and Hayes Model	*−$0.86*	*Yes*
Adding Price of Oil	−$0.48	Yes
Adding Price of Oil and Price of NG	−$0.35	Yes
Adding Price of Oil, Price of NG, and Lagged Dependent Variable	−$0.12	No

Note: Statistical significance at 5%.

$0.13 and statistically insignificant. Finally, the model that includes a lagged dependent variable produces the smallest estimated impact is also statistically insignificant.

We estimated two additional specifications that are not shown in the tables, one with the difference between gasoline and crude oil prices as the dependent variable and one with the difference between distillate and crude oil prices as the dependent variable. The implied ethanol effects from these models were within a few cents of those we report. Importantly, the distillate model produces a negative coefficient on ethanol, which runs counter to the notion that ethanol production may have caused an increase in distillate prices and suggests that any effect of ethanol on refining margins may have come from relieving capacity constraints.

We hesitate to endorse any of these models. We only claim that the number reported by the RFA and Secretary Vilsack is inconsistent with the basic economics of the industry and far exceeds the estimates one obtains from better specified regression models. The smoothness of the ethanol production variable means that it is easily conflated with other trends in the data. We eliminate some of these trends by controlling for the energy cost of refining using oil and natural gas prices. Doing so reduces the estimated effect to the statistically insignificant amount of $0.13 in the crack-spread model. We see these results as representing the most plausible effects, conditional on the modeling approach. However, as we note in Section 2, this modeling approach does not separate the short- and long-run effects, so it is not surprising that the effect is small. The next two pieces of evidence highlight the difficulty of estimating the true impact of ethanol on gasoline prices with these data.

6.1 Additional Evidence: PADD-specific Effects

Table 2 shows that the PADD-level results exhibit similar variation. Figure 12 graphs the implied effect on gas prices. Using the exact Du and Hayes model implies ethanol reduces gasoline prices by an average $0.81 cents. Like in Figure 11, the models based on the crack spread produce smaller average effects.

The PADD-level results provide for an additional reality check of the empirical results. PADDs are areas of the country that are connected by oil and gasoline pipelines. Figure 13 maps the five PADDs. While gasoline pipeline capacity is sometimes constrained allowing for price differences across PADDs, certain PADDs are well integrated. This is illustrated in Borenstein and Kellogg (2012) which shows that lower crude prices in the Midwest (PADD 2) do not translate into lower gasoline prices in the Midwest because the gasoline pipeline network arbitrages any potential gasoline price difference.

This market integration makes the stark difference in the ethanol effects across PADDs puzzling. Using the Du-Hayes specification, the price decline in PADD 2 is estimated to be $1.49, while the effect in PADD 1 is 54 cents. A similar difference exists between PADDs 2 and 3 despite the fact that currently refined product in PADD 2 is being piped to PADD 3. To illustrate that these price-effect differences are unrealistic, Figure 14 plots the implied price difference between PADDs 2 and 3 from the Du and Hayes crack-ratio model following the elimination of ethanol in 2010, as well as the observed price difference. The peak price difference between the two PADDs is 26 cents, yet the predicted Du and Hayes price difference is always above 80 cents.

6.2 Additional Evidence: Implied Effects on Unrelated Variables

Next, we estimate the same models for the crack ratio and crack spread, but replace these dependent variable with both the price of natural gas and the rate of national unemployment for

Table 2: Implied Gasoline Price Effects from Elimination of Ethanol for 2010 Using the PADD-level Results

Model	PADD I	PADD II	PADD III	PADD IV	PADD V	Average	Share Statistically Signficant
Crack Spread							
Du and Hayes Model (unreported)	*−0.18*	*−0.44*	*−0.23*	*−0.28*	*−0.13*	*−0.25*	100%
Du and Hayes Model using CPI to Deflate	−0.16	−0.52	−0.71	−0.78	−0.50	−0.60	80%
CPI to Deflate and Price of Oil	−0.21	−0.69	−0.66	−0.74	−0.55	−0.62	100%
CPI to Deflate, Prices of Oil and Natural Gas	−0.19	−0.67	−0.56	−0.61	−0.35	−0.52	100%
CPI to Deflate, Prices of Oil and Natural Gas, Lagged Dependent Variable	−0.11	−0.38	−0.28	−0.04	−0.18	−0.27	60%
Crack Ratio							
Du and Hayes Model	*−0.54*	*−1.49*	*−0.65*	*−0.39*	*−0.63*	*−0.81*	80%
Adding Price of Oil	−0.22	−1.25	−0.77	−0.45	−0.37	−0.75	60%
Adding Prices of Oil and Natural Gas	−0.19	−1.21	−0.63	−0.34	0.04	−0.60	40%
Adding Prices of Oil and Natural Gas, Lagged Dependent Variable	−0.12	−0.66	−0.18	0.10	0.06	−0.23	20%

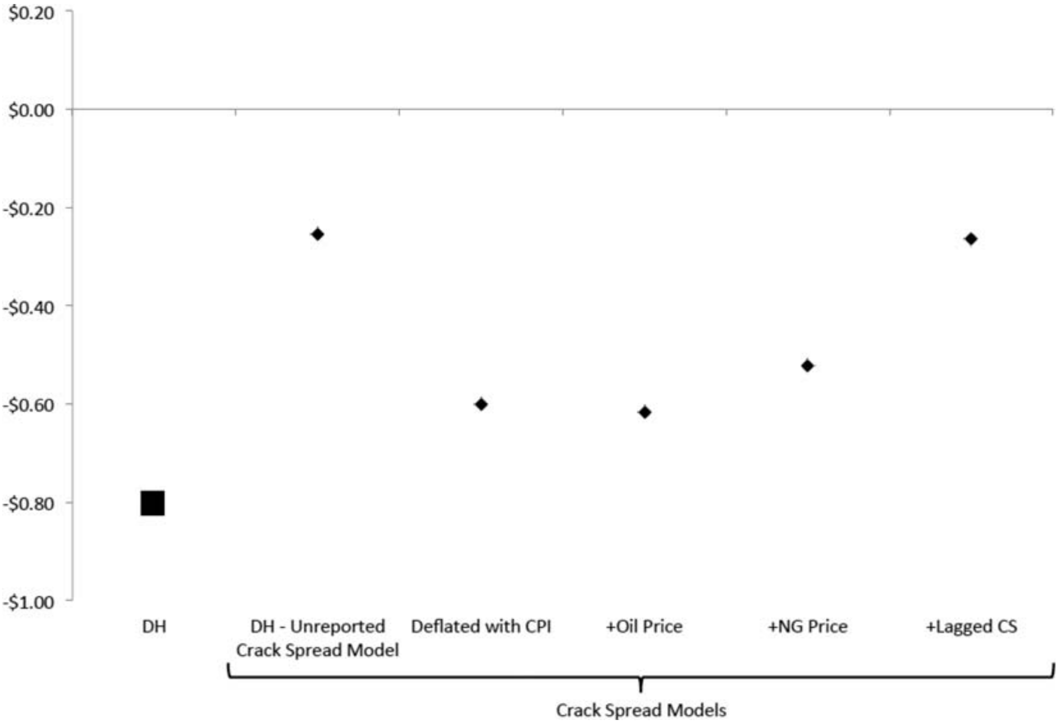
both the U.S. and Europe. This analysis forms a "anti-test" because we know natural gas prices and unemployment are unaffected by U.S. ethanol production. See Dranove and Wehner (1994) for another example of an anti-test.

We first present results for three placebo variables: U.S. wellhead natural gas prices, U.S. unemployment, and unemployment in Europe. Table 3 presents the empirical results using the same models discussed above, the first of which is the same model used in Du and Hayes (2011) and Du and Hayes (2012) to calculate the impact of ethanol production on gasoline prices, replacing the dependent variable with U.S. natural gas prices. These results suggest that ethanol production "causes" reductions in natural gas prices. The estimated effects are large. For example, using the same model used in Du and Hayes, had we eliminated ethanol in 2010, natural gas prices would have increased by 65 percent.[20] These results are robust to the alternative specifications we suggest above.

Table 4 replaces the crack ratio with U.S. national unemployment. These results suggest that U.S. ethanol production "causes" increases in unemployment. Again the implied effect is large; eliminating ethanol production in 2010 would have decreased U.S. unemployment by 65 percent. These results are also robust to the alternative specifications we present above for the crack ratio and the crack spread. Should we therefore doubt the RFA's claims on its website that ethanol creates jobs?

20. Whistance et al. (2010) argue that mandated ethanol production could affect natural gas prices, but this affect would be small and of the opposite sign that estimated from this spurious model.

Figure 12: Implied PADD-level Gasoline Price Effects from Elimination of Ethanol for 2010



Note: Details of model specifications in Section 4. The share of statistical significance is based on a 5% significance level for each PADD.

Figure 13: Map of Petroleum Administration for Defense Districts (PADDs)

Figure 14: Implied Gasoline Price Difference between PADDs 2 and 3 from the Du and Hayes Model following the Elimination of Ethanol in 2010

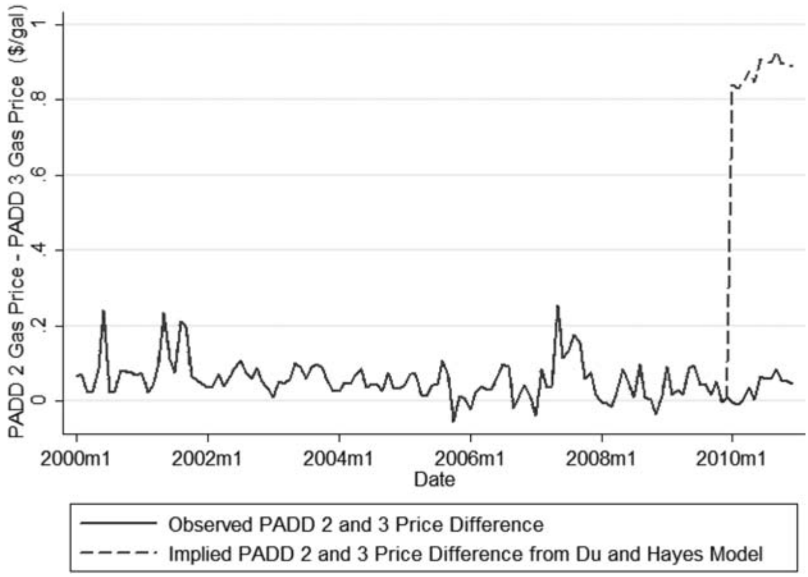


Table 5 replaces the crack ratio with unemployment rates in France, the UK, Italy and all of the European Union. We find statistically significant effects for France, the UK, and the EU. While the effects in France and the EU are more modest—eliminating ethanol in 2010 would have decreased unemployment by 7 and 12 percent, respectively—the effect in the UK is large; eliminating ethanol in 2010 would have decreased unemployment by 42 percent.

These empirical relationships are a classic example of spurious correlation. Ethanol production during this time period is increasing. Therefore, other variables that have a predominant trend, either upward in the case of unemployment or downward in the case of natural gas prices, are likely to correlate well with ethanol production. Figure 15 illustrates this correlation for unemployment and ethanol production.

Finally, in case there are any doubts that ethanol production does not impact unemployment in the U.S. and Europe, we offer a silly example. Table 6 replaces the crack ratio with the age of our children (Caiden Knittel and Hayley Smith). The results suggest every million barrels of ethanol increases Caiden's age by just under 26 days. Ethanol has an even larger effect on Hayley's age, with every million barrels increasing her age by nearly two months. Eliminating all ethanol in 2010 is estimated to cause Caiden to be a newborn (12 days old) and would cause Hayley's age to be negative. These results are statistically significant and remain roughly the same size and statistically significant if we include oil and natural gas prices as covariate. These results underscore danger of drawing causal inference from two variables exhibiting trends: age and ethanol production. Gasoline prices, crack ratios, and crack spreads also exhibited trends during this time period as shown, for example, in Figures 4 and 6. Taken together, our results suggest strongly that results reported in Du and Hayes (2011) and Du and Hayes (2012) are spurious.

7. CONCLUSION

Understanding the relationship between ethanol production and gasoline prices is important. The U.S. has historically subsidized ethanol production and capacity expansion explicitly

Table 3: Replacing the Crack Spread and Crack Ratio with the Price of Natural Gas

	(1)	(2)	(3)	(4)
VARIABLES	Real NG Price, DH	Real NG Price, w/ CPI	Real NG Price w/ CPI, oil price	Real NG Price, w/ CPI, oil price, lag
U.S. Ethanol Production	−0.0510***	−0.0289	−0.1893***	−0.0649***
	(0.0038)	(0.0489)	(0.0249)	(0.0111)
Real Price of Oil			0.0779***	0.0266***
			(0.0069)	(0.0036)
Lagged Natural Gas Price				0.6883***
				(0.0453)
Gasoline Imports	0.0075	0.1595***	0.0681**	0.0136
	(0.0051)	(0.0384)	(0.0276)	(0.0105)
Stock of Oil Reserves	−0.0024	−0.0600**	−0.0159	−0.0103**
	(0.0022)	(0.0246)	(0.0112)	(0.0042)
Stock of Gasoline Reserves	−0.0035	−0.1210***	−0.0638***	−0.0130
	(0.0051)	(0.0371)	(0.0228)	(0.0147)
PADD Refining Capacity	0.0098	0.3304***	0.1288***	0.0325**
	(0.0087)	(0.0567)	(0.0359)	(0.0154)
PADD HHI	0.2973	26.3876***	9.6291**	0.6404
	(0.8009)	(6.2408)	(3.8105)	(1.8742)
Hurricane	0.3632***	4.6950***	3.8976***	2.7588***
	(0.0583)	(0.2581)	(0.2746)	(0.1706)
January	−0.2846**	−0.1425	−0.2621	−0.3554
	(0.1397)	(0.4185)	(0.4130)	(0.2517)
February	−0.3603**	−0.4037	−0.7622*	−0.6865**
	(0.1602)	(0.4939)	(0.4467)	(0.3124)
March	−0.3735**	−0.4043	−0.7946	−0.4466
	(0.1780)	(0.6252)	(0.5940)	(0.3366)
April	−0.4466***	−0.5939	−1.2075**	−0.7702***
	(0.1543)	(0.5746)	(0.4751)	(0.2667)
May	−0.4042**	−0.4018	−1.0402**	−0.4440*
	(0.1624)	(0.6191)	(0.5250)	(0.2347)
June	−0.3823**	−0.3100	−1.1690**	−0.5544**
	(0.1497)	(0.6287)	(0.5692)	(0.2526)
July	−0.3720***	−0.4559	−1.2474**	−0.6562***
	(0.1320)	(0.5919)	(0.4972)	(0.2185)
August	−0.4643***	−1.0675**	−1.6847***	−1.0280***
	(0.1296)	(0.4197)	(0.4714)	(0.2908)
September	−0.4928***	−1.5328***	−1.9882***	−1.0692***
	(0.1291)	(0.4351)	(0.4959)	(0.2482)
October	−0.3549***	−1.3687***	−1.6276***	−0.7821***
	(0.1005)	(0.3258)	(0.3603)	(0.2359)
November	−0.2551***	−0.4038*	−0.6328**	−0.1932
	(0.0809)	(0.2203)	(0.2908)	(0.2788)
PADD II	0.0912	2.7291*	0.5670	0.2516
	(0.1623)	(1.5072)	(0.7073)	(0.3657)
PADD III	0.0280	−1.0892	−1.4291	0.2720
	(0.3552)	(3.9982)	(1.7056)	(0.5965)
PADD IV	0.0076	1.0089	−0.4428	−0.2050
	(0.2480)	(1.9707)	(1.3092)	(0.7780)
PADD V	0.0140	0.0906	−0.6979	−0.0505
	(0.1915)	(1.4101)	(0.7516)	(0.5250)
Constant	3.7052***	3.4199*	4.2473***	1.8638**
	(0.3541)	(1.9980)	(1.5887)	(0.9498)
Observations	660	660	660	655
R-squared	0.7575	0.3359	0.6918	0.9023

Table 4: Replacing the Crack Spread and Crack Ratio with the U.S. National Unemployment Rate

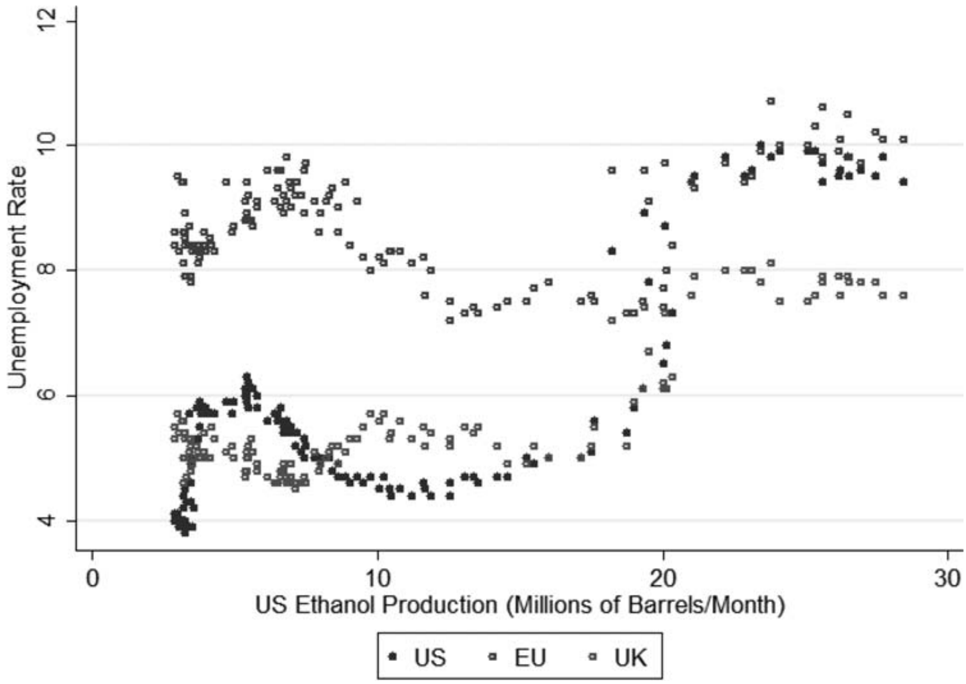
VARIABLES	(1) Rate of Unemployment	(2) Rate of Unemployment oil price	(3) Rate of Unemployment oil price lag
U.S. Ethanol Production	0.2155***	0.3228***	0.0311***
	(0.0323)	(0.0243)	(0.0106)
Real Price of Oil		−0.0521***	−0.0054**
		(0.0081)	(0.0024)
Lagged Unemployment			0.9218***
			(0.0254)
Gasoline Imports	−0.0312	0.0300***	−0.0034
	(0.0249)	(0.0108)	(0.0022)
Stock of Oil Reserves	0.0153	−0.0142**	−0.0014
	(0.0185)	(0.0070)	(0.0011)
Stock of Gasoline Reserves	0.0843***	0.0460**	−0.0018
	(0.0279)	(0.0212)	(0.0033)
PADD Refining Capacity	−0.1819***	−0.0470	0.0015
	(0.0659)	(0.0397)	(0.0062)
PADD HHI	−15.5510***	−4.3403	−1.3336**
	(4.9399)	(2.7485)	(0.5445)
Hurricane	0.0556	0.5891***	0.1042**
	(0.3347)	(0.2201)	(0.0434)
January	−0.1273	−0.0473	0.0074
	(0.1465)	(0.1163)	(0.0727)
February	0.1115	0.3513**	0.0715
	(0.2144)	(0.1474)	(0.0735)
March	0.0280	0.2891*	0.0326
	(0.2289)	(0.1636)	(0.0616)
April	0.1227	0.5331***	0.0482
	(0.2779)	(0.2013)	(0.0691)
May	0.0134	0.4404*	0.0502
	(0.2641)	(0.2309)	(0.0778)
June	0.0878	0.6624**	0.0898
	(0.2408)	(0.2636)	(0.0579)
July	0.0682	0.5977**	0.0631
	(0.2007)	(0.2463)	(0.0581)
August	0.2053	0.6181***	0.0533
	(0.1716)	(0.2217)	(0.0667)
September	0.2107	0.5153**	0.0083
	(0.1745)	(0.2153)	(0.0595)
October	0.1967	0.3699*	0.0546
	(0.1578)	(0.2016)	(0.0545)
November	0.1263	0.2795**	0.0477
	(0.1144)	(0.1223)	(0.0696)
PADD II	0.0580	1.5044***	−0.1483
	(1.0268)	(0.4943)	(0.1119)
PADD III	3.5666	3.7940**	−0.0684
	(2.8683)	(1.5911)	(0.2500)
PADD IV	0.8347	1.8058**	−0.2744
	(1.3396)	(0.7959)	(0.1878)
PADD V	1.6234	2.1509***	−0.1694
	(1.1391)	(0.7338)	(0.1515)
Constant	4.0643**	3.5107***	0.8344***
	(1.6789)	(1.0541)	(0.2963)
Observations	660	660	655
R-squared	0.7026	0.8710	0.9928

