The Renewable Fuel Standard Program:
Measuring the Impact on Crude Oil and Gasoline Prices

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This paper examines the impact of the Renewable Fuel Standard program (RFS) on crude oil and gasoline prices. The RFS program was enacted fourteen years ago in 2005, but the particular focus of this paper is on the period from 2015 to 2018. The conclusions offered from this research are that the RFS program has provided economic benefits to consumers in the United States and worldwide. Retail gasoline prices are lower thanks to the program. The findings from an econometric model show that the savings to consumers resulting from the RFS averaged $0.22 per gallon from 2015 through 2018.

Quantifying the Benefits of Renewable Fuels

The first and most obvious benefit from renewables lies in the price of crude oil. The blending of approximately one million barrels per day of ethanol into U.S. motor fuels over the 2015 through 2018 period has lowered the average price of crude by $6 per barrel. This reduction has cut the retail gasoline price by $0.22 per gallon from the level that would have obtained absent the presence of ethanol in the motor gasoline supply.

The lowering of gasoline prices confers a second benefit on consumers. Because gasoline demand is price inelastic, consumers have been able to allocate a smaller percentage of their total consumption budget to fuel purchases. This has allowed them to expend more on other goods. Over four years, US consumers have been able to spend almost $90 billion per year more on other goods because of gasoline prices being pulled down by renewable fuel use.

The annual savings in consumption represents 0.33% of the US nominal GDP. Allowing for multiplier effects, one can conclude that the use of renewable fuels has raised the US GDP by 0.5% in each of the last four years relative to the level that would have been observed had the RFS program not required the blending of ethanol into gasoline.

The benefits of ethanol may have been even greater, though, because the use of renewable fuels has reduced global demand for crude oil. Over the last two years, a group of oil-exporting countries (OPEC+) has worked to limit global supplies and boost world prices. Their efforts have had some

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success. That success would have been greater had almost one million barrels per day of renewable fuels not been blended into the fuels consumed by the public. Since many of the OPEC+ countries seek a higher price than what has been achieved, one can surmise, again, that the economic benefits of renewable fuels may have been greater than the amount calculated here.

These findings are based on a simulation run using a model of the global crude market called the “but-for” or BF model. The BF model is linked to an equation that ties the crude price to the retail gasoline price. The model was first calibrated to actual data and then simulated under the assumption that the volume of renewable fuels in the US fuel supply was reduced due to the ending of the RFS in January 2015 (hereafter, the “No RFS” case).

The simulations produced price scenarios for crude oil and gasoline that would have occurred in a situation where smaller volumes of renewable fuels were blended into the US fuel supply. The higher gasoline prices were then used to determine how much consumers would need to reallocate from purchases of other goods and services to gasoline.

The discussion that follows is divided into four parts.

- The first part explains how renewable fuel use has helped lower the world price of crude oil. The BF model is also introduced.

- The second shows how lower usage of renewable fuels in the “No RFS” case starting in January 2015 would have pushed up crude prices.

- The third shows how lower usage of renewable fuels in the “No RFS” case starting in January 2015 would have pushed up gasoline prices.

- The fourth discusses the cost to consumers of reducing renewable fuels consumption under the “No RFS” case starting in January 2015.

The paper ends by offering conclusions on the impact of lower US renewable fuels consumption on global crude oil prices, US retail gasoline prices, US consumer spending, and US gross domestic product.

The analysis of the RFS program starts from January 1, 2015. This date was chosen because 2015 was a unique year for the global oil market. At the end of November 2014, OPEC abandoned its efforts to control oil prices and began producing at full capacity. For the first time in at least fifteen years, the organization made no effort to limit global crude output. All available capacity to produce crude oil was put into service.

The resulting absence of any surplus productive capacity created a situation where removing any supply source would cause prices to increase. Prices would have risen had the 951,000 barrels per day of renewable fuels blended into US petroleum supplies at that time been taken away because no alternative hydrocarbon sources were available.

These circumstances persisted until late 2016 when Russia and Saudi Arabia began to discuss removing some crude oil from the market to raise global crude prices. Thus, the two-year period from January 2015 to December 2016 provides a unique test of the RFS program's consumer price impact and its benefits to the economy.

