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Air and Radiation Docket
Docket ID No. EPA-HQ-OAR-2012-0632
Mail code: 6102T
Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Re: Docket No. EPA-HQ-OAR-2012-0632

Dear Administrator Jackson:

The National Chicken Council (NCC) is pleased to submit these comments in support of the petition by the Governors of North Carolina and Arkansas requesting that the U.S. Environmental Protection Agency (EPA) exercise a waiver of the Renewable Fuel Standard (RFS) for corn ethanol. NCC is pleased that the Governors of Delaware, Maryland, Virginia, Georgia, Texas, and New Mexico have similarly voiced their support for waiving the RFS to alleviate the severe economic harm it is causing to their states, regions, and the national economy.

NCC is the national trade association representing vertically integrated companies that produce, process, and market over 95 percent of the chicken in the United States. 1/ In addition, NCC members include allied industry firms that supply necessary inputs and services for the chicken industry. As part of the subgroup of corn users forced to absorb all of the costs imposed by the RFS, NCC's members are directly harmed by the RFS and have a strong interest in restoring the competitive marketplace for corn.

In the comments that follow, we outline the vital role of corn in the food supply, the legal standard for a waiver of the RFS, and the severe economic harm that will result from the implementation of the RFS. As discussed below, implementation of the RFS would severely harm consumers, the food industry, the feed industry, and the U.S. economy as a whole. A full waiver of the RFS requirement for 2013 would alleviate this severe harm.

1/ In this submission of comments, the terms "chicken" and "broiler" are often used interchangeably.

I. Background

A. Corn is a Crucial Element in the U.S. Food and Feed Supply, as well as in the Global Economy

Each year, U.S. farmers plant millions of acres of corn to meet domestic and global demand. In March 2012, the United States Department of Agriculture (USDA) reported that U.S. farmers intended to plant 95.9 million acres of corn in 2012, up 4 percent from the previous year. 2/ Final corn yields are affected by a number of factors, including environmental conditions such as temperature and moisture, crop rotation, the length of the growing season, and the quality of soil.

Corn is the highest ranking commodity in the U.S. by wholesale value and is a key commodity in U.S. food production. 3/ Corn is integral to our food supply, as approximately 75 percent of foods on grocery store shelves contain corn, corn byproducts, or corn processed-foods. The vast majority of corn planted in the United States is field corn, which is used in applications such as livestock feed, cereal products, alcohol, and processed foods including corn sweeteners, corn-based vegetable oils, corn starch, and corn flour. Field corn is used for ethanol production. A very small percentage of corn acreage is devoted to sweet corn, which is consumed as kernels. Because field corn and sweet corn compete for the same acreage, their prices track one another; as the cost of field corn rises, sweet corn becomes more expensive too. These comments generally address field corn, but, underscoring the extent to which field corn is interwoven into the economy, the effects on field corn will be felt by users of sweet corn as well.

The National Research Council estimates that an increase in the price of corn of 20 to 40 percent results in a 2 to 4 percent increase in the prices of corn-based food products at the retail level. 4/ USDA's Economic Research Service states that on average, a 50 percent increase in corn prices results in a 1 percent increase in overall food prices, with particular categories of food, including meat, poultry, and dairy, affected more severely. 5/ More generally, as the price of a commodity increases, about 15 percent of that increase is passed on to retail prices for products that use that commodity as an ingredient. 6/

2/ USDA National Agricultural Statistics Service, *USDA Expects 75-Year-High Corn Acreage in 2012*, Mar. 30, 2012, http://www.nass.usda.gov/Newsroom/2012/03_30_2012.asp.

3/ USDA, World Agricultural Supply and Demand Estimates, Sept. 12, 2012, http://usda01.library.cornell.edu/usda/waob/wasde//2010s/2012/wasde-09-12-2012.pdf.

4/ Committee on Economic and Environmental Impacts of Increasing Biofuels Production, National Research Council, *Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy* 133 (2011), http://www.nap.edu/openbook.php?record_id=13105&page=1 (hereinafter National Research Council).