Table 5: Replacing the Crack Spread and Crack Ratio with European Unemployment Rates

VARIABLES	(1) France	(2) UK	(3) Italy	(4) EU 17
U.S. Ethanol Production	0.0242	0.1249***	−0.0196	0.0460*
	(0.0227)	(0.0168)	(0.0345)	(0.0275)
Gasoline Imports	0.0158	−0.0339**	−0.0598*	0.0073
	(0.0164)	(0.0147)	(0.0332)	(0.0185)
Stock of Oil Reserves	0.0092	0.0217***	0.0103	0.0063
	(0.0149)	(0.0068)	(0.0084)	(0.0166)
Stock of Gasoline Reserves	0.0094	0.0252***	0.0828***	0.0458*
	(0.0205)	(0.0094)	(0.0300)	(0.0245)
PADD Refining Capacity	−0.0186	−0.1061***	−0.2226***	−0.0793
	(0.0482)	(0.0177)	(0.0588)	(0.0612)
PADD HHI	4.3624	−4.5432**	−17.1060***	−2.1339
	(3.6248)	(2.1077)	(4.1910)	(4.0200)
Hurricane	0.6304***	−0.0647	0.7712***	0.8178***
	(0.1704)	(0.1097)	(0.2441)	(0.2381)
January	0.1756	0.1988*	0.3580*	0.2731**
	(0.1194)	(0.1023)	(0.2048)	(0.1202)
February	0.1094	0.4105***	0.6798***	0.4499***
	(0.1558)	(0.1332)	(0.2127)	(0.1571)
March	−0.1824	0.2128*	0.6391**	0.3476**
	(0.1642)	(0.1290)	(0.2531)	(0.1730)
April	−0.4799***	0.0877	0.2962	0.0484
	(0.1717)	(0.1513)	(0.2099)	(0.1852)
May	−0.6548***	0.0676	−0.0259	−0.1735
	(0.1568)	(0.1412)	(0.1855)	(0.1720)
June	−0.8686***	0.3094**	−0.2124	−0.2743*
	(0.1426)	(0.1299)	(0.1932)	(0.1463)
July	−0.7658***	0.4429***	−0.2650	−0.3205**
	(0.1292)	(0.1004)	(0.2564)	(0.1367)
August	−0.2916**	0.5269***	−0.6316***	−0.2024*
	(0.1447)	(0.0968)	(0.1949)	(0.1189)
September	−0.3133**	0.5071***	−0.1462	−0.2247*
	(0.1333)	(0.0884)	(0.1996)	(0.1338)
October	−0.1511	0.3120***	0.6116***	−0.0444
	(0.1284)	(0.0738)	(0.1558)	(0.1354)
November	0.0332	0.0886*	0.3704***	0.0282
	(0.0713)	(0.0467)	(0.1247)	(0.0791)
PADD II	0.4934	−0.4292	0.4038	0.8543
	(0.5837)	(0.5223)	(0.9469)	(0.7063)
PADD III	0.2157	0.8229	5.8412**	2.3681
	(1.1358)	(1.0840)	(2.6377)	(1.5861)
PADD IV	1.0238	−0.3610	−0.0232	1.5862
	(1.0237)	(0.5984)	(1.0564)	(1.0993)
PADD V	0.6378	0.0633	1.7313	1.6127*
	(0.7733)	(0.5462)	(1.2199)	(0.9355)
Constant	7.3281***	4.7174***	9.8566***	6.7900***
	(1.3634)	(0.7153)	(1.3347)	(1.4539)
Observations	660	660	660	660
R-squared	0.2989	0.8044	0.4123	0.2464

through the Volumetric Ethanol Excise Tax Credit (VEETC) and capacity subsidies and implicitly through policies such as the Renewable Fuel Standard and state-level blend mandates. The benefits of ethanol, relative to gasoline, are that it diversifies our fuel mix, can have lower emissions, and

Figure 15: Scatterplot of U.S., EU, and UK National Unemployment and U.S. Ethanol Production



increases farmer wealth. An additional, potential, benefit is that it may decrease the price of gasoline by relieving refining capacity constraints.

While the VEETC recently expired, policies that support ethanol production continue to be ubiquitous, and there are calls for a national policy that would require blending 15 percent ethanol with gasoline. Accurate cost/benefit analysis of policies such as these requires understanding whether the potential benefits listed above exist, and, if they do, their magnitudes. The Renewable Fuel Association continues to make claims regarding the effect of ethanol on gasoline prices. They claim that ethanol production decreased gasoline prices by an average of 89 cents per gallon and $1.09 per gallon in 2010 and 2011, respectively. We investigate the accuracy of this claim. We show that their results are driven by implausible assumptions in terms of both the economics and statistical work. In doing so, we show that the empirical results are extremely sensitive to the empirical specification; however, empirical models that are most consistent with economic theory suggest effects that are near zero and statistically insignificant.

We also show that the empirical results behind the RFA's claims are driven by spurious correlation: over the sample period crack spreads and crack ratios fell while ethanol production increased. To illustrate the danger of inferring causal relationships between gasoline prices and ethanol production, we estimate the same models used in Du and Hayes (2011) and Du and Hayes (2012) and replace the crack ratio with natural gas prices, U.S. unemployment, and European unemployment. We find that ethanol production "causes" lower natural gas prices and higher unemployment rates in both the U.S. and Europe.

More important than our empirical work, however, is our discussion of the basic economics of the industry. The results of Du and Hayes are at odds with the historical levels of either the crack

Table 6: Replacing the Crack Spread and Crack Ratio with the Age of our Children

VARIABLES	(1) Caiden's Age	(2) Hayley's Age
U.S. Ethanol Production	25.8865***	53.8108***
	(5.7118)	(4.7647)
Gasoline Imports	−3.1858	−8.7102**
	(3.3247)	(3.9439)
Stock of Oil Reserves	4.0113**	3.1661**
	(1.8910)	(1.3167)
Stock of Gasoline Reserves	10.9784***	11.4741***
	(3.6859)	(3.5632)
PADD Refining Capacity	−28.0678***	−33.4530***
	(8.4381)	(7.4211)
PADD HHI	−879.7402**	−2,387.1209***
	(351.8799)	(636.9141)
Hurricane	10.3884	−29.4121
	(26.2655)	(40.3126)
January	−34.6948	−17.5209
	(28.4884)	(25.0491)
February	−9.6649	30.7343
	(28.4839)	(26.3026)
March	−23.1607	−4.6545
	(31.0048)	(25.6808)
April	−12.7036	23.2237
	(31.9306)	(27.1828)
May	−23.5306	1.0996
	(31.4708)	(26.3290)
June	−13.2790	20.0907
	(29.0449)	(23.7165)
July	−11.3031	10.5299
	(26.8571)	(20.7181)
August	10.9361	29.9701
	(24.6202)	(20.7446)
September	20.8261	51.9167***
	(22.5878)	(19.8808)
October	16.2497	34.8851**
	(19.6468)	(16.9128)
November	8.6881	21.8478*
	(13.7765)	(12.5424)
PADD II	102.1897	−7.3319
	(133.6321)	(136.3652)
PADD III	541.5290*	670.8513*
	(324.5961)	(393.3148)
PADD IV	221.4995	−26.6085
	(177.2805)	(138.7572)
PADD V	289.9066	190.6577
	(177.7480)	(156.6392)
Constant	−337.5345	−102.3287
	(223.9487)	(178.1661)
Observations	660	660
R-squared	0.7411	0.9174

spread or crack ratio and are inconsistent with an equilibrium in the oil refining industry. While an instantaneous surprise elimination of all ethanol sold in the U.S. might raise gasoline prices for a short time period, one cannot assume these instantaneous effects would persist for more than a few weeks. Overall, we see no compelling reason to believe that the effect of ethanol use on gasoline prices has been more than \$0.10 per gallon.

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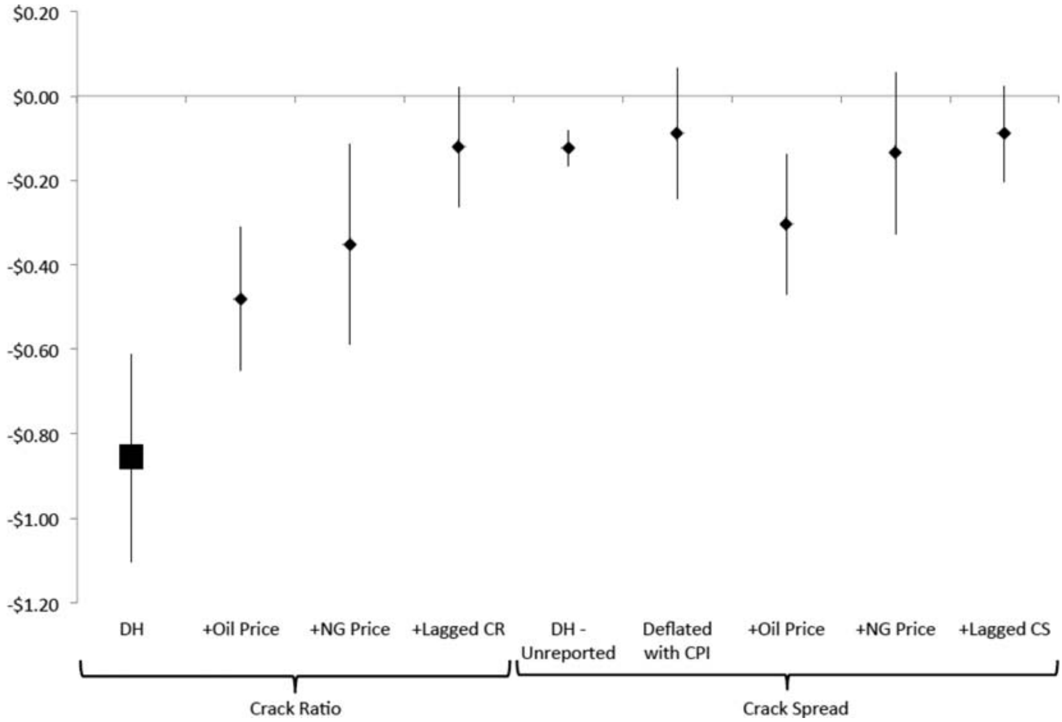
APPENDIX: FULL EMPIRICAL RESULTS

Figure 16: Implied Gasoline Price Effects from Elimination of Ethanol for 2010 with Expanded Crack Ratio Models



Note: Details of model specifications in Section 4. The vertical lines denote 95% confidence intervals. The large square indicates the results obtained from the Du and Hayes model.

Table 7: Deflated Crack Spread Results

VARIABLES	(1) Real Crack Spread DH	(2) Real Crack Spread w/ CPI	(3) Real Crack Spread w/ CPI oil price	(4) Real Crack Spread w/ CPI oil price NG price	(5) Real Crack Spread w/CPI oil price NG price lag
U.S. Ethanol Production	−0.0047***	−0.0033	−0.0112***	−0.0049	−0.0032
	(0.0008)	(0.0029)	(0.0031)	(0.0036)	(0.0021)
Real Price of Oil			0.0038***	0.0012	0.0011
			(0.0014)	(0.0015)	(0.0008)
Natural Gas Price				0.0329***	0.0040
				(0.0101)	(0.0082)
Lagged Real Crack Spread					0.6696***
					(0.0551)
Gasoline Imports	−0.0028***	0.0047*	0.0003	−0.0020	−0.0013
	(0.0009)	(0.0027)	(0.0022)	(0.0018)	(0.0011)
Stock of Oil Reserves	0.0017***	−0.0003	0.0019**	0.0024***	0.0005
	(0.0005)	(0.0009)	(0.0009)	(0.0008)	(0.0003)
Stock of Gasoline Reserves	−0.0009	−0.0120***	−0.0092***	−0.0071**	−0.0059***
	(0.0016)	(0.0038)	(0.0032)	(0.0028)	(0.0014)
PADD Refining Capacity	0.0027*	0.0263***	0.0165***	0.0122***	0.0064***
	(0.0016)	(0.0056)	(0.0038)	(0.0038)	(0.0016)
PADD HHI	0.3883***	2.3653***	1.5468***	1.2297**	0.3259*
	(0.1343)	(0.5332)	(0.4378)	(0.4782)	(0.1675)
Hurricane	0.0066	0.3383***	0.2994***	0.1710***	0.1635***
	(0.0142)	(0.0257)	(0.0203)	(0.0435)	(0.0368)
January	−0.0041	0.0111	0.0052	0.0139	0.0442***
	(0.0109)	(0.0173)	(0.0186)	(0.0189)	(0.0114)
February	0.0105	0.0304*	0.0129	0.0380*	0.0511***
	(0.0129)	(0.0168)	(0.0178)	(0.0221)	(0.0137)
March	0.0323***	0.0742***	0.0551***	0.0813***	0.0835***
	(0.0123)	(0.0184)	(0.0199)	(0.0183)	(0.0227)
April	0.0588***	0.1320***	0.1021***	0.1418***	0.1009***
	(0.0168)	(0.0251)	(0.0276)	(0.0270)	(0.0197)
May	0.0700***	0.1671***	0.1359***	0.1702***	0.0913***
	(0.0199)	(0.0370)	(0.0395)	(0.0382)	(0.0222)
June	0.0511***	0.1299***	0.0880***	0.1265***	0.0293**
	(0.0167)	(0.0273)	(0.0284)	(0.0315)	(0.0129)
July	0.0322**	0.0752***	0.0365*	0.0776***	0.0054
	(0.0140)	(0.0211)	(0.0218)	(0.0235)	(0.0145)
August	0.0442***	0.0726***	0.0424*	0.0979***	0.0477***
	(0.0121)	(0.0236)	(0.0219)	(0.0174)	(0.0158)
September	0.0588***	0.0699**	0.0477*	0.1131***	0.0482
	(0.0161)	(0.0312)	(0.0273)	(0.0324)	(0.0342)
October	0.0453***	0.0247	0.0120	0.0656**	−0.0069
	(0.0150)	(0.0243)	(0.0225)	(0.0258)	(0.0240)
November	0.0121**	0.0224**	0.0112	0.0320**	−0.0075
	(0.0059)	(0.0112)	(0.0133)	(0.0128)	(0.0256)
PADD II	−0.1148***	−0.0809	−0.1865**	−0.2052***	−0.1181***
	(0.0340)	(0.0974)	(0.0743)	(0.0711)	(0.0397)
PADD III	−0.3866***	−0.8325***	−0.8491***	−0.8021***	−0.3181***
	(0.0850)	(0.2983)	(0.2175)	(0.2046)	(0.0800)
PADD IV	0.0250	−0.0171	−0.0880	−0.0735	−0.2047***
	(0.0651)	(0.1538)	(0.1358)	(0.1244)	(0.0765)
PADD V	−0.0450	−0.1632	−0.2018*	−0.1788*	−0.1780***
	(0.0506)	(0.1281)	(0.1101)	(0.1058)	(0.0621)
Constant	0.1697**	0.2228	0.2632*	0.1233	0.2529***
	(0.0708)	(0.1676)	(0.1357)	(0.1229)	(0.0954)
Observations	660	660	660	660	655
R-squared	0.5245	0.4792	0.5871	0.6297	0.8158

Table 8: Crack Ratio Results

VARIABLES	(1) Crack Ratio DH	(2) Crack Ratio oil price	(3) Crack Ratio oil price NG price	(4) Crack Ratio oil price NG price lag
U.S. Ethanol Production	−0.0178***	−0.0100***	−0.0073***	−0.0025*
	(0.0026)	(0.0018)	(0.0025)	(0.0015)
Real Price of Oil		−0.0038***	−0.0049***	−0.0022***
		(0.0005)	(0.0009)	(0.0006)
Natural Gas Price			0.0145	0.0069
			(0.0104)	(0.0075)
Lagged Crack Ratio				0.5970***
				(0.0422)
Gasoline Imports	−0.0070***	−0.0026	−0.0036**	−0.0023***
	(0.0026)	(0.0018)	(0.0017)	(0.0009)
Stock of Oil Reserves	0.0035**	0.0014**	0.0016**	0.0006
	(0.0014)	(0.0007)	(0.0008)	(0.0005)
Stock of Gasoline Reserves	0.0000	−0.0028	−0.0018	−0.0046***
	(0.0028)	(0.0025)	(0.0026)	(0.0012)
PADD Refining Capacity	−0.0002	0.0096***	0.0078***	0.0048***
	(0.0038)	(0.0030)	(0.0030)	(0.0015)
PADD HHI	−0.1868	0.6283**	0.4888*	0.1166
	(0.2652)	(0.2742)	(0.2590)	(0.1298)
Hurricane	0.0896***	0.1284***	0.0719	0.0560
	(0.0289)	(0.0250)	(0.0487)	(0.0383)
January	0.0048	0.0107	0.0145	0.0489***
	(0.0258)	(0.0236)	(0.0228)	(0.0143)
February	0.0108	0.0282	0.0393	0.0479***
	(0.0295)	(0.0253)	(0.0271)	(0.0175)
March	0.0766***	0.0956***	0.1072***	0.0879***
	(0.0284)	(0.0214)	(0.0234)	(0.0275)
April	0.1306***	0.1604***	0.1779***	0.1231***
	(0.0412)	(0.0332)	(0.0361)	(0.0277)
May	0.1633***	0.1943***	0.2094***	0.1105***
	(0.0461)	(0.0403)	(0.0425)	(0.0222)
June	0.1076***	0.1493***	0.1663***	0.0500**
	(0.0317)	(0.0266)	(0.0308)	(0.0235)
July	0.0608***	0.0993***	0.1173***	0.0242
	(0.0233)	(0.0213)	(0.0237)	(0.0205)
August	0.0628***	0.0929***	0.1173***	0.0515*
	(0.0240)	(0.0263)	(0.0278)	(0.0277)
September	0.0694**	0.0915**	0.1203***	0.0659**
	(0.0332)	(0.0372)	(0.0393)	(0.0299)
October	0.0313	0.0439*	0.0675**	0.0048
	(0.0231)	(0.0242)	(0.0296)	(0.0253)
November	0.0077	0.0189	0.0280	0.0017
	(0.0177)	(0.0152)	(0.0179)	(0.0239)
PADD II	−0.2800***	−0.1749***	−0.1831***	−0.1342***
	(0.0874)	(0.0562)	(0.0517)	(0.0294)
PADD III	−0.6675***	−0.6510***	−0.6303***	−0.3176***
	(0.2149)	(0.1091)	(0.1069)	(0.0492)
PADD IV	−0.0541	0.0165	0.0230	−0.1915***
	(0.1345)	(0.1158)	(0.1174)	(0.0628)
PADD V	−0.0838	−0.0454	−0.0353	−0.1477***
	(0.0996)	(0.0839)	(0.0814)	(0.0469)
Constant	1.5678***	1.5276***	1.4660***	0.8051***
	(0.1532)	(0.1380)	(0.1522)	(0.0862)
Observations	660	660	660	655
R-squared	0.6623	0.7462	0.7527	0.8434

Table 9: Crack Ratio Results PADD I

VARIABLES	(1) Crack Ratio DH	(2) Crack Ratio oil price	(3) Crack Ratio oil price NG price	(4) Crack Ratio oil price NG price lag
U.S. Ethanol Production	−0.0109**	−0.0044	−0.0039	−0.0025
	(0.0045)	(0.0037)	(0.0036)	(0.0021)
Real Price of Oil		−0.0037***	−0.0044***	−0.0023***
		(0.0007)	(0.0009)	(0.0006)
Natural Gas Price			0.0093	0.0069
			(0.0083)	(0.0055)
Lagged Crack Ratio				0.5269***
				(0.0707)
Gasoline Imports	−0.0030	0.0017	−0.0001	−0.0023
	(0.0052)	(0.0041)	(0.0042)	(0.0027)
Stock of Oil Reserves	0.0048	0.0023	0.0003	−0.0030
	(0.0071)	(0.0057)	(0.0057)	(0.0045)
Stock of Gasoline Reserves	−0.0068**	−0.0100***	−0.0095***	−0.0077***
	(0.0032)	(0.0025)	(0.0025)	(0.0017)
PADD Refining Capacity	−0.0207	0.0008	0.0007	0.0001
	(0.0191)	(0.0149)	(0.0145)	(0.0081)
PADD HHI	−1.1021	0.1659	0.1214	−0.0293
	(0.9256)	(0.7287)	(0.7137)	(0.3781)
Hurricane	0.1926**	0.1798***	0.1560**	0.1164**
	(0.0798)	(0.0660)	(0.0680)	(0.0522)
January	0.0364	0.0382*	0.0402*	0.0507**
	(0.0247)	(0.0213)	(0.0214)	(0.0210)
February	0.0058	0.0196	0.0260	0.0123
	(0.0335)	(0.0289)	(0.0292)	(0.0257)
March	0.0425	0.0497*	0.0603*	0.0494*
	(0.0352)	(0.0302)	(0.0309)	(0.0262)
April	0.1125***	0.1279***	0.1421***	0.1075***
	(0.0355)	(0.0299)	(0.0317)	(0.0260)
May	0.1486***	0.1700***	0.1828***	0.1084***
	(0.0363)	(0.0299)	(0.0313)	(0.0270)
June	0.0936**	0.1312***	0.1434***	0.0502*
	(0.0369)	(0.0307)	(0.0320)	(0.0283)
July	0.0419	0.0744**	0.0886***	0.0241
	(0.0358)	(0.0300)	(0.0318)	(0.0267)
August	0.0008	0.0231	0.0409	0.0064
	(0.0358)	(0.0304)	(0.0333)	(0.0271)
September	−0.0101	0.0091	0.0277	0.0092
	(0.0355)	(0.0308)	(0.0341)	(0.0284)
October	−0.0526	−0.0476	−0.0312	−0.0490*
	(0.0352)	(0.0301)	(0.0325)	(0.0284)
November	−0.0281	−0.0267	−0.0200	−0.0253
	(0.0229)	(0.0201)	(0.0208)	(0.0209)
Constant	2.2534***	2.0340***	2.0322***	1.2363***
	(0.2867)	(0.2241)	(0.2197)	(0.1732)
Observations	132	132	132	131
R-squared	0.6956	0.7922	0.7956	0.8689

Table 10: Crack Ratio Results PADD II

VARIABLES	(1) Crack Ratio DH	(2) Crack Ratio oil price	(3) Crack Ratio oil price NG price	(4) Crack Ratio oil price NG price lag
U.S. Ethanol Production	−0.0298***	−0.0251***	−0.0242***	−0.0133***
	(0.0061)	(0.0061)	(0.0056)	(0.0042)
Real Price of Oil		−0.0020**	−0.0032***	−0.0017**
		(0.0010)	(0.0011)	(0.0008)
Natural Gas Price			0.0206**	0.0139*
			(0.0094)	(0.0073)
Lagged Crack Ratio				0.4150***
				(0.0850)
Gasoline Imports	0.4664***	0.4450**	0.4138**	0.3509**
	(0.1801)	(0.1762)	(0.1730)	(0.1567)
Stock of Oil Reserves	0.0084***	0.0057***	0.0070***	0.0046***
	(0.0018)	(0.0021)	(0.0020)	(0.0015)
Stock of Gasoline Reserves	−0.0059	−0.0055	−0.0049	−0.0083**
	(0.0045)	(0.0043)	(0.0041)	(0.0032)
PADD Refining Capacity	0.0176	0.0331	0.0309*	0.0113
	(0.0202)	(0.0201)	(0.0185)	(0.0126)
PADD HHI	−5.6917	−5.2691	−7.4178**	−3.1641
	(3.8942)	(3.5966)	(3.4187)	(2.4371)
Hurricane	0.0588	0.0714	0.0034	−0.0126
	(0.0838)	(0.0816)	(0.0847)	(0.0744)
January	0.0619*	0.0501	0.0559	0.0883***
	(0.0353)	(0.0349)	(0.0340)	(0.0341)
February	0.0479	0.0439	0.0558	0.0673*
	(0.0443)	(0.0436)	(0.0430)	(0.0397)
March	0.0633*	0.0702*	0.0817**	0.0716**
	(0.0385)	(0.0381)	(0.0378)	(0.0338)
April	0.0948**	0.1123***	0.1285***	0.1001***
	(0.0398)	(0.0394)	(0.0393)	(0.0338)
May	0.1682***	0.1853***	0.2001***	0.1420***
	(0.0392)	(0.0389)	(0.0388)	(0.0360)
June	0.1326***	0.1495***	0.1667***	0.0808**
	(0.0403)	(0.0402)	(0.0401)	(0.0400)
July	0.0648*	0.0823**	0.1012***	0.0326
	(0.0383)	(0.0384)	(0.0387)	(0.0371)
August	0.0846**	0.0962***	0.1267***	0.0767**
	(0.0368)	(0.0363)	(0.0381)	(0.0344)
September	0.0910**	0.0953**	0.1326***	0.0855**
	(0.0382)	(0.0378)	(0.0407)	(0.0376)
October	0.0334	0.0350	0.0671	0.0125
	(0.0396)	(0.0395)	(0.0410)	(0.0412)
November	0.0052	0.0076	0.0192	−0.0014
	(0.0291)	(0.0290)	(0.0288)	(0.0303)
Constant	1.4446***	1.2281***	1.2963***	1.0116***
	(0.3501)	(0.3399)	(0.3183)	(0.2328)
Observations	132	132	132	131
R-squared	0.7312	0.7446	0.7578	0.8047

Table 11: Crack Ratio Results PADD III

VARIABLES	Crack Ratio DH	Crack Ratio oil price	Crack Ratio oil price NG price	Crack Ratio oil price NG price lag
U.S. Ethanol Production	−0.0130**	−0.0154***	−0.0126***	−0.0036
	(0.0059)	(0.0044)	(0.0045)	(0.0032)
Real Price of Oil		−0.0031***	−0.0040***	−0.0019***
		(0.0007)	(0.0008)	(0.0007)
Natural Gas Price			0.0148*	0.0066
			(0.0080)	(0.0059)
Lagged Crack Ratio				0.5019***
				(0.0837)
Gasoline Imports	−0.0099	0.0052	0.0021	0.0061
	(0.0133)	(0.0116)	(0.0115)	(0.0105)
Stock of Oil Reserves	0.0021**	0.0003	0.0005	0.0003
	(0.0010)	(0.0008)	(0.0008)	(0.0006)
Stock of Gasoline Reserves	−0.0010	−0.0005	0.0012	−0.0030
	(0.0038)	(0.0032)	(0.0032)	(0.0025)
PADD Refining Capacity	0.0003	0.0166**	0.0141**	0.0047
	(0.0088)	(0.0073)	(0.0071)	(0.0048)
PADD HHI	−0.5350	−5.5157	−5.8708*	−1.9171
	(4.8382)	(3.6905)	(3.5242)	(2.3411)
Hurricane	0.1556*	0.1526**	0.1131	0.0708
	(0.0805)	(0.0709)	(0.0726)	(0.0610)
January	0.0160	0.0104	0.0141	0.0475**
	(0.0273)	(0.0244)	(0.0238)	(0.0239)
February	0.0102	0.0066	0.0173	0.0201
	(0.0351)	(0.0317)	(0.0315)	(0.0281)
March	0.0481	0.0716**	0.0816**	0.0644**
	(0.0360)	(0.0325)	(0.0323)	(0.0278)
April	0.0945**	0.1243***	0.1397***	0.0999***
	(0.0387)	(0.0337)	(0.0339)	(0.0279)
May	0.1178***	0.1483***	0.1617***	0.0855***
	(0.0368)	(0.0327)	(0.0329)	(0.0294)
June	0.0640*	0.0959***	0.1114***	0.0278
	(0.0371)	(0.0334)	(0.0336)	(0.0308)
July	0.0228	0.0600*	0.0764**	0.0105
	(0.0345)	(0.0316)	(0.0323)	(0.0285)
August	0.0132	0.0519	0.0772**	0.0216
	(0.0353)	(0.0324)	(0.0346)	(0.0296)
September	0.0155	0.0421	0.0701**	0.0329
	(0.0339)	(0.0317)	(0.0343)	(0.0301)
October	−0.0107	0.0122	0.0337	−0.0074
	(0.0328)	(0.0310)	(0.0323)	(0.0301)
November	−0.0242	−0.0034	0.0033	−0.0121
	(0.0239)	(0.0225)	(0.0222)	(0.0229)
Constant	1.1806***	1.0005***	0.9581***	0.7354***
	(0.2845)	(0.2221)	(0.2139)	(0.1624)
Observations	132	132	132	131
R-squared	0.6543	0.7334	0.7438	0.8090

Table 12: Crack Ratio Results PADD IV

VARIABLES	Crack Ratio DH	Crack Ratio oil price	Crack Ratio oil price NG price	Crack Ratio oil price NG price lag
U.S. Ethanol Production	−0.0078	−0.0090	−0.0068	0.0020
	(0.0112)	(0.0092)	(0.0092)	(0.0040)
Real Price of Oil		−0.0035***	−0.0046***	−0.0015**
		(0.0009)	(0.0013)	(0.0007)
Natural Gas Price			0.0148	0.0068
			(0.0124)	(0.0067)
Lagged Crack Ratio				0.6719***
				(0.0651)
Gasoline Imports	−4.4383	−4.7409*	−4.7303*	−3.9291**
	(3.0995)	(2.6563)	(2.6205)	(1.6646)
Stock of Oil Reserves	0.0124	0.0055	0.0118	0.0007
	(0.0193)	(0.0161)	(0.0164)	(0.0082)
Stock of Gasoline Reserves	−0.0409	−0.0311	−0.0244	−0.0364***
	(0.0301)	(0.0253)	(0.0252)	(0.0132)
PADD Refining Capacity	−0.1942	−0.0263	−0.0307	−0.0781
	(0.1907)	(0.1605)	(0.1582)	(0.0674)
PADD HHI	0.5455	0.3326	0.9788	0.5303
	(3.5839)	(2.9471)	(2.9920)	(1.2416)
Hurricane	0.0866	0.1126	0.0609	0.0637
	(0.0966)	(0.0847)	(0.0877)	(0.0608)
January	0.0091	−0.0147	−0.0122	0.0516*
	(0.0396)	(0.0350)	(0.0347)	(0.0280)
February	0.0273	0.0068	0.0162	0.0769**
	(0.0517)	(0.0455)	(0.0458)	(0.0333)
March	0.0876*	0.0877**	0.0957**	0.1142***
	(0.0466)	(0.0416)	(0.0416)	(0.0305)
April	0.1600***	0.1745***	0.1903***	0.1590***
	(0.0552)	(0.0481)	(0.0488)	(0.0323)
May	0.1999***	0.2194***	0.2323***	0.1371***
	(0.0514)	(0.0448)	(0.0452)	(0.0315)
June	0.1312***	0.1548***	0.1724***	0.0455
	(0.0503)	(0.0442)	(0.0456)	(0.0329)
July	0.0912*	0.1210***	0.1441***	0.0310
	(0.0487)	(0.0433)	(0.0458)	(0.0326)
August	0.1148**	0.1468***	0.1757***	0.0858**
	(0.0494)	(0.0442)	(0.0483)	(0.0339)
September	0.1161**	0.1336***	0.1649***	0.0872**
	(0.0462)	(0.0420)	(0.0475)	(0.0350)
October	0.0811*	0.0985**	0.1219***	0.0289
	(0.0423)	(0.0387)	(0.0417)	(0.0345)
November	0.0599**	0.0682**	0.0763***	0.0371
	(0.0289)	(0.0266)	(0.0270)	(0.0261)
Constant	2.2329**	1.8459**	1.6077**	0.9279**
	(0.9410)	(0.7781)	(0.7929)	(0.3691)
Observations	132	132	132	131
R-squared	0.6921	0.7614	0.7664	0.8786

Table 13: Crack Ratio Results PADD V

VARIABLES	Crack Ratio DH	Crack Ratio oil price	Crack Ratio oil price NG price	Crack Ratio oil price NG price lag
U.S. Ethanol Production	−0.0127**	−0.0075**	0.0008	0.0013
	(0.0054)	(0.0036)	(0.0040)	(0.0025)
Real Price of Oil		−0.0057***	−0.0081***	−0.0040***
		(0.0010)	(0.0011)	(0.0010)
Natural Gas Price			0.0330***	0.0187**
			(0.0105)	(0.0077)
Lagged Crack Ratio				0.5219***
				(0.0831)
Gasoline Imports	0.0924***	0.0909***	0.0846***	0.0507***
	(0.0311)	(0.0236)	(0.0220)	(0.0181)
Stock of Oil Reserves	0.0005	−0.0021	−0.0004	−0.0017
	(0.0054)	(0.0040)	(0.0037)	(0.0028)
Stock of Gasoline Reserves	−0.0054	−0.0043	−0.0028	−0.0134***
	(0.0093)	(0.0069)	(0.0063)	(0.0049)
PADD Refining Capacity	−0.0509	0.0028	−0.0164	−0.0162
	(0.0317)	(0.0221)	(0.0197)	(0.0115)
PADD HHI	−5.8918	−6.4468*	−6.4131**	−3.4420*
	(5.3855)	(3.6234)	(3.1335)	(2.0681)
Hurricane	0.0886	0.1232	0.0010	0.0198
	(0.1174)	(0.0899)	(0.0903)	(0.0726)
January	−0.0075	−0.0186	−0.0028	0.0481
	(0.0387)	(0.0337)	(0.0332)	(0.0349)
February	0.0342	0.0408	0.0734*	0.0979**
	(0.0498)	(0.0433)	(0.0435)	(0.0394)
March	0.0967*	0.1137**	0.1463***	0.1266***
	(0.0554)	(0.0466)	(0.0458)	(0.0400)
April	0.1665***	0.1950***	0.2395***	0.1595***
	(0.0537)	(0.0438)	(0.0438)	(0.0391)
May	0.1324**	0.1701***	0.2077***	0.0993**
	(0.0567)	(0.0453)	(0.0445)	(0.0411)
June	0.1059*	0.1567***	0.1994***	0.0825*
	(0.0543)	(0.0439)	(0.0438)	(0.0428)
July	0.0479	0.0986**	0.1440***	0.0367
	(0.0514)	(0.0422)	(0.0425)	(0.0397)
August	0.0042	0.0500	0.1113**	0.0400
	(0.0573)	(0.0470)	(0.0483)	(0.0416)
September	0.0561	0.0881*	0.1589***	0.0949**
	(0.0541)	(0.0464)	(0.0496)	(0.0439)
October	0.0386	0.0654	0.1191**	0.0283
	(0.0526)	(0.0461)	(0.0479)	(0.0447)
November	0.0192	0.0355	0.0579*	0.0183
	(0.0372)	(0.0331)	(0.0333)	(0.0345)
Constant	3.4041***	2.7061***	2.7753***	1.9449***
	(1.0385)	(0.7327)	(0.6515)	(0.4650)
Observations	132	132	132	131
R-squared	0.6701	0.7985	0.8201	0.8658

