Response to "Ethanol Production and Gasoline Prices: A Spurious Correlation" by Knittel and Smith

Dermot Hayes

Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu

Dermot Hayes is a professor of economics and of finance at Iowa State University.

Questions or comments about the contents of this paper should be directed to Dermot Hayes at dhayes@iastate.edu.

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Introduction

In a recent working paper, Christopher Knittel and Aaron Smith present an attack on a peer-reviewed paper "The Impact of Ethanol Production on US and Regional Gasoline Markets Relating Ethanol Production to Gasoline Prices" written by myself and Xiaodong Du, and published in 2009 in *Energy Policy* (Vol. 37 No.8), as well as two subsequent working papers in 2011 and 2012. Our work found that as ethanol production increased, the price of gasoline fell relative to the price of crude oil. Knittel and Smith claim to have refuted this result, and conclude that their "Empirical models that are most consistent with economic theory suggest effects that are near zero and statistically insignificant."

This topic is of current relevance because of the current drought in the Corn Belt, and it is an issue where attention should be paid. The Knittel and Smith paper however, misrepresents our work and is presented in a mean-spirited and accusatory manner. The tone of their paper was picked up in a recent editorial by the Wall Street Journal that we discuss below.[1]

A distinguished colleague, who is well known to all of us, sent the following email to me when he voluntarily wrote to warn me about the working paper:

> "This is not a friendly or professional way to argue against particular empirical results. There are better ways to criticize others' work."

Given the way the paper was written and presented, it is clear that Knittel and Smith were out to discredit our work and imply that our results were influenced by the ethanol industry and that our results were mined to suit that industry. Nothing could be further from the truth.

For example, the cover page of the Knittel and Smith working paper includes a statement that "Neither author received financial support from relevant stakeholders for this study." Our paper,

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[1] See http://online.wsj.com/article/SB10000872396390444184704577589812320819988.html

as published in *Energy Policy* has no such claim, and by inference, Knittel and Smith infer that outside funding influenced our paper. For the record, there was no outside funding—Xiaodong Du provided his time on this paper as part of his unfunded dissertation work, and I provided my time as part of regular research duties.

Knittel and Smith make an issue out of the lack of explanation found in the 2011 and 2012 updates, but these papers are simply mechanistic re-runs of the gasoline price results from the original paper. There is no excuse for stating that the methods we used in these updates were unclear or unexplained because we explicitly tell the reader that the explanations are found in the *Energy Policy* paper. We relied on industry funds to run the updates and state this very clearly in both working papers.

An example of the tone Knittel and Smith take in their paper is their claim that the particular model structure we use is "a curious choice." What they do not tell readers is that we estimated and provided results for the alternative model that they propose.

Many of the errors in the Knittel and Smith paper could have been addressed had they simply asked us for our data and input. We could have saved them countless hours of data collection and coding had they let us know they were interested, and we would have been happy to explain our work and our conclusions. This would have been standard academic practice.

Immediate Policy Relevance

The editorial and others that have used the Knittel and Smith paper sets up a false dichotomy: If you believe there is an ethanol price impact, you serve the ethanol industry. But if you believe there is no impact, then you serve the petroleum and food industries. This is simply wrong. Below, I present a realistic example of how our research is beneficial to any industry that uses corn. I have been using this example in extension talks and pork industry presentations.

The renewable fuel standard for 2013 effectively mandates that 13.8 billion gallons of corn ethanol be blended in gasoline.[2] This output level will require slightly more than 5 billion bushels of corn. Because of the drought in the Midwest, it now appears that the US corn crop

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[2] See Schnepf, R. and Yacobucci, B. 2010. *Renewable fuel standard (RFS): overview and issues*, U.S. Congress Research Service, Washington, DC. CRS R40155

will fall to less than 11 billion bushels. If the mandate is binding in 2013, then approximately half of US corn production will be consumed by an industry that is not sensitive to price.

Suppose that political and economic circumstances in spring of 2013 are such that the United States decides to relax the mandate. This might happen because of a devastating cull in the US livestock breeding herd or poor weather in the southern hemisphere in the October to March growing season. If we are right about the ethanol to gas price linkage, a sudden closure of ethanol facilities (equivalent to closing 7% to 10% of our crude oil refining capacity) just prior to the summer driving season will cause a large increase in gasoline prices. High gasoline prices will lead to elevated ethanol prices and allow the ethanol industry to remain in business without the mandate. The problem will last at least until new corn crop becomes available in October 2013.

This outcome is avoidable. The obvious solution is to announce a relaxation of the 2013 mandate now. This will provide time for the United States to import, and then stockpile, gasoline to prepare for a downturn in ethanol production. With the appropriate market incentives, ethanol use would be restricted to 6% blends to enhance the octane level of poor quality fuel. If there is no link between ethanol production and gasoline prices as some have used the Knittel and Smith paper to claim, then the price impact of ethanol closures is not a concern.

Next, we provide an explanation for why we wrote the paper, as this helps explain our motives and our model structure. We do this because a reading of the Knittel and Smith paper would lead one to conclude that we purposefully mined the data to publish the biggest gasoline price impact that we could, and that we used the crack ratio for this purpose.

Motivation for the *Energy Policy* paper
In the fall of 2006, we were part of a group that predicted a major increase in corn prices.[3] The logic was that corn should sell at its energy value when sold as ethanol. This 2006 paper linked the price of corn to the price of crude oil. In late 2007, we noticed that the formula we had developed was not working as well as it had earlier. The corn to ethanol link did not cause the problem. Instead, to our surprise, what was breaking down was the gasoline to crude oil link. We wrote the *Energy Policy* paper to help us understand why this link was not working, and we incorporated the impacts we discovered there in our CARD-FAPRI model system.

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[3] See

Because we were interested in the relative prices of gasoline and crude oil, we focused on the ratio of gasoline to crude oil prices. We adjusted this simple ratio to allow us to directly compare the gasoline prices with crude oil prices by first dividing the crude oil price by 42. Figure 1 shows the ratio.
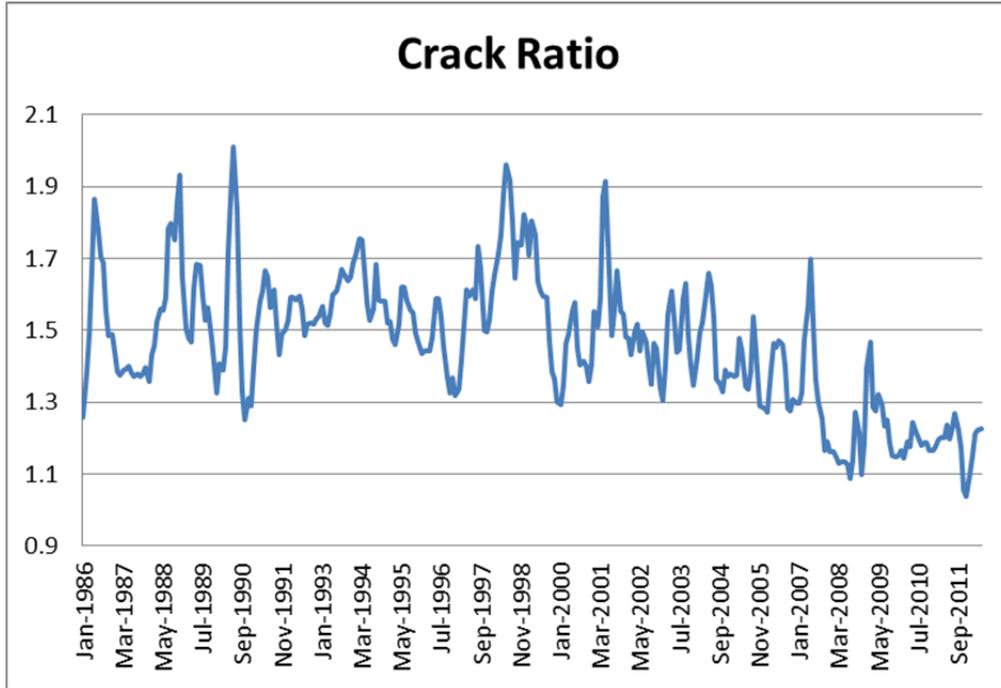
FIGURE 1. Gasoline and crude oil crack ratios from Jan. 1986–Sep. 2011

As can be seen from the long-term data in the figure above, the crack ratio is stable up to the year 2000. After this, the ratio falls by about 30%, and this is what was causing the trouble with our corn price projection model.

In the Knittel and Smith paper, they argue that if we were interested in the behavior of the refining industry, then we should have used an alternative measure called the crack spread. This is the weighted average of the gasoline and distillate products produced by a barrel of crude oil, minus the cost of the crude. They make a major issue of this point and constantly refer to the difference in results between the crack ratio and the crack spread. It leaves the reader with the distinct and false impression that we did not use this measure because it did not support our desired results.

This assertion is puzzling because our paper clearly provides a full set of results for both the crack spread and the crack ratio. In fact, Table 1 of the original paper presents the crack spread results right beside the crack ratio results. We have reproduced this table below to reinforce this point.

Table 1
Estimation results for fixed effects model on the crack ratio and crack spread.

Variable	Crack ratio		Crack spread	
	Estimate	Robust std. err.	Estimate	Robust std. err.
Oil stock	3.55e-06***	1.65e-06	0.000083***	0.000015
Gasoline stock	3.36e-06	3.87e-06	−0.000016	0.000028
Refinery capacity	2.67e-09	3.54e-09	4.64e-08	5.25e-08
Ethanol production	−0.000031***	3.77e-06	−0.00025***	0.000061
Supply disruption	0.12***	0.037	0.79	0.64
Gasoline import	−0.000016**	7.10e-06	−0.00040***	0.000061
HHI	0.00018***	0.000084	0.0024***	0.0010
January	0.00090	0.011	−0.24	0.19
February	0.0017	0.013	0.36	0.22
March	0.091***	0.015	1.91***	0.26
April	0.16***	0.020	3.32***	0.34
May	0.19***	0.022	3.51***	0.43
June	0.15***	0.019	2.91***	0.39
July	0.10***	0.017	2.22***	0.29
August	0.10***	0.018	2.67***	0.28
September	0.071***	0.018	2.66***	0.36
October	0.034*	0.018	2.02***	0.35
November	0.014	0.014	0.63	0.22
R^2	0.4349		0.3643	

Note: The STATA *xtivreg2* command with the *robust* and *bw* options is used. Single (*), double (**), and triple (***) asterisks denote significance at the 0.10, 0.05, and 0.01 levels, respectively.

Source: Du and Hayes 2009.

The estimate of the impact of ethanol on refiner's profit that we ***report in our paper*** is clearly provided in the summary of the results. We explain the importance of these measures below.

Basic Economics

The $1.33 per barrel reduction in the crack spread that we report corresponds to a $0.032 per gallon reduction in the refiner's profit. Our gasoline price impact is $0.14 per gallon. This means that the decline in refiners profits accounts for only 24% of the gasoline price reduction. We

conclude that the difference must have arisen because the refiners charged more for other distillates or found efficiencies in the production process. Given the sophisticated management in the oil industry, it is difficult to see why they would simply accept a 1:1 deterioration in their profit margin as ethanol forced gasoline prices down.

Knittel and Smith assume that *all* of the change in gasoline prices must have come directly from the refiner's profit margin. They use the change in refiner's profits and the change in gasoline prices interchangeably, as shown in their quotation below:

> "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***." (Emphasis added.)

They then *assume* that the estimated change in crack spread ($0.032) is a gasoline price change, and report getting a lower gasoline price change with the crack spread model. It is by means of this unrealistic assumption that they provide "evidence" that gasoline prices did not fall by the $0.14 per gallon we had reported.

In our original paper, we did not pursue the other possible causes for the difference between the change in gasoline price and the change in the refiner's margin. Figure 2 shows what happened to the value of the profits the refiners made from other distillates. This would seem to suggest that refiners do in fact have the ability to stabilize their profits by charging more for some outputs when the market for gasoline is weak.
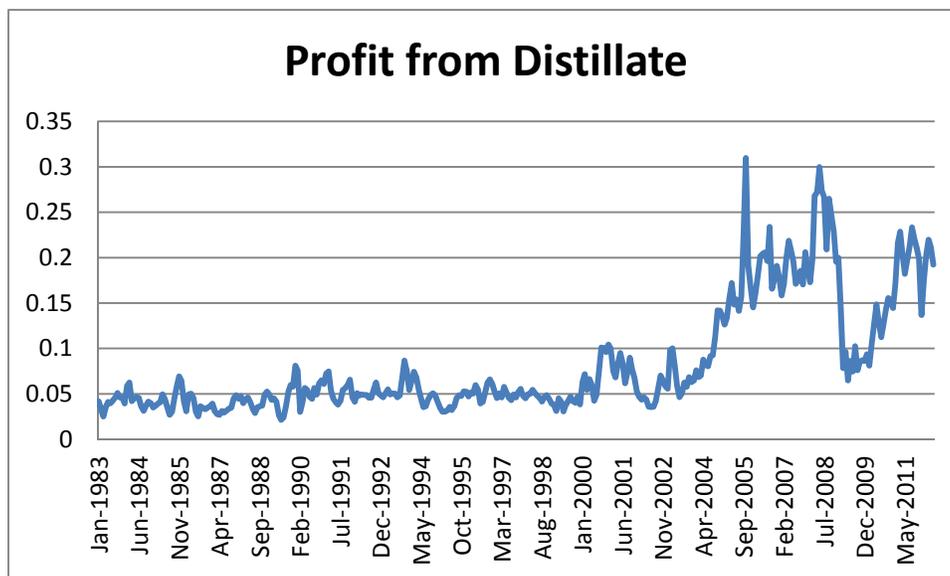
Profit from Distillate

FIGURE 2. Profit from crude oil distillates Jan. 1983–May 2011

The Knittel and Smith paper repeatedly infers that we biased the results because we did not report the impact of ethanol on gasoline prices using the crack spread model. So let us be very clear about this—**we estimated two equations and reported two sets of results**. The first equation has the relative price of gasoline on the left hand side. We use this equation to report gasoline price impacts. The second equation has the margin made by refiners on the left hand side. We use this equation to report the impact of ethanol on refiner's margin.

There is no way to use the refiners margin equation to measure the impact on gasoline prices, unless one is prepared to make the completely unrealistic assumption that for every penny by which gasoline prices are reduced the refining industry takes a one penny reduction in profit. If this assumption were true then the measure of the profits from distillates shown above would be perfectly flat. Knittel and Smith make this flawed assumption and use the second equation to report gasoline price impacts, when in fact they are reporting changes in refiner's profits. Because we call the change in margin exactly that — a "change in margin" and not a change in gasoline prices, their paper accuses us of hiding this data. They spend pages and pages fretting over this and give us a lecture on why the refining industry could not survive if all of the gasoline price impact was coming from profits.

Knittel and Smith also argue that the refining industry would have expanded capacity had ethanol production not surged as it did. Interestingly, this argument (presented on page five of their paper) relies on there being an ethanol-to-gas-price link.

We make this same point. In the results section of our paper we stated that:

> "The availability of ethanol essentially increased the ''capacity'' of the US refining industry, and in doing so prevented some of the dramatic price increases often associated with an industry operating at close to capacity. Because these results are based on capacity, it would be wrong to extrapolate the results to today's markets. ***Had we not had ethanol, it seems likely that the crude oil refining industry would be slightly larger today than it actually is***, and in the absence of this additional crude oil refining capacity, the impact of eliminating ethanol would be extreme." (Emphasis added.)

While on the subject of basic economics, consider this—ethanol now provides approximately 10% of the fuel used in gasoline engines. In any other commodity market, a rapid increase in the production of a close substitute would be expected to cause a reduction in prices and profitability. Why do Knittel and Smith believe the gasoline market would act any differently? Consider the following scenario, removing any issue related to ethanol. Suppose that the US refining industry found a magical catalyst that allowed it to squeeze 7% to 10% more gasoline from each barrel of crude, without impacting the production of other distillates or requiring new capacity. Basic economics would say that gasoline prices would fall relative to the price of other distillates; and yet if Knittel and Smith are to be believed, there is no indication that this would occur.

Another relevant piece of basic economic data is that the United States was a major net importer of gasoline at the beginning of our sample period. It is now a net exporter. Although we did not explore this trade reversal in our paper, it seems possible that it is due to the widespread availability of ethanol. As an importer of gasoline, the United States was paying world gasoline prices **plus** transportation cost, it is now exporting at world prices **minus** transportation cost. If ethanol is responsible for this turn around in trade, then it is surprising the impacts are not any greater than we report.

Finally, the price of gasoline was higher than diesel at the beginning of our sample period. Now it is significantly lower. We believe that our results explain this. If ethanol is not responsible for this, as Knittel and Smith assert, then what is?

Big versus Small Impact Numbers

The abstract of our 2009 paper is provided in its entirety below.

"Our contribution is two-fold. First, ethanol production is found to have a significant negative effect of $0.14/gallon (or 8% on average) on wholesale gasoline prices over the sample period. The price effect varies over regional markets, with the largest impact in the Midwest where regular retail gasoline prices were reduced by $0.28/gallon. The West Coast and East Coast are found to have experienced $0.23/gallon and $0.26/gallon reductions, respectively, in their retail gasoline prices, while for the Gulf Coast region, the average price reduction is about $0.20/gallon. The smallest impact is found in the Rocky Mountain region, at $0.07/ gallon, possibly because of its comparatively low gasoline and ethanol consumption. Our second contribution is to quantify the welfare impacts of ethanol production on multiple agricultural and energy markets, and on overall welfare changes. After accounting for the federal corn subsidy and ethanol tax credit, we find a net welfare loss of $0.5 billion in 2007."

We report a national average gasoline price-impact of $0.14 per gallon. This impact is estimated for the period 1995–2008 and can loosely be interpreted as the impact of the 4 to 5 billion gallons of ethanol that were produced at the mid-point of the data (i.e., 2001–2003). In later updates, we added more recent data and reported national average price impacts of $.25 and $.29 per gallon. This increase in the price impact makes sense because of the rapid increase in ethanol production in the more recent period.

Given the trend in the estimated national average impact described above, it is tempting to ask what the impact would be of current production levels of 13 billion or 14 billion gallons of ethanol. This calculation is of particular relevance given the possibility of lifting the mandate described earlier; but there are problems with this calculation. First, the method we use assumes that all else, including refining capacity, is held constant at measured levels. Second, we are not sure if the impact we measure is linear or not. Will 10 billion gallons have twice the impact of 5 billion gallons?

Faced with a legitimate need for the estimate, but concerned about its accuracy, we decided to provide it, but also provide our reservations about this number. In the quote provided above we state that:

> "Because these results are based on capacity, it would be wrong to extrapolate the results to today's markets" (Du and Hayes 2009).

In case anyone missed this the first time, we also state that:

> "These results may be questionable because we multiply a mean coefficient that is estimated over the entire sample period against data that is specific to the end of the sample period. We can be much more confident in the statistical accuracy of the estimated average impact but this estimate is not relevant to the current debate because ethanol production has surged since the mid-point of the historic data" (Du and Hayes 2012).

In their paper, Knittel and Smith ignore these qualifications and chose to cite speeches and press releases by others over whom we had no control. They then imply that we provided calculations without qualifications and used them in ways that we did not.

Sensitivity Analysis

Knittel and Smith provide a series of sensitivity analyses that purport to show that our results are too large. Instead of comparing our national average results against theirs, they focus on the marginal results and compare our 2010 marginal results against theirs. They do this analysis for the crack spread and crack ratio.

As we have discussed before, the Knittel and Smith measure found using the crack spread is actually a measure of the change in refiner's margin. We had already reported that this change was smaller than the change in gas prices. We will therefore focus this discussion on the crack ratio comparison. These results are in Table 1 of their paper.

The marginal impact for 2010 reported in our paper is $0.89 per gallon. Knittel and Smith essentially reproduce this result using our data and model and report an impact of $0.86 per gallon. They then add the price of crude oil as an explanatory variable and the estimated impact falls to $0.48 per gallon. When they add crude oil and natural gas, the impact falls to $0.35. This sensitivity analysis is relevant only if it makes sense to add crude oil and natural gas. Knittel and Smith assert that these are added because crude oil and natural gas are important costs incurred in operating a refinery. This logic might make sense in a model that is trying to explain refinery margin, but it makes no sense in a model that is attempting to explain the relative prices of gasoline and crude oil.

The dependent variable in our regression is the price of gasoline divided by the price of crude oil. The addition of crude oil on the right hand side will obviously cause endogeneity and bias the parameters.

That these two experienced econometricians had to resort to an alternative regression model that has the crude oil price on the left *and* the right hand sides of the estimated regression shows how hard they must have tried to find an alternative model that reduced our estimate.

Unrelated Variables

The most bizarre part of the Knittel and Smith paper is when they elect to make their point by replacing our dependent variables with the price of natural gas, the unemployment rate, and the age of their kids.

If it were really true that our results are simply due to a coincidental upward trend in ethanol production at a time when the crack ratio was falling, then our paper would not have withstood the peer-review process and would not and should not have been published. As can be seen from the table of results reproduced above from our study, we controlled for every variable that we could think of that might impact the crack spread and the crack ratio.

When Knittel and Smith chose to make their point by using our model to explain unemployment (and the other unrelated variables), they used the same control variables that we used. However, our control variables were chosen to explain behavior in the crude oil market and have nothing to do with unemployment. Had Knittel and Smith properly controlled for the forces that might influence unemployment (or the unrelated natural gas or age questions), then the "impact" of ethanol on those would disappear, as would their intended point.

Knittel and Smith claim that "Because ethanol production increased smoothly during the sample period, statistical analysis with this variable is fraught with danger." This is not true. Figure 5 in their paper shows that ethanol production grew quite slowly up to 2007 and then accelerated rapidly. Moreover, there is clear month-to-month variation in output as large new plants came on line and as plants closed for seasonal vacations. The method we used takes advantage of this variability to tease out ethanol specific impacts.

Ethanol consumption grew at different rates in each of the regions we modeled. For example, adoption was far greater in the Midwest than in the Rocky Mountain region. Again, we used this regional disparity to measure regional price impacts. These results show that areas where ethanol

adoption was greatest also experienced the greatest changes in the crack ratio. Knittel and Smith ignore this aspect of our work. (In their facetious example on unemployment, they do not attempt to show that **regional** unemployment trended up in proportion to ethanol use. They do not report this because they cannot—unemployment has been lower in Midwestern states.)

Citing this part of the paper, the Wall Street Journal editorial states that:

> "The claim that ethanol cuts gas prices is so silly that Messrs. Knittel and Smith have a little fun. To show how silly, they take "the same empirical models" Messrs. Du and Hayes used and replace the crack spread with the unemployment rate. The model then "proves" that if the U.S. had eliminated ethanol production in 2010, joblessness would have plunged by 60%, a finding that is statistically significant. Of course, their practical joke only shows that unemployment was rising when ethanol was also rising, even though ethanol has little to do with jobs. Whatever trend you plug into this model, ethanol becomes the cause. They use the model to show that every million barrels of ethanol cause Mr. Knittel's son Caiden to become 26 days older, while eliminating ethanol in 2010 would have caused Mr. Smith's daughter Hayley to have a negative age."

On a personal note, what I find most troubling is that the two authors' efforts to gain attention and score points come at the expense of my co-author, a new, untenured assistant professor at a prestigious university. Knittel and Smith are tenured professors who should serve as examples of mentoring and growing the academic reputation of young faculty. That they found this exercise to be a fun and humorous project is both a surprise and disappointment.

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