5/ USDA, Economic Research Service, *Food Price Outlook: Highlights*, http://www.ers.usda.gov/data-products/food-price-outlook/highlights.aspx; Hibah Yousuf, *Corn Price Spike: Food Inflation a "Real Threat*," CNN Money, July 18, 2012, http://money.cnn.com/2012/07/18/investing/corn-prices-food-inflation/index.htm.

6/ USDA, Economic Research Service, *Food Price Outlook: Highlights*, http://www.ers.usda.gov/data-products/food-price-outlook/highlights.aspx.

The U.S. corn supply is also used in producing meat, poultry, and dairy products. Corn feeds the nation's livestock and poultry and comprises 94 percent of the grains fed to animals. 7/ For every $1 increase in the price of corn per ton, feed costs increase 45-67 cents per ton. 8/ Further, feed represents the dominant cost in producing animal products. For example, for broilers, feed costs constitute 69 percent of live production costs. 9/ Meat, poultry, and dairy producers are heavily dependent on corn as a feedstock, thereby linking increased corn prices with increases in meat, poultry, and dairy prices.

As a lynchpin of domestic food production, corn's price also affects the prices of other key commodities that are viewed by farmers as corn substitutes. Due to competition for land on the production end between corn, soybeans, and wheat, the prices of soybeans and wheat track the price of corn. When the price of corn increases, so do the prices of soybeans and wheat. Field corn also competes for land with sweet corn and other vegetables, and an increase in the price of field corn means farmers plant less of other vegetables and the prices of those vegetables increase,

U.S. corn serves not only domestic uses but also feeds the developing world. The U.S. is the largest exporter of corn in the world, exporting 60 percent of the world's corn. 10/ As a result, shocks in the price of U.S. corn put the Middle East, North Africa, and Sub-Saharan Africa in danger of food shortages. 11/ In some markets in Sub-Saharan Africa, corn prices increased by 113 percent between April and June 2012. 12/ Significantly higher food prices are disastrous for the impoverished, especially in developing countries where up to three-quarters of their income may be spent on food. 13/ And, as the price of U.S. corn exports increases, U.S. corn becomes less competitive with that produced by foreign countries.

Any changes in the price of corn come in the context of overall increasing food costs and the current economic recession. Since 2005, food prices have steadily increased, with the inflation levels for all food at 17.8 percent; for cereals at 76.6 percent; and for meats, poultry, and fish at 78.8 percent. 14/ In July 2012, the World Bank's Food Price Index, which weighs the U.S. dollar price of several internationally traded food commodities, rose 10 percent from the previous month. 15/ Increases in food prices are acutely felt by consumers, who in 2010 spent 13 percent of their annual expenditures

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7/ National Research Council at 134.
8/ *Id.*
9/ *Id.*
10/ USDA, Economic Research Service, *Corn*, Aug. 14, 2012, http://ers.usda.gov/topics/crops/corn/trade.aspx.
11/ World Bank, Food Price Watch, Aug. 2012, http://siteresources.worldbank.org/EXTPOVERTY/Resources/336991-1311966520397/Food-Price-Watch-August-2012.pdf.
12/ *Id.*
13/ See Policy Report including contributions by FAO, IMF, UN, World Bank, WTO, *Price Volatility in Food and Agricultural Markets: Policy Responses* (June 2, 2011), http://www.oecd.org/tad/agriculturaltrade/48152638.pdf.
14/ Thomas E. Elam, President, FarmEcon LLC, *The RFS, Fuel and Food Prices, and the Need for Statutory Flexibility*, July 16, 2012, http://www.nationalchickencouncil.org/wp-content/uploads/2012/07/RFS-issues-FARMECON-LLC-7-16-12-FINAL.pdf [hereinafter Elam].
15/ World Bank Food Price Watch.

on food. 16/ Most vulnerable to increases in food prices are the lowest 20 percent income earners in the U.S. population, who spend more than one-third of their income on food. 17/

U.S. corn production depends heavily on favorable growing conditions, and the nation has experienced one of its worst droughts in decades, decimating the corn crop. USDA estimated in June 2012 a current harvest of 14.79 billion bushels of corn, but that projected production dropped to 10.73 billion bushels in the Department's most recent September 2012 estimates, a projected loss of more than 27 percent of the year's crop. 18/ More than 50 percent of this year's crop was rated as poor or very poor. 19/ This harvest would mark the lowest production since 2006 and a 13 percent decrease from last year. 20/ Despite 13 percent less corn than last year to go around (and more than 27 percent less than expected), the RFS mandate for 2013 would require 5 percent more corn be diverted to ethanol production.

Corn is a key component in the domestic and global food supply, and any change in the price of corn sends ripple effects throughout the U.S. and global economy.

B. The Use of Ethanol in Fuel Production

Ethanol is used in liquid fuel as an oxygenate, an octane enhancer, and as a less-efficient alternative to petroleum-based fuels. Oxygenates are added to gasoline to reduce the amount of carbon monoxide created when the fuel is burned. As the oxygenate methyl tertiary butyl ether (MTBE) was phased out during the last decade due to environmental concerns, fuel refiners turned to ethanol as a substitute. The use of ethanol as an oxygenate focused on ethanol's carbon monoxide reducing qualities; any energy derived from the ethanol was an incidental bonus. Ethanol replaces MTBE as an oxygenate on approximately a 1:1 basis. 21/ Ethanol also has a higher octane than gasoline and is blended into gasoline to help achieve a desired octane level. 22/

Lastly, ethanol may be used as an alternative source of energy in liquid fuels, but ethanol, while of a higher octane than gasoline, contains significantly less energy per gallon. One gallon of ethanol provides only 67 percent as much energy as a gallon of 87 octane gasoline. 23/ With current engine

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16/ Bureau of Labor Statistics, *Economic News Release: Consumer Expenditures—2011*, Sept. 25, 2012, http://www.bls.gov/news.release/cesan.nr0.htm.

17/ Bureau of Labor Statistics, Quintile Data (Sept. 2011), http://www.bls.gov/cex/2010/Standard/quintile.pdf.

18/ USDA, *World Agricultural Supply and Demand Estimates*, Aug. 10, 2012, http://usda01.library.cornell.edu/usda/waob/wasde//2010s/2012/wasde-08-10-2012.pdf; Energy Policy Research Foundation, Inc. (EPRINC), *Ethanol's Lost Promise: An Assessment of the Economic Consequences of the Renewable Fuels Mandate*, at 2, Sept. 14, 2012, http://eprinc.org/pdf/EPRINC-ETHANOL-LOSTPROMISE-2012.pdf [hereinafter EPRINC].

19/ USDA, Crop Progress Report, Sept. 24, 2012, http://usda01.library.cornell.edu/usda/current/CropProg/CropProg-09-24-2012.pdf.

20/ EPRINC at 2.

21/ *See id.* at 10.

22/ *Id.* at 10.

23/ Elam at 3.

technology, a vehicle's fuel economy decreases as the ethanol content of its fuel increases. 24/ To be competitive as a fuel source, a gallon of ethanol must sell at a significant price discount compared to a gallon gasoline because of its poorer energy content. Adjusting for their relative energy levels, though, ethanol has not been priced competitively with 87 octane gasoline since 1982. 25/ Ethanol has thus historically been used in gasoline primarily as an oxygenate and an octane enhancer.

The RFS program changed that balance by mandating that predetermined, increasing amounts of ethanol be blended into the fuel supply each year. Producers blending more ethanol than required are assigned Renewable Identification Number (RIN) credits, which they may apply toward ethanol blending obligations in the subsequent year. There are an estimated 2.6 billion gallons (BG) worth of RIN credits in the marketplace. 26/ The RFS requires that 13.2 BG of ethanol be blended into the fuel supply in 2012, and that requirement is scheduled to increase to 13.8 BG for 2013.

About 95 percent of gasoline sold in the U.S. in 2011 was E10, a blend formulation allowing for up to 10 percent ethanol by volume, with the remainder gasoline. 27/ Although higher-ethanol blends exist, they have not achieved market success due to their price. Because there is little market for fuel blends with more than 10 percent ethanol, surplus ethanol is exported; the U.S. exported 1.2 billion gallons of ethanol in 2011. 28/ Although ethanol made up about 10 percent of the volume of gasoline sold in 2011, it accounted for only 6.7 percent of the energy content of gasoline sold in the U.S., and only 3.1 percent of total U.S. liquid fuel consumption in 2011. 29/

C. Congress Contemplated Waiving the RFS to Prevent Economic Harm

Congress has authorized EPA to waive part or all of the RFS to prevent economic hardship. EPA is authorized under the Clean Air Act to issue a whole or partial waiver of the RFS if the Administrator determines that "implementation of the requirement would severely harm the economy or environment of a State, region, or the United States." 30/ In 2008, the state of Texas petitioned EPA to issue a 50 percent waiver of the RFS based on severe harm to the economy of Texas. In rejecting the petition, EPA offered its preliminary interpretation of the statutory requirements for issuing a waiver.

EPA required (1) a showing that implementation of the RFS program itself is the cause of the severe harm; (2) a generally high degree of confidence that the implementation of the RFS "would" severely harm the economy of a state, region, or the United States; and (3) that the potential harm to the

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24/ *Id.* at 3.

25/ *Id.* at 5.

26/ Wallace Tyner, Farzad Taheripour and Chris Hurt, *Potential Impacts of a Partial Waiver of the Ethanol Blending Rules* 8 (Aug. 16, 2012), http://www.farmfoundation.org/news/articlefiles/1841-Perdue%20paper%20final.pdf [hereinafter Purdue].

27/ Elam at 4.

28/ *Id.*

29/ *Id.* at 14.

30/ Clean Air Act, Sec. 211(o)(7), 42 U.S.C. § 7545..

economy be "severe," which, although not fully defined, falls short of "extreme." 31/ EPA also noted that the party requesting the waiver should show severe harm to the entire economy of a state, region, or the United States, not merely one sector of the economy. 32/

EPA found that the information received in 2008 showed that "the most likely result [in 76 percent of the modeled scenarios] is that the RFS would have no impact on ethanol production volumes in the relevant time frame, and therefore no impact on corn, food, or fuel prices." 33/ Even in the modeled scenarios where a waiver of the RFS might reduce the production of ethanol, EPA noted, the resulting decrease in corn prices was estimated at $0.30 per bushel of corn, and there would be an accompanying small increase in the price of fuel (on average $0.01 per gallon in fuel costs). 34/ Therefore, EPA concluded that the high threshold of showing severe harm to the economy was not met.

D. The Petitions for Relief from the RFS

In August 2012, the Governors of Arkansas and North Carolina requested that EPA issue a waiver of the RFS for corn ethanol. Governors from Delaware, Maryland, Virginia, Georgia, Texas, Iowa, and New Mexico have joined in the request due to the severe harm that their states, regions, and nation as a whole face. On August 20, 2012, EPA issued a request for comments on the request for a waiver. 35/ In particular, EPA requested comments on the following five questions:

1. Whether compliance with the RFS would severely harm the economy of Arkansas, North Carolina, other states, a region, or the United States;
2. Whether the relief requested will remedy the harm;
3. To what extent, if any, a waiver would change demand for ethanol and affect prices of corn, other feedstocks, feed, and food;
4. The amount of ethanol that is likely to be consumed in the U.S. during the relevant time period, based on its value to refiners for octane and other characteristics and other market conditions in the absence of the RFS volume requirements; and
5. If a waiver were appropriate, the amount of required renewable fuel volume appropriate to waive, the date on which any waiver should commence and end, and to which compliance years it would apply.

In the comments that follow, we explain the severe economic harm that would result from implementation of the RFS and the projected relief that a waiver would offer with respect to the prices of corn, feed, and food. We also demonstrate that a waiver would not adversely affect the gasoline industry or consumer gasoline prices. On the whole, waiving the full RFS ethanol blending requirement for 2013 would provide significant economic relief commensurate with the harm the requirement would otherwise inflict on the nation's economy.

31/ EPA Notice of Decision Regarding the State of Texas Request for a Waiver of a Portion of the Renewable Fuel Standard, 73 Fed. Reg. 47168, 47170–72 (Aug. 13, 2008).

32/ *Id.* at 47172.

33/ *Id.* at 47169.

34/ *Id.*

35/ EPA extended the comment period through October 11, 2012. 77 Fed. Reg. 57565 (Sept. 18, 2012).

II. Implementation of the RFS as Scheduled for 2013 Would Result in Severe Harm to the U.S. Economy

The economic hardship that spurred the 2008 Texas petition has grown only worse as the RFS requirement has siphoned increasingly large amounts of corn from the food supply. The price of corn has skyrocketed since the RFS was implemented, more than doubling since the 2005/2006 crop year. 36/ Corn futures are now selling for $7.56 per bushel. 37/ Whereas the partial waiver requested by Texas in 2008 would have reduced corn prices by $0.30 per bushel, a full waiver of the 2013 RFS requirement would reduce the price of corn by more than $2.00 per bushel without materially affecting motor fuel costs. The economic harm corn users now face due to the RFS is more than six times as severe as that faced in 2008, and a waiver is vital to preventing severe harm to the nation's economy.

EPA has recognized that a waiver is appropriate when "implementation of the program itself [is] the cause of the severe economic harm." 38/ The inquiry thus becomes, in light of all other conditions—including the severe drought and reduced corn production—would imposing the RFS ethanol blending mandate in 2013 cause severe economic harm to the U.S., a state, or a region? The answer is unequivocally "yes."

A. The RFS Blending Requirement Will Cause Serious Harm by Driving Up Significantly the Price of Corn

i. The Structure of the Corn Market in Light of the RFS

By far the two largest purchasers of corn are feed and food producers and ethanol refiners, although that has not always been the case. The RFS blending requirement has significantly—and artificially—disrupted the market for corn by requiring an every-growing, predetermined amount be diverted to ethanol use. The RFS increases demand for corn by forcing more users to compete for a supply that has not kept pace with demand. Approximately 15 percent of the 2005/2006 corn crop was devoted to ethanol production. For the 2010/2011 harvest, ethanol production consumed 40 percent of the crop. 39/ With a decreased projected yield for the current harvest and a higher blending requirement, next year's RFS requirement will consume an even greater percentage of the corn crop and drive corn prices even higher.

This pressure on corn prices is exacerbated by the fixed blending requirements. The fixed blending requirements create an inelastic demand curve for corn purchased by blenders. Blenders must purchase the predetermined amount of corn required by federal law regardless of the price and have only a limited ability to reduce production due to corn price increases. Refiners and blenders may

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36/ Elam at 19.
37/ Owen Fletcher and Bill Tomson, *Corn Prices Jump on USDA Report,* WALL ST J. (Sept. 28, 2012), http://online.wsj.com/article/SB10000872396390443389604578024180178198160.html.
38/ 73 Fed. Reg. at 47171.
39/ EPRINC at 29.

use RINs to offset production, but only an estimated 2.6 BG worth of RINS have accumulated during the RFS program, or the equivalent of 19 percent of the 2013 ethanol requirement.

Moreover, conventional wisdom holds that refiners and blenders are likely to hold onto their RINs to offset the "blend wall" that is fast approaching, the point at which ethanol will completely saturate the E10 blend market and gasoline producers will be unable to incorporate the increasingly higher levels of ethanol into their fuels. 40/ Because gasoline producers cannot meaningfully reduce consumption below the RFS mandate as prices increase, 41/ the remaining 60 percent of corn purchasers are forced to absorb 100 percent of the increase in corn prices and adjust to the drastically decