

# The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to 2012

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**Abstract**

We update the findings of the impact of ethanol production on U.S. and regional gasoline markets as reported previously in Du and Hayes (2009 and 2011), by extending the data to December 2011. The results indicate that over the period of January 2000 to December 2011, the growth in ethanol production reduced wholesale gasoline prices by \$0.29 per gallon on average across all regions. The Midwest region experienced the biggest negative impact of \$0.45/gallon, while the regions of East Coast, West Coast, and Gulf Coast experienced negative impacts of similar magnitudes around \$0.20/gallon. Based on the data of 2011 only, the marginal impacts on gasoline prices are found to be substantially higher given the increasing ethanol production and higher crude oil prices. The average effect across all regions increases to \$1.09/gallon and the regional impact ranges from \$0.73/gallon in the Gulf Coast to \$1.69/gallon in the Midwest.

## **Introduction**

The impact of US ethanol production on national and regional gasoline prices has been evaluated in Du and Hayes (2009 and 2011). Du and Hayes (2009) was based on data that was available prior to 2008. The results were updated in Du and Hayes (2011) using the data of January 2000-December 2010. Since then, US transportation fuel markets, including ethanol and gasoline markets, have experienced significant changes. Average crude oil price increased from about \$80/barrel in 2010 to about \$95/barrel in 2011. Correspondingly, average U.S. wholesale gasoline prices have risen 30% from 2010-2011. A wider than normal price differential between ethanol and gasoline prices provides further economic incentives for ethanol production and consumption, which reached approximately 13.9 billion gallons by the end of 2011 (see Figure 1). The purpose of this report is to update the earlier analysis using an additional year of historical data.

We calculate the average impact of ethanol production both nationally and regionally over the period of January 2000-December 2011 and specifically for 2011. Estimation results indicate that on average, over the whole sample period and all five PADDs (Petroleum Administration for Defense Districts), the growth in ethanol production reduced wholesale gasoline prices by \$0.29/gallon. The Midwest region (PADD II) experienced the biggest negative impact of \$0.45/gallon, while the other regions such as East Coast (PADD I), West Coast (PADD V), and Gulf Coast (PADD III) had similar negative impacts around \$0.20/gallon. Based on the data of 2011 only, the marginal impacts on gasoline prices are found to be substantially higher given the dramatic increase in ethanol production and higher crude oil prices. The national average effect increases to \$1.09/gallon and the regional impact ranges from \$0.73/gallon in the Gulf Coast to \$1.69/gallon in the Midwest.

### **The impact of ethanol production on wholesale gasoline prices**

Here we briefly describe the updates and changes to Du and Hayes (2009 and 2011). In the current study, we extend the sample period to January 2000-December 2011.

### *Dependent variables*

As in the previous studies, two dependent variables, the crack ratio and the crack spread, are employed.

(a) The crack ratio ( $\pi_{CR}$ ) is defined as the relative gasoline price to the price of crude oil,

$$(1) \quad \pi_{CR} = P_G * 42 / P_O$$

where  $P_G$  is the average wholesale gasoline price (\$/gallon), and  $P_O$  is the U.S. crude oil composite acquisition cost to refiners (\$/barrel).

(b) The crack spread ( $\pi_{CS}$ ) represents the refinery's profit margin and is defined as the price differential between the crude oil and refinery products,

$$(2) \quad \pi_{CS} = \frac{2}{3} P_G * 42 + \frac{1}{3} P_H * 42 - P_O$$

where  $P_H$  is the wholesale price of No. 2 distillate fuel (\$/gallon). The crack spread is deflated by the Producer Price Index (PPI) of crude energy material. Monthly data of all related prices are collected from Energy Information Administration (EIA) website.

### *Explanatory variables*

As described in Du and Hayes (2009), explanatory variables include monthly U.S. ethanol production, monthly seasonal dummies (January to November), monthly crude oil ending stocks (excluding the Strategic Petroleum Reserve (SPR)), total motor gasoline ending stocks, complexity-adjusted refinery capacity, the HHI index representing regional refinery market concentration, dummy variables for September and October 2005 representing the unexpected supply disruptions induced by Hurricanes Katrina and Rita, and regional gasoline imports. Du and Hayes (2009) provides justifications for the included variables.

### *Estimation*

A fixed-effects panel data model is specified as

$$(3) \quad \pi_{it} = \alpha_i + X_{it}'\beta + \varepsilon_{it} \quad i = 1, \dots, N; t = 1, \dots, T.$$

where  $i = 1, \dots, N$  denotes the cross-section dimension, the PADD regions, and  $t = 1, \dots, T$  denotes the time-series dimension.  $\pi_{it}$  is the crack ratio (crack spread) on the  $i$ th region for time period  $t$ .  $X_{it}$  is the  $K$ -dimensional vector of explanatory variables listed above.

The parameter estimates for the crack ratio and crack spread are reported in Table 1. All explanatory variables have the expected signs and largely consistent with previous studies. Evaluating at the sample mean, the wholesale gasoline price is lowered by \$0.29/gallon due to ethanol production. This is equivalent to a 17% reduction over what gasoline prices would have been without ethanol production.

We use the crack ratio to quantify the gasoline price impact. Specifically, the change of wholesale gasoline price, -0.29/gallon, is calculated as:

$$\begin{aligned} \text{Price change} &= \text{estimated coefficient} \times \text{Average ethanol production} \times \text{Average crude oil price (\$/gallon)} \\ &= -0.0000175 \times 12324.61 \times \frac{57.10 \text{ (\$/barrel)}}{42} \\ &= -0.2932 \text{ (\$/gallon)} \end{aligned}$$

where the sample average ethanol production and crude oil price are employed.

### **Regional analysis**

The crack ratio is employed as the dependent variable for the regional analysis. Ordinary Least Squares (OLS) estimation results are reported in Table 2. The results indicate that ethanol production has a significant and negative effect on wholesale gasoline prices in all regions. The Midwest has the largest impact of \$0.45/gallon. The other regions such as East Coast, West Coast, and Gulf Coast experience negative impacts of similar magnitude on gasoline prices, which is around \$0.20/gallon. The Rocky Mountain region has a \$0.30/gallon reduction in wholesale gasoline prices. The impacts are estimated based on the data for the whole sample period. The change of gasoline price in a regional market, for example, \$0.45/gallon in the Midwest region (PADD II), is calculated as

$$\begin{aligned}
\text{Price change} &= \text{estimated coefficient} \times \text{Average ethanol production} \times \text{Average crude oil price (\$/gallon)} \\
&= -0.000027 \times 12324.61 \times \frac{57.10 (\$/\text{barrel})}{42} \\
&= -0.4524 (\$/\text{gallon})
\end{aligned}$$

Basing only on the data of 2011, we calculate the marginal impact of increasing ethanol production on wholesale gasoline prices. We find that the average effect across regions increases to \$1.09/gallon and the regional impact ranges from \$0.73/gallon in the East Coast to \$1.69/gallon in the Midwest. The average and marginal effects of ethanol production on the US and regional markets are summarized in Table 3.

***Why do the regional impacts vary so much?***

In our original analysis we had hypothesized that the impact of national production ethanol should have had a greater impact on PADDs where ethanol penetration is greatest and we used the larger estimated impact in the Midwest as evidence in support of the ethanol impact hypothesis. The PADDs are also very different in terms of their economic conditions, oil and petroleum characteristics, oil related pipeline infrastructure, and local product supply and demand conditions. Therefore one would expect different gasoline price impacts for each region, especially because we estimate different parameters for each region.

Because of its high population density, the East Coast (PADD I) has the highest demand for refined products in the country, but it has very limited refinery capacity. Its regional demand is largely satisfied by the Gulf Coast and by foreign imports. The Midwest PADD II is distinct in its coexistence of a highly industrialized section and a rural agricultural section. Much of the crude oil used in the Midwest is piped in from the Gulf Coast and Canada. The Gulf Coast region (PADD III), including Texas, Louisiana, New Mexico, Arkansas, Alabama, and Mississippi, produces over 50% of the nation's crude oil and 47% of its final refined products. This region also serves as a national hub for crude oil and is the center of the pipeline system. It also exports gasoline. The Rocky Mountain region, or PADD IV, has the smallest and fastest-growing oil market in the U.S. With only 3% of national petroleum product consumption, it has the lowest ethanol penetration. The West Coast region, PADD V, is independent of other regions since it is geographically separated by the Rocky Mountains. In addition, the refinery market of this region

is highly concentrated. Given this regional differentiation in our explanatory variables, it is not surprising that we end up with different estimates of the impact of ethanol.

### ***Why are the 2011 results so large?***

The results for 2011 are very large. 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. With higher crude oil price and expanding ethanol production, the marginal impact of ethanol growth on gasoline prices becomes increasingly pronounced.

The surge in ethanol production in recent years has essentially added 10% to the volume of fuel available for gasoline powered cars and in so doing it has allowed the US to switch from being a major importer of finished gasoline to a major exporter of both gasoline and ethanol. Countries that switch trade patterns in this way will see dramatic price impacts because internal prices switch from world prices *plus* transportation costs to world prices *minus* transportation costs. In the early period, the US gasoline price had to be equal to the EU gasoline price plus the costs of transporting the gasoline from the EU to the US. Now that ethanol has allowed the US to reverse this trade pattern, US prices are lower than EU gasoline prices by an amount equal to transportation costs. In this context a \$1.09 per gallon marginal impact for 2011 seems reasonable.

### ***How does the lower energy density of ethanol affect the results?***

The gasoline price that we use is the “Wholesale/Resale Price by Refiners” taken from EIA website. These prices are averaged over grade (regular, midgrade and premium) and formulation (conventional, oxygenated, and reformulated). This is the wholesale gasoline that retailers buy. Since these are finished motor gasolines, not the gasoline blendstock, the price will already include ethanol where it is blended. Ethanol has lower energy content per gallon than gasoline and this raises the question of how our results might differ on a cost-per-mile basis reflecting the slightly lower energy content of ethanol-blended gasoline compared to unblended gasoline. .

According to EPA, “the theoretically expected decrease in fuel energy as a result of oxygenate use is in the 2% to 3% range when compared to gasoline. This corresponds to 0.5 to 0.8 miles per gallon for a car that averages 27 miles per gallon.”<sup>1</sup> This means a driver using ethanol-blended gasoline would have to fill up his car slightly more often in order to travel the same distance as he would if he were using unblended gasoline. Using a gasoline price of \$3.50 per gallon, a 2.5% reduction in energy value would equate to \$0.087 per gallon. In theory, this means a gallon of gasoline blended with 10% ethanol would need to be priced at \$3.41 per gallon to provide the same cost per mile as a gallon of unblended gasoline priced at \$3.50 per gallon. However, ethanol is blended with gasoline primarily for its additive properties, such as boosting octane and oxygen content, not strictly as a source of energy for combustion. Regardless, the impact of ethanol’s lower energy content on gas prices is much smaller than the price impacts we have measured and does not change the overall conclusions of our analysis. .

## References

- Du, X., and D.J. Hayes. 2009. The impact of ethanol production on US and regional gasoline markets. *Energy Policy* 37: 3227-3234.
- Du, X., and D.J. Hayes. 2011. The impact of ethanol production on US and regional gasoline markets: an update to May 2009. CARD Working Paper 11-WP 523. Center for Agricultural and Rural Development, Iowa State University.

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<sup>1</sup> See (<http://www.epa.gov/otaq/regs/fuels/ostp-3.pdf>)

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

Variable	Crack Ratio		Crack Spread	
	Estimate	Std. Err.	Estimate	Std. Err.
Oil stock	3.05e-06***	5.66e-07	6.89e-05***	1.10e-05
Gasoline stock	1.78e-06	1.58e-06	-2.11e-05	3.08e-05
Equivalent Refinery capacity	2.71e-06	2.30e-6	1.36e-04***	4.48e-5
Ethanol production	-1.75e-5***	6.97e-07	-.00016***	1.36e-05
Supply disruption	.09**	.04	.15	.71
Gasoline import/export	-8.26e-6**	2.28e-06	-1.70e-4***	4.45e-05
HHI	2.60e-5	3.31e-5	0.001	0.0006
January	0.01	.02	0.15	.39
February	0.02	.02	0.74*	.39
March	.09***	.02	1.85***	.39
April	.14***	.02	2.92***	.39
May	.17***	.02	3.51***	.39
June	.12***	.02	2.77***	.39
July	.08***	.02	2.18***	.39
August	.08***	.02	2.66***	.39
September	.08***	.02	3.11***	.39
October	.05**	.02	2.34*	.40
November	.01	.02	0.71	.39

Note: Single (\*), double (\*\*), and triple (\*\*\*) asterisks denote significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 2. Regression results for the crack ratio with individual PADD regional data

Variable	PADD I	PADD II	PADD III	PADD IV	PADD V
Oil stock	3.99e-6	6.78e-6***	2.04e-6***	2.51e-5	4.01e-6
Gasoline stock	-5.78e-6**	-5.57e-6	2.15e-6	-2.50e-5	2.34e-7
Refinery capacity	-1.92e-5**	1.11e-5	-1.17e-6	2.41e-5	-6.15e-5***
Ethanol production	-0.000121***	-0.000027***	-0.000116**	-0.000178**	-0.000138**
Supply disruption	.18***	0.04	.19**	.13	.05
Gasoline import/export	-3.45e-6	.0005**	-1.59e-5	.004**	.00003
HHI	-0.001***	-0.0003	-0.00005	.0003*	.00004
January	.04	.06	.02	.01	.02
February	.01	.04	.02	.04	.06
March	.05	.07	.06	.09*	.16***
April	.11***	0.10**	.10***	.12**	.19***
May	.15***	.17***	.12***	.19***	.18***
June	.10**	.13***	.07**	.16***	.13**
July	.06	.07*	.04	.12***	.09
August	.02	.09**	.04	.13***	.09
September	-0.009	.09**	0.03	.15***	.11*
October	-.03	.04	0.002	.08*	.08
November	-.02	.001	-.002	.04	.04
Constant	2.25***	1.25***	1.06***	.91	3.15***
$R^2$	.69	.71	.61	.69	.63

Note: Single (\*), double (\*\*), and triple (\*\*\*) asterisks denote significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 3. The negative impact of ethanol production on wholesale gasoline prices (in \$/gallon)

	Average across regions	PADD I  (East Coast)	PADD II  (Midwest)	PADD III  (Gulf Coast)	PADD IV  (Rocky Mountain)	PADD V  (West Coast)
Average effect (based on monthly data of 01/2000- 12/2011)	0.29	0.20	0.45	0.19	0.30	0.23
Marginal effect (based only on data of 2011)	1.09	0.76	1.69	0.73	1.11	0.86

Figure 1. U.S. historical ethanol production (in billion gallons), 1980-2011.