Table 14: Crack Spread Results PADD I

VARIABLES	(1) Real Crack Spread DH	(2) Real Crack Spread w/ CPI	(3) Real Crack Spread w/ CPI oil price	(4) Real Crack Spread w/ CPI oil price NG price	(5) Real Crack Spread w/CPI oil price NG price lag
U.S. Ethanol Production	−0.0067***	−0.0057	−0.0077**	−0.0069**	−0.0039*
	(0.0019)	(0.0036)	(0.0036)	(0.0034)	(0.0023)
Real Price of Oil			0.0012	0.0000	0.0005
			(0.0008)	(0.0009)	(0.0006)
Natural Gas Price				0.0167**	0.0040
				(0.0083)	(0.0062)
Gasoline Imports	−0.0053**	0.0042	0.0027	−0.0004	−0.0002
	(0.0022)	(0.0042)	(0.0040)	(0.0040)	(0.0028)
Stock of Oil Reserves	−0.0008	0.0026	0.0034	−0.0002	−0.0003
	(0.0032)	(0.0060)	(0.0059)	(0.0057)	(0.0046)
Stock of Gasoline Reserves	−0.0019	−0.0132***	−0.0123***	−0.0115***	−0.0090***
	(0.0014)	(0.0026)	(0.0026)	(0.0025)	(0.0018)
PADD Refining Capacity	0.0060	0.0427***	0.0360**	0.0358**	0.0146
	(0.0081)	(0.0150)	(0.0150)	(0.0140)	(0.0095)
PADD HHI	0.6087	3.5383***	3.1474***	3.0679***	1.3910***
	(0.3810)	(0.7184)	(0.7284)	(0.6802)	(0.4992)
Hurricane	0.0498	0.2480***	0.2520***	0.2095***	0.1785***
	(0.0360)	(0.0687)	(0.0676)	(0.0675)	(0.0523)
January	0.0030	0.0180	0.0174	0.0210	0.0310
	(0.0118)	(0.0207)	(0.0203)	(0.0204)	(0.0210)
February	−0.0037	−0.0088	−0.0130	−0.0015	−0.0032
	(0.0153)	(0.0274)	(0.0271)	(0.0272)	(0.0246)
March	0.0145	0.0052	0.0030	0.0220	0.0239
	(0.0162)	(0.0298)	(0.0295)	(0.0300)	(0.0253)
April	0.0435***	0.0682**	0.0635**	0.0889***	0.0664**
	(0.0168)	(0.0314)	(0.0311)	(0.0325)	(0.0265)
May	0.0569***	0.1156***	0.1090***	0.1317***	0.0798***
	(0.0175)	(0.0325)	(0.0325)	(0.0333)	(0.0277)
June	0.0351**	0.0902***	0.0786**	0.1004***	0.0334
	(0.0178)	(0.0333)	(0.0338)	(0.0346)	(0.0291)
July	0.0188	0.0278	0.0178	0.0431	−0.0048
	(0.0173)	(0.0322)	(0.0326)	(0.0337)	(0.0278)
August	0.0111	−0.0195	−0.0264	0.0053	−0.0164
	(0.0169)	(0.0317)	(0.0317)	(0.0340)	(0.0276)
September	0.0133	−0.0199	−0.0258	0.0075	−0.0082
	(0.0162)	(0.0303)	(0.0301)	(0.0330)	(0.0277)
October	0.0044	−0.0728**	−0.0744***	−0.0450	−0.0659**
	(0.0160)	(0.0289)	(0.0285)	(0.0307)	(0.0275)
November	−0.0069	−0.0386**	−0.0390**	−0.0270	−0.0360*
	(0.0112)	(0.0194)	(0.0191)	(0.0200)	(0.0208)
Lagged Real Crack Spread					0.4962***
					(0.0737)
Constant	0.2460**	−0.0815	−0.0139	−0.0171	0.2522
	(0.1228)	(0.2317)	(0.2279)	(0.2152)	(0.1537)
Observations	132	132	132	132	131
R-squared	0.3647	0.7269	0.7385	0.7518	0.8290

Table 15: Crack Spread Results PADD II

VARIABLES	Real Crack Spread DH	Real Crack Spread w/ CPI	Real Crack Spread w/ CPI oil price	Real Crack Spread w/ CPI oil price NG price	Real Crack Spread w/CPI oil price NG price lag
U.S. Ethanol Production	−0.0165***	−0.0193***	−0.0255***	−0.0246***	−0.0141***
	(0.0022)	(0.0058)	(0.0056)	(0.0052)	(0.0039)
Real Price of Oil			0.0026***	0.0015	0.0016**
			(0.0009)	(0.0010)	(0.0007)
Natural Gas Price				0.0203**	0.0074
				(0.0088)	(0.0069)
Gasoline Imports	0.3100***	0.4557***	0.4840***	0.4531***	0.3601**
	(0.0766)	(0.1728)	(0.1660)	(0.1620)	(0.1419)
Stock of Oil Reserves	0.0042***	−0.0002	0.0033*	0.0045**	0.0029**
	(0.0007)	(0.0017)	(0.0019)	(0.0019)	(0.0013)
Stock of Gasoline Reserves	−0.0038**	−0.0138***	−0.0143***	−0.0138***	−0.0118***
	(0.0019)	(0.0043)	(0.0041)	(0.0039)	(0.0030)
PADD Refining Capacity	0.0377***	0.1106***	0.0901***	0.0880***	0.0425***
	(0.0069)	(0.0192)	(0.0185)	(0.0172)	(0.0138)
PADD HHI	−4.5157***	0.4841	−0.0739	−2.1981	0.1505
	(1.3431)	(3.7014)	(3.2975)	(3.1913)	(2.2223)
Hurricane	−0.0224	0.2185***	0.2020***	0.1347*	0.1283*
	(0.0348)	(0.0804)	(0.0767)	(0.0789)	(0.0661)
January	0.0093	0.0188	0.0345	0.0402	0.0702**
	(0.0147)	(0.0336)	(0.0325)	(0.0316)	(0.0313)
February	0.0132	0.0304	0.0357	0.0475	0.0646*
	(0.0179)	(0.0420)	(0.0400)	(0.0393)	(0.0351)
March	0.0164	0.0486	0.0396	0.0510	0.0635**
	(0.0162)	(0.0365)	(0.0352)	(0.0348)	(0.0301)
April	0.0281	0.0853**	0.0622*	0.0782**	0.0724**
	(0.0171)	(0.0380)	(0.0372)	(0.0368)	(0.0304)
May	0.0571***	0.1486***	0.1261***	0.1407***	0.1066***
	(0.0172)	(0.0382)	(0.0375)	(0.0370)	(0.0320)
June	0.0526***	0.1261***	0.1038***	0.1208***	0.0603*
	(0.0176)	(0.0396)	(0.0389)	(0.0386)	(0.0342)
July	0.0286*	0.0703*	0.0473	0.0660*	0.0187
	(0.0170)	(0.0373)	(0.0370)	(0.0369)	(0.0326)
August	0.0485***	0.0729**	0.0575*	0.0876**	0.0613**
	(0.0162)	(0.0351)	(0.0345)	(0.0359)	(0.0304)
September	0.0651***	0.0743**	0.0687**	0.1057***	0.0648*
	(0.0162)	(0.0363)	(0.0351)	(0.0376)	(0.0332)
October	0.0459***	0.0177	0.0155	0.0473	0.0029
	(0.0162)	(0.0373)	(0.0360)	(0.0373)	(0.0357)
November	0.0120	0.0181	0.0149	0.0264	0.0004
	(0.0124)	(0.0276)	(0.0269)	(0.0265)	(0.0279)
Lagged Real Crack Spread					0.4307***
					(0.0738)
Constant	−0.2538**	−1.5299***	−1.2441***	−1.1768***	−0.4654**
	(0.1232)	(0.3330)	(0.3140)	(0.2964)	(0.2327)
Observations	132	132	132	132	131
R-squared	0.6494	0.6867	0.7163	0.7329	0.7941

Table 16: Crack Spread Results PADD III

VARIABLES	Real Crack Spread DH	Real Crack Spread w/ CPI	Real Crack Spread w/ CPI oil price	Real Crack Spread w/ CPI oil price NG price	Real Crack Spread w/CPI oil price NG price lag
U.S. Ethanol Production	−0.0088***	−0.0262***	−0.0241***	−0.0206***	−0.0104***
	(0.0020)	(0.0059)	(0.0050)	(0.0048)	(0.0036)
Real Price of Oil			0.0027***	0.0015*	0.0014**
			(0.0007)	(0.0009)	(0.0006)
Natural Gas Price				0.0187**	0.0033
				(0.0087)	(0.0068)
Gasoline Imports	0.0069	0.0498***	0.0367***	0.0328***	0.0184*
	(0.0051)	(0.0131)	(0.0115)	(0.0113)	(0.0104)
Stock of Oil Reserves	0.0013***	0.0006	0.0021**	0.0023***	0.0008
	(0.0003)	(0.0010)	(0.0009)	(0.0009)	(0.0006)
Stock of Gasoline Reserves	0.0004	−0.0038	−0.0042	−0.0020	−0.0024
	(0.0015)	(0.0038)	(0.0034)	(0.0034)	(0.0026)
PADD Refining Capacity	0.0082***	0.0438***	0.0297***	0.0266***	0.0127**
	(0.0029)	(0.0088)	(0.0083)	(0.0078)	(0.0056)
PADD HHI	−3.4882**	−11.0419**	−6.6994	−7.1475*	−2.7575
	(1.6044)	(4.8200)	(4.1898)	(3.8378)	(2.6603)
Hurricane	0.0043	0.1539*	0.1566**	0.1068	0.1501**
	(0.0316)	(0.0793)	(0.0722)	(0.0728)	(0.0601)
January	−0.0172	−0.0404	−0.0355	−0.0308	0.0126
	(0.0109)	(0.0271)	(0.0248)	(0.0239)	(0.0250)
February	−0.0151	−0.0580*	−0.0548*	−0.0413	−0.0102
	(0.0137)	(0.0340)	(0.0309)	(0.0307)	(0.0276)
March	0.0009	0.0140	−0.0065	0.0060	0.0355
	(0.0144)	(0.0357)	(0.0328)	(0.0324)	(0.0279)
April	0.0138	0.0363	0.0104	0.0299	0.0478*
	(0.0154)	(0.0383)	(0.0354)	(0.0352)	(0.0281)
May	0.0288*	0.0748**	0.0483	0.0652*	0.0482*
	(0.0151)	(0.0372)	(0.0350)	(0.0348)	(0.0283)
June	0.0092	0.0265	−0.0014	0.0181	−0.0044
	(0.0150)	(0.0381)	(0.0360)	(0.0358)	(0.0291)
July	0.0015	0.0159	−0.0165	0.0042	−0.0161
	(0.0145)	(0.0350)	(0.0337)	(0.0341)	(0.0282)
August	0.0093	0.0170	−0.0167	0.0153	0.0043
	(0.0148)	(0.0350)	(0.0337)	(0.0357)	(0.0293)
September	0.0215	0.0209	−0.0023	0.0331	0.0194
	(0.0139)	(0.0337)	(0.0317)	(0.0345)	(0.0295)
October	0.0103	−0.0091	−0.0290	−0.0019	−0.0228
	(0.0131)	(0.0315)	(0.0295)	(0.0310)	(0.0285)
November	−0.0080	0.0037	−0.0144	−0.0059	−0.0195
	(0.0099)	(0.0238)	(0.0223)	(0.0220)	(0.0231)
Lagged Real Crack Spread					0.4900***
					(0.0786)
Constant	−0.2013**	−1.0301***	−0.8731***	−0.9266***	−0.3455*
	(0.0994)	(0.2839)	(0.2469)	(0.2290)	(0.1922)
Observations	132	132	132	132	131
R-squared	0.5526	0.7082	0.7597	0.7740	0.8320

Table 17: Crack Spread Results PADD IV

VARIABLES	Real Crack Spread DH	Real Crack Spread w/ CPI	Real Crack Spread w/ CPI oil price	Real Crack Spread w/ CPI oil price NG price	Real Crack Spread w/CPI oil price NG price lag
U.S. Ethanol Production	−0.0108**	−0.0285**	−0.0272**	−0.0223**	−0.0013
	(0.0047)	(0.0136)	(0.0113)	(0.0106)	(0.0047)
Real Price of Oil			0.0036***	0.0011	0.0018***
			(0.0012)	(0.0015)	(0.0007)
Natural Gas Price				0.0342**	−0.0027
				(0.0144)	(0.0078)
Gasoline Imports	−3.0672**	−5.4832	−5.1694	−5.1450*	−4.1527**
	(1.4425)	(3.5254)	(3.1813)	(3.0044)	(1.7480)
Stock of Oil Reserves	0.0176**	0.0054	0.0125	0.0269	−0.0063
	(0.0084)	(0.0232)	(0.0198)	(0.0191)	(0.0090)
Stock of Gasoline Reserves	−0.0001	−0.0144	−0.0245	−0.0092	−0.0478***
	(0.0134)	(0.0353)	(0.0309)	(0.0292)	(0.0142)
PADD Refining Capacity	0.0812	0.4670**	0.2929	0.2828	−0.0383
	(0.0796)	(0.2334)	(0.1986)	(0.1825)	(0.0791)
PADD HHI	0.5524	−2.8828	−2.6620	−1.1710	−0.7035
	(1.5045)	(4.3830)	(3.6434)	(3.4532)	(1.3772)
Hurricane	−0.0068	0.2934***	0.2664***	0.1471	0.1982***
	(0.0449)	(0.1083)	(0.0984)	(0.0980)	(0.0603)
January	−0.0343*	−0.0869*	−0.0623	−0.0565	0.0648**
	(0.0182)	(0.0448)	(0.0400)	(0.0380)	(0.0303)
February	−0.0232	−0.0781	−0.0568	−0.0350	0.0927***
	(0.0236)	(0.0578)	(0.0515)	(0.0503)	(0.0347)
March	0.0205	0.0396	0.0395	0.0579	0.1340***
	(0.0218)	(0.0508)	(0.0467)	(0.0458)	(0.0312)
April	0.0677***	0.1250**	0.1100*	0.1463***	0.1501***
	(0.0259)	(0.0622)	(0.0569)	(0.0555)	(0.0334)
May	0.0827***	0.1825***	0.1622***	0.1920***	0.1340***
	(0.0247)	(0.0581)	(0.0540)	(0.0524)	(0.0322)
June	0.0496**	0.1014*	0.0770	0.1178**	0.0208
	(0.0244)	(0.0571)	(0.0535)	(0.0535)	(0.0333)
July	0.0530**	0.0922*	0.0613	0.1146**	0.0115
	(0.0238)	(0.0544)	(0.0521)	(0.0533)	(0.0336)
August	0.0917***	0.1664***	0.1332**	0.2000***	0.0962***
	(0.0237)	(0.0546)	(0.0519)	(0.0549)	(0.0349)
September	0.0924***	0.1276**	0.1095**	0.1817***	0.0636*
	(0.0220)	(0.0496)	(0.0470)	(0.0529)	(0.0358)
October	0.0884***	0.1139**	0.0959**	0.1501***	0.0165
	(0.0203)	(0.0444)	(0.0420)	(0.0449)	(0.0350)
November	0.0431***	0.0837***	0.0751***	0.0938***	0.0374
	(0.0142)	(0.0301)	(0.0286)	(0.0285)	(0.0271)
Lagged Real Crack Spread					0.7309***
					(0.0597)
Constant	−0.2455	−0.6792	−0.2780	−0.8277	0.6498
	(0.3957)	(1.1456)	(0.9573)	(0.9130)	(0.4079)
Observations	132	132	132	132	131
R-squared	0.5428	0.5410	0.6280	0.6589	0.8495

Table 18: Crack Spread Results PADD V

VARIABLES	Real Crack Spread DH	Real Crack Spread w/ CPI	Real Crack Spread w/ CPI oil price	Real Crack Spread w/ CPI oil price NG price	Real Crack Spread w/CPI oil price NG price lag
U.S. Ethanol Production	−0.0049***	−0.0185***	−0.0201***	−0.0127***	−0.0068***
	(0.0018)	(0.0038)	(0.0037)	(0.0044)	(0.0025)
Real Price of Oil			0.0017*	−0.0004	0.0005
			(0.0010)	(0.0012)	(0.0007)
Natural Gas Price				0.0293***	0.0046
				(0.0111)	(0.0073)
Gasoline Imports	0.0472***	0.0911***	0.0916***	0.0860***	0.0331**
	(0.0127)	(0.0242)	(0.0235)	(0.0221)	(0.0165)
Stock of Oil Reserves	0.0018	−0.0029	−0.0021	−0.0006	−0.0029
	(0.0020)	(0.0040)	(0.0039)	(0.0036)	(0.0024)
Stock of Gasoline Reserves	−0.0038	−0.0116*	−0.0119*	−0.0106*	−0.0157***
	(0.0036)	(0.0070)	(0.0067)	(0.0063)	(0.0042)
PADD Refining Capacity	0.0035	0.1285***	0.1120***	0.0950***	0.0345***
	(0.0108)	(0.0226)	(0.0231)	(0.0220)	(0.0132)
PADD HHI	−1.2832	−1.9201	−1.7495	−1.7196	−0.9857
	(1.9349)	(3.9293)	(3.7297)	(3.3967)	(1.9099)
Hurricane	−0.0186	0.2490***	0.2384***	0.1301	0.1162*
	(0.0465)	(0.0894)	(0.0866)	(0.0868)	(0.0623)
January	−0.0163	−0.0589*	−0.0555*	−0.0415	0.0245
	(0.0170)	(0.0309)	(0.0303)	(0.0297)	(0.0297)
February	0.0089	−0.0219	−0.0239	0.0050	0.0720**
	(0.0215)	(0.0390)	(0.0380)	(0.0384)	(0.0333)
March	0.0278	0.0359	0.0307	0.0596	0.0898***
	(0.0231)	(0.0431)	(0.0422)	(0.0418)	(0.0335)
April	0.0647***	0.1103***	0.1015**	0.1410***	0.1048***
	(0.0226)	(0.0424)	(0.0417)	(0.0423)	(0.0327)
May	0.0464*	0.1088**	0.0972**	0.1305***	0.0657*
	(0.0242)	(0.0450)	(0.0445)	(0.0440)	(0.0344)
June	0.0426*	0.0859**	0.0703	0.1081**	0.0265
	(0.0233)	(0.0429)	(0.0429)	(0.0431)	(0.0351)
July	0.0277	0.0383	0.0227	0.0630	−0.0113
	(0.0224)	(0.0414)	(0.0415)	(0.0419)	(0.0335)
August	0.0260	0.0159	0.0019	0.0563	0.0180
	(0.0241)	(0.0453)	(0.0450)	(0.0468)	(0.0355)
September	0.0594***	0.0380	0.0282	0.0910**	0.0332
	(0.0227)	(0.0422)	(0.0417)	(0.0454)	(0.0366)
October	0.0521**	0.0305	0.0222	0.0698	−0.0116
	(0.0228)	(0.0413)	(0.0406)	(0.0426)	(0.0368)
November	0.0107	0.0095	0.0045	0.0244	−0.0189
	(0.0167)	(0.0299)	(0.0296)	(0.0296)	(0.0291)
Lagged Real Crack Spread					0.6314***
					(0.0722)
Constant	0.3629	−1.2435	−1.0290	−0.9676	0.2036
	(0.3784)	(0.7641)	(0.7394)	(0.6858)	(0.4286)
Observations	132	132	132	132	131
R-squared	0.5259	0.6516	0.6733	0.7037	0.8191