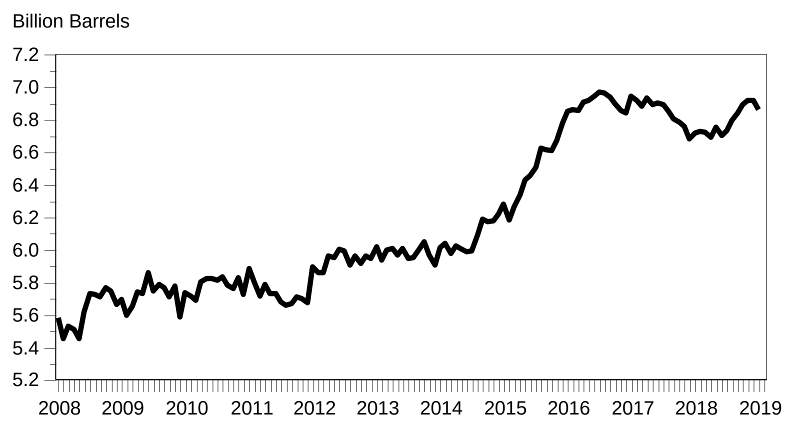
Impact of Renewable Fuels Use on Global Crude Oil Prices

In order to assess the impact of ethanol use and the RFS program on consumer gasoline prices, a model was constructed of global crude oil prices. Renewable fuel use in the US has removed a substantial portion of crude oil demand from the world market, which, under the tight supply environment that existed from 2011 to 2014, reduced the magnitude of the price increase that would have otherwise occurred. The model calculates the Dated Brent (DB) oil prices that would have prevailed "but for" the RFS program using an econometric approach that relates changes in DB prices to changes in inventories and seasonal variables.

The Energy Intelligence Group (EIG) publishes detailed data on inventories held across the globe and enables analysts to separate commercial inventories from strategic stocks. Figure 1 shows data on total global commercial stocks of crude and products. Government-controlled strategic stocks, which account for approximately 16% of world inventories, are excluded. Experience shows that these stocks have been "sterilized," that is, they are never used and therefore do not factor into price formation. In this study, the movement of commercial stocks and prices was compared to an indicator of the influence of financial markets on these two items.

The role of inventories and consumption in price formation has been studied by economists for centuries. Invariably, the basic conclusion is simple: prices are less likely to rise if there are ample supplies relative to the amount demanded by consumers than they are if the available supplies are limited compared to the amount demanded. The analytical way of expressing this simple relationship is to compute a ratio between the level of demand and the level of consumption.

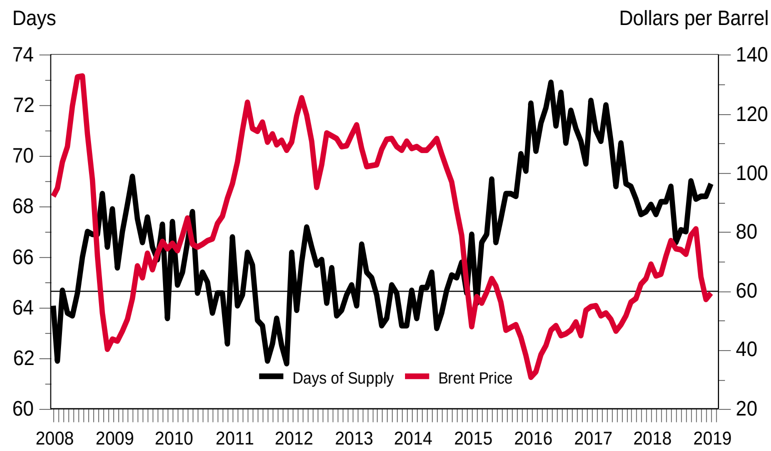
Figure 1
Global Commercial Inventories of Crude Oil and Petroleum Products, 2008 to 2019



Source: Energy Intelligence Group.

Figure 2 (page 4) compares the DB price movement to the levels of consumption divided by inventories, expressed as the number of days of consumption that are covered by supplies. The data shown in the graph seem to confirm this relationship. Note that DB prices were very high in 2008 when inventories were low relative to consumption. Prices dropped as stock coverage rose in 2009 and 2010 and then rose back to high levels until the end of 2014 when OPEC abandoned production controls. Days of coverage then rose again, and prices fell.

Figure 2
Days of Supply of Commercial Crude and Product Stocks vs. Dated Brent Price, 2008 to 2019



Source: PKVerleger LLC>

In modeling this relationship, the practice noted in other commodity market models was followed. Specifically, monthly data on the crude price change was regressed on the change in a sequence of current and lagged values of inverse days of supply (the standard method used for measuring the relationship between inventories and consumption) and seasonal dummy variables. The equation takes this form:

$$\Delta P_t = \alpha + \beta_1\, \Delta(1/day_t) + \beta_2\, \Delta(1/day_{t-1}) + \beta_3\, \Delta(1/day_{t-2}) + \beta_4\, \Delta(1/day_{t-3}) + \beta_5\, \text{Volatility} + \beta_6\, \text{N14} + \varepsilon$$

P_t represents the DB price; *1/day* represents the reciprocal of commercial days of supply with the subscript identifying days of supply at the end of the current month (current consumption divided by end-of-month stocks), the previous month, two months previous, and three months previous; *Volatility* measures the volatility of oil prices; *N14* is a dummy variable to mark the breakdown in OPEC control of production that occurred in November 2014. The parameters α and β_1 through β_6 are estimated using standard statistical techniques.

The model was estimated using the monthly data shown in Figure 2 for the period 2006 through 2013. Table 1 (page 5) lists the estimated parameters and the standard summary statistics.

In addition to the measures of days of supply, the model includes two additional variables that account for key structural developments in the global oil market. First, the model includes an adjustment for the breakdown of the OPEC cartel in November 2014. At the OPEC meeting held that month, the Saudi oil minister concluded that the organization could not make the cuts in output required to bring the market into balance given the surge in US oil production. As a result, Saudi Arabia announced that it would produce at capacity. The organization's efforts to stabilize prices were suspended. The current model includes a dummy variable for the November 2014 breakdown.

Table 1: Estimated Parameters and Summary Statistics for Inverse Days of Supply Price Model

Parameter	Coefficient	Standard Error	t-Statistic
α	0.06		
β_1	2,671.67	3,240.29	0.82
β_2	2,325.91	3,669.59	0.63
β_3	6,106.65	3,660.04	1.67
β_4	4,937.21	3,229.09	1.53
β_5	-0.24	0.13	-1.81
β_6	-9.35	5.65	-1.65

R^2 = 0.199
Standard Error = $6.17 per barrel
Source: PKVerleger LLC.

Second, the model contains a variable measuring price volatility. Price volatility is a surrogate for the demand for futures by the firms that are writing options to producers that have hedged by purchasing puts. At the end of the third quarter of 2018, such hedges covered 700 million barrels.

The introduction of this type of activity in oil and other commodity markets is a relatively new development that, in the case of oil, has only come into use in the last ten years. It involves the issuance of price insurance to producers such as independent oil companies or consumers such as airlines by financial institutions. These institutions, in turn, buy or sell oil, creating claims on physical barrels with changes in prices. Price volatility provides a way of measuring these unseen but very real determinants of prices. In essence, increases in price volatility can cause an increase in demand for short futures positions given the price levels chosen by oil producers.[2]

Readers may note that the equation explains only 20% of the variance in the dependent variable. This should not come as a surprise because the dependent variable measures the change in DB, not the level of DB. The procedure used here is a standard approach taken to remove the effect of autocorrelation from the data when the predicted values are compared to the actual values after "reconstructing the variables." (In other words, explaining the predicted price based on the data for the current month and the previous month's price, the equation explains eighty percent of the variance.)

The parameters on the inverse of days of supply remained close to the original values. All had the correct sign, meaning an increase in inverse days of supply caused prices to increase, while a decrease caused prices to decline.

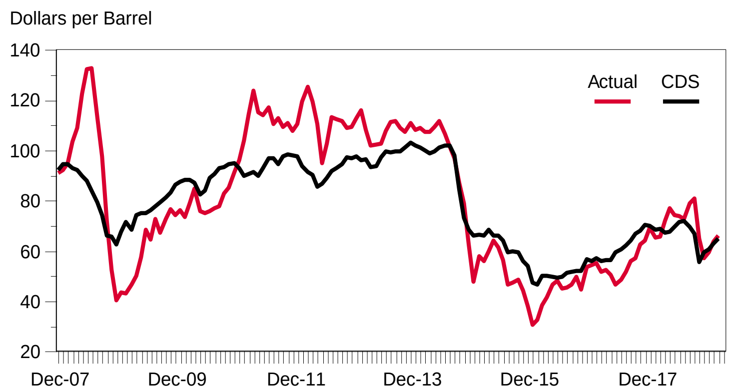
[2] As volatility increased, the firms writing the hedges were forced to sell more futures to remain "delta neutral." The selling sent prices down from $85 per barrel to $50. This activity is now an important determinant of oil prices. The delta measures the number of barrels of crude a firm writing the insurance to a producer or consumer would need to buy or sell as the price of oil changes. For further details, see Franklin R. Edwards and Cindy W. Ma, *Futures and Options* (New York: McGraw Hill, 1992), Chapter 19.

The parameter on volatility was significant and again had the correct sign. An increase in volatility tends to cause prices to decline because those who are writing puts will enter the market and sell futures, effectively adding to the oil supply.[3]

The dummy variable for the OPEC November 2014 collapse was also significant. This suggests that prices dropped by $9 per barrel in each of the two months when the value was one: December 2014 and January 2015.

To test the model's usefulness, a "conditional dynamic simulation" (CDS) was run. In a CDS, one uses the model to compute the predicted price based on the exogenous variables, using the predicted rather than the actual value for the dependent variable for period t-1. Thus, the predicted value for December 2018 is based on the actual price of Brent 121 months earlier in December 2007 and the changes in the exogenous values since the date. There are no corrections for errors in a CDS.

Figure 3
Actual Dated Brent Prices vs. Prices Predicted by CDS Model, January 2007 to March 2019



Note: CDS = conditional dynamic simulation.
Source: PKVerleger LLC.

Figure 3 compares actual DB prices to values calculated by the CDS. As can be seen from the graph, the model tracks the actual price movement, particularly from January 1, 2015, to December 31, 2018. Sixty-five percent of the variance in the DB movement was explained by the CDS.

Impact of Reducing Renewable Fuels Consumption on Crude Oil Prices

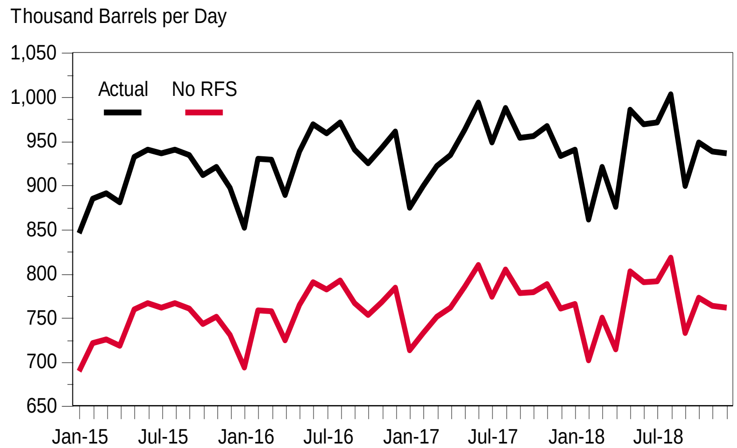
The model linking crude price fluctuations to inventories can also be used to assess the specific impact of the RFS program. Specifically, the cancelation of the RFS on January 1, 2015, would have lifted crude by $8 per barrel by the end of 2018. Over the 2015 to 2018 period, crude oil prices would have been $6 per barrel higher on average.

[3] The following example may help. Suppose Bank A has guaranteed a producer that it will receive at least $60 per barrel for its production in 2019. This means that Bank A will need to pay the producer the difference between the price received and $60 per barrel *if* the price falls below $60. The bank will acquire assets that will provide it with insurance against such a loss. Few assets will be acquired if prices are high, say $90. More assets will be acquired as prices fall. An increase in volatility will predict that the probability of prices being less than $60 has increased. To protect against losses, the bank will need additional assets. One type of asset purchase is a put. A second is a short position against crude oil. One form of the short is the sale of a future.

This assessment assumes that the RFS program stopped on January 1, 2015. At the time, almost one million barrels per day of renewable fuels were being mixed into US petroleum product supplies.

Cancelation of the RFS program would lead to a reduction but not a full termination of ethanol blending. Estimates made by researchers associated with the National Center for Food and Agricultural Policy (NCFAP) indicate that economics, not regulation, drive approximately 80% of current ethanol blending with gasoline, with the RFS prompting the remaining 20%. Thus, some volume of ethanol would presumably continue to be blended even if the RFS had ended. Figure 4 compares the actual volumes of ethanol blended with the volumes the NCFAP estimates would have been used in the RFS' absence.[4]

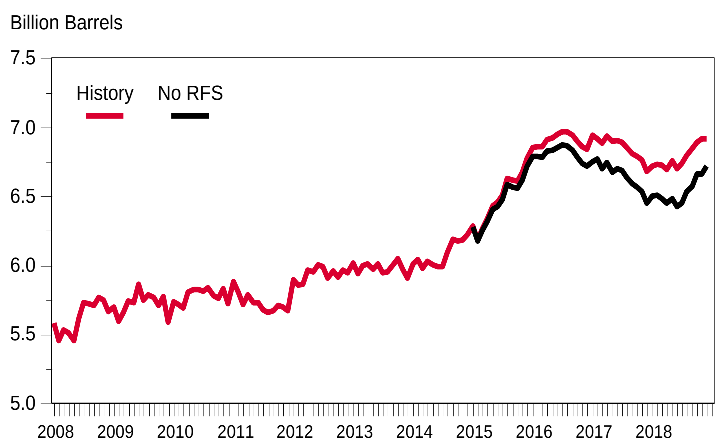
Figure 4
Renewable Fuel Volume Blended into US Motor Fuels vs. No RFS Volume, January 2015 to December 2018



Source: US DOE; PKVerleger LLC based on NCFAP data.

Reducing the volume of renewable fuels would have led to a decline in global stocks because there were no constraints on the volumes produced by OPEC members or any other oil-exporting country.

Figure 5
Global Commercial Crude and Product Stocks: History vs. Stock Levels If RFS Program Had Ended after 2014



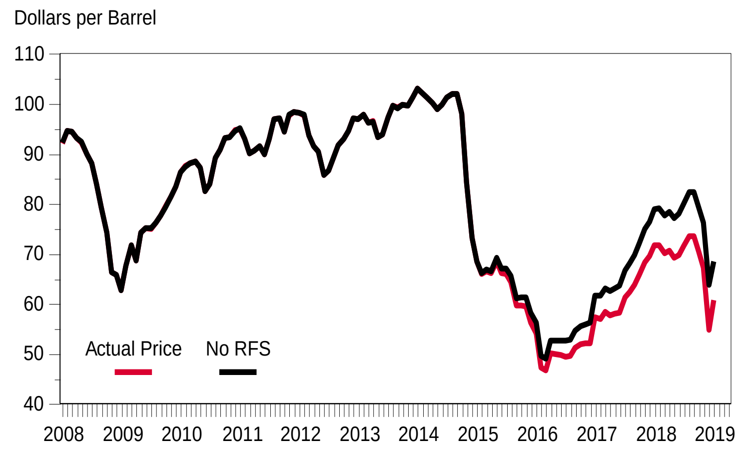
Source: US EIA; PKVerleger LLC.

Figure 5 above shows the trend that would have occurred in global stocks had the RFS not been in effect after January 2015. By December 2018, global stocks would have fallen to the levels last

[4] Farzad Taheripour, Harry Baumes, and Wallace E. Tyner, "Analysis of Impacts of Possible Increase in Conventional Biofuel RFS Level," NCFAP, Forthcoming. Findings from these researchers regarding the volume of ethanol that would have been used in 2016 in the absence of the RFS were prorated on a monthly basis over the 2015-2018 period

observed in late 2016. As Figure 6 illustrates, the lower inventories would have pushed global crude prices higher. A simulation with the BF model shows that the DB price would have increased by more than $8 per barrel by the end of 2018 and would have been $6 per barrel higher on average over the 2015 through 2018 period.

Figure 6
Impact on Brent Price Predicted by But-For Model Had RFS Program Ended after 2014



Source: PKVerleger LLC.

Actions by OPEC members require that the increase in the crude price associated with reducing renewable fuels blending in US petroleum supply be divided into two intervals: 2015 through 2016 and 2017 through 2018.

During the first two years, there were no constraints on global crude production. Saudi Arabia elected to abandon limits on output hoping to stop further expansion by the US independent oil producers known as “frackers.” This action caused prices to fall as low as $32 per barrel in 2015. The surge in US light tight oil (LTO) production led to the global inventory increase discussed above.

The reduction of renewable fuel blending in the United States simulated here would have brought world stocks down and pushed prices higher. The BF model projected that by December 2016 DB would have traded for $56.50 per barrel rather than the $53.80 reported, a 5% difference.

By the end of the simulation period in December 2018, one finds that the price has risen to $68.50 per barrel, 13% higher than the $57 price reported for the year end. The average increase in oil prices in the no-RFS case over the entire period is $6 per barrel.

Impact of Reducing Renewable Fuels Consumption on Gasoline Prices

Changes in crude prices have a direct effect on the gasoline price. The impact of reducing renewable fuel use on this price was tested using a simple regression between the change in the retail gasoline price and the change in the spot crude price. The specification of the model was as follows:

$$\Delta Gas_t = \beta_1 \Delta(P_t) + \beta_2 \Delta(P_{t-1}) + \varepsilon_t$$

where ΔGas_t measures the change in the retail gasoline price from one month to the next and $\Delta(P_t)$ measures the change in Brent crude price.

The equation was estimated for all types of regular gasoline. The estimated parameters are shown in Table 2.

Table 2. Estimated Parameters and Summary Statistics for Gasoline CDS Model

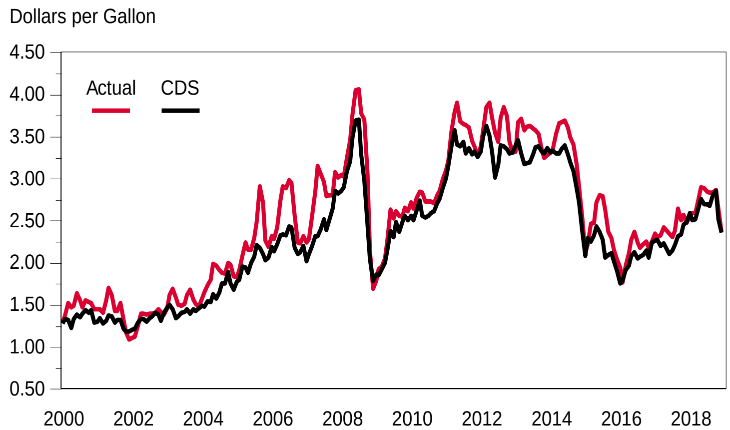
Parameter	Coefficient	Standard Error	t-Statistic
β_1	0.76	0.13	5.66
β_2	0.24	0.13	1.79
R^2 = .27			
Standard Error = $0.23/gallon			

Source: PKVerleger LLC.

The equation explains 99% of the variance in the level of gasoline prices one month ahead.

Once again, CDS was used to test the model's reliability. The simulations performed well, as can be seen from Figure 7. This graph shows the movement of retail gasoline prices compared to the prices predicted from the simulation. For the simulation period of 227 months, the model explains 95% of the retail price variance even though the simulation used only the actual retail gasoline prices from January 2000.

Figure 7
Actual US Retail Gasoline Prices vs. Prices Predicted by CDS Model Linking Changes in Retail Prices to Changes in Dated Brent Prices



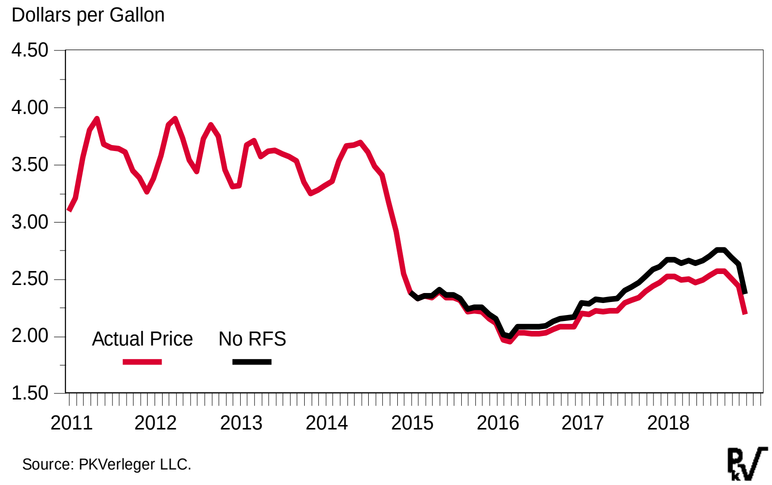
Note: CDS = conditional dynamic simulation.
Source: PKVerleger LLC.

A second CDS was then conducted using the DB prices predicted by the crude oil price model under the assumption that the RFS program would have been terminated after December 2014. The results from this CDS appear in Figure 8 (page 10). In this simulation, retail gasoline prices rose to $3 per gallon in September 2018.

The US Energy Information Administration reported that the actual price for retail gasoline sold in September 2018 was $2.83 per gallon. Thus, by September 2018, retail gasoline prices would have been $0.22 per gallon higher (7%) than actually reported, as Figure 8 shows.

The Cost to US Consumers of Reducing Renewable Fuels Consumption

Figure 8
Impact on Retail Gasoline Price Predicted by But-For Model Had RFS Program Ended after 2014



Professor James Hamilton has studied the impact of fluctuating energy prices on US economic activity for decades. Following the rise in US oil prices in 2008, he wrote an important article assessing the increase's effect on domestic economic activity.[5] He began by noting that the National Bureau of Economic Research had concluded that a recession had begun in the fourth quarter of 2007 and then noted that the likelihood of a recession starting at that time would have been low but for the rise in oil prices.

Hamilton then described the critical link between consumer expenditures, economic activity, and oil prices. Starting from the fact that US economic activity is critically tied to consumption, which accounts for sixty-eight percent of GDP, he explained that increases in energy prices depress consumption of all other goods and services:

> Another key parameter for determining the consequences of an energy price increase is the value share of energy purchases in total expenditure. The fact that the U.S. income elasticity of demand has been substantially below unity over the last quarter century induces a downward trend in that share: for a given relative price, if the percentage growth in energy use is less than the percentage growth in income, total dollar expenditure on energy will decline as a percentage of income. On the other hand, the very low short-run price elasticity of demand causes the value share to move in the same direction as the relative price: if the percentage increase in price is greater than the percentage decrease in quantity demanded, dollar spending as a share of income will rise when the price of energy goes up.

[5] James D. Hamilton, "Causes and Consequences of the Oil Shock of 2007-08," *Brookings Papers on Economic Activity*, Spring 2009 [https://tinyurl.com/y3l6uuwn].

This effect is captured in two figures. Figure 9 shows total expenditures by US consumers on motor fuels as a percentage of total consumption expenditures by month from 1960. One can observe that from 1960 to 1974 roughly 3.5% of consumer expenditures were allocated to motor fuels. The share then jumped to 4% following the Arab Embargo and 5% in 1980 after the fall of the Shah in Iran. The share plummeted in the mid-1980s at the time of the price collapse and rose back to 4% in 2007. It has oscillated since 2010.

Figure 9
US Motor Fuels Expenditures as Share of Total Consumer Expenditures, Monthly Data, 1959 to 2018

Source: PKVerleger LLC.

The data used to produce Figure 9 come from the national income accounts. The US Bureau of Economic Analysis publishes detailed statistics on the allocation of consumer spending. Figure 9 was created by taking the amount spent on motor fuels, one of the three hundred spending categories, as a percentage of total consumption.

A key finding of this exercise is that consumers spend less on other items when gasoline prices are high and more on other goods and services when prices are low. Figure 10 (page 12) shows this effect. This graph shows the share of consumer spending allocated to "everything but motor fuels" as a function of the relative price of motor fuels.

The relative price of motor fuels was calculated using the standard approach of comparing the gasoline price to the price of all the items purchased by consumers. The data shown in Figure 10 (page 12) are for the period from 2000 to 2018. One can note from the graph that 96% of consumer spending goes to items other than motor fuels when prices are high, and 98% of consumer spending goes to items other than motor fuels when prices are low.

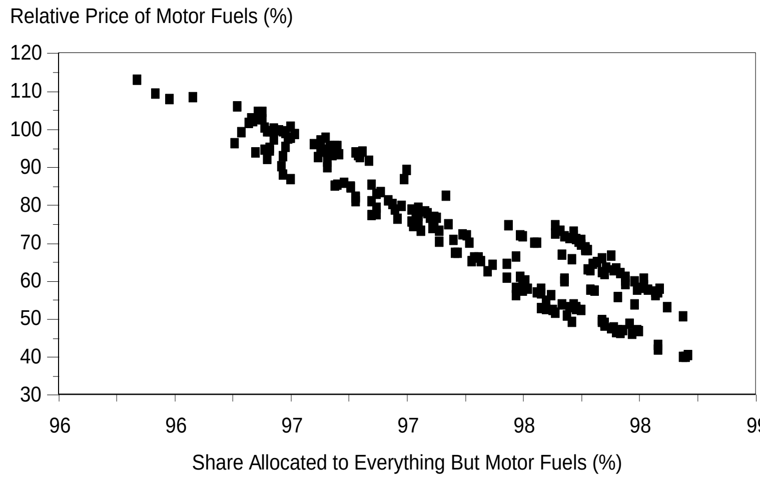
The two-percentage-point difference between the amount spent on gasoline when prices are low compared to when prices are high is worth almost $300 billion today. This amounts to 1.4% of GDP. As Hamilton has shown, a rise in the relative price of motor fuels from a low level to a high level that would cut consumption on other goods by 1.4%—specifically, rising from 40% of personal consumption expenditures to 120%—could, after multiplier impacts, lower GDP as much as three percentage points.

This methodology was used to estimate the impact of if the RFS program had ended beginning in 2015. This was done by first translating the 7% increase in gasoline prices calculated in the previous section to the gasoline price deflator.

The effect of the higher gasoline prices on consumer expenditures from 2015 to 2018 can be seen from Figure 11. By the end of 2018, consumer spending on all other items would have been reduced by $88 billion. This would represent 0.33% of the US GDP. The impacts on US GDP would be greater, though, due to "multiplier" effects.

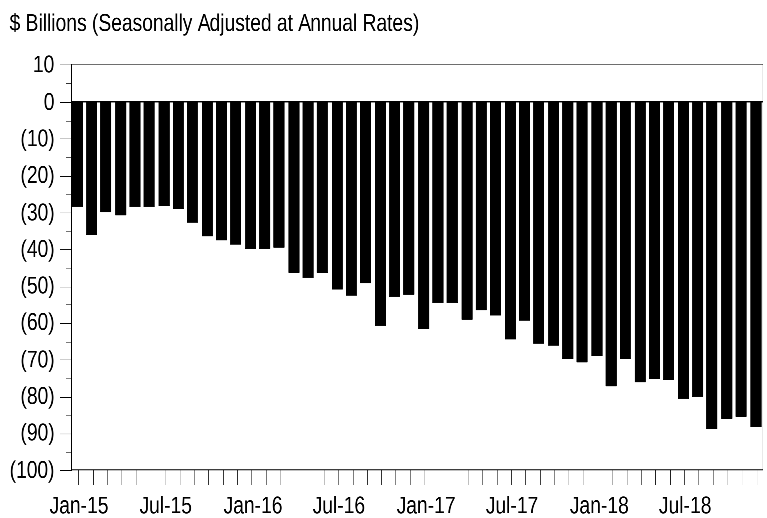
Economic research has shown that a decline in consumer spending often has these secondary effects because cuts in spending by consumers cause businesses to respond by cutting employment. For example, a decline in purchases at restaurants will lead to layoffs in the sector. The laid-off workers will spend less, adding to the losses begun when gasoline prices increased. US GDP would have been as much as 0.5% lower than the $20.5 trillion reported for 2018.

Figure 10
Share of US Consumer Spending Allocated to Goods and Services Other than Motor Fuels as Function of Motor Fuel Price Relative to Price of All Other Consumer Goods



Source: PKVerleger LLC.

Figure 11
Loss in Consumer Expenditures Resulting Had the RFS Program Ended after 2014



Source: PKVerleger LLC.

Conclusions

In calling for the expansion of the RFS program in his 2006 State of the Union message, President George W. Bush noted that the United States had become “addicted to oil.” President Bush couched the proposal to increase renewable fuel use in the context of energy security. The economic value of renewables was not in dispute, though, because the focus of his speech was on “keeping America competitive.” The opening sentence in his discussion of energy addiction said everything:

> “Keeping America competitive requires affordable energy.”

This analysis has shown that crude oil prices over the last four years have been 11% lower than they would have been had the United States ended the RFS program in January 2015, at a time when oil-exporting countries abandoned their efforts to limit output. The decline in consumption of renewable fuels would have cut the supply of fuels and led to a steady increase in prices.

The almost one million barrels per day of renewable supplies that helped reduce crude prices have also directly affected gasoline prices. Retail prices would have been 10% higher over the last four years had the RFS been suspended in 2015. The lower gasoline prices, in turn, allowed consumers to spend more on the things they wanted rather than motor fuels, which, while essential to their needs, are not an item that provides a sense of satisfaction to most individuals. The economic benefit of lower gasoline prices that is directly attributable to the availability of renewable fuels adds as much as 0.5% to US GDP every year.

The calculations presented here actually underestimate the full benefit of renewable fuels. Crude oil prices are today 44% lower than they would have been had the United States abandoned renewable fuels entirely in January 2015 at a time when oil-exporting countries dropped their efforts to limit output. The removal of renewable fuels would have cut the supply of hydrocarbons and led to a steady increase in price.

The almost one million barrels per day of renewable supplies lost would have also directly affected gasoline prices. Retail prices would today be above $4 per gallon, not $2.90, were renewable supplies removed from the supply mix. The lower gasoline prices, in turn, allowed consumers to spend more on the things they wanted rather than motor fuels, which, while essential to their needs, are not an item that provides a sense of satisfaction to most individuals. The economic benefit of lower gasoline prices that is directly attributable to the availability of renewable fuels adds one to two percentage points to US GDP every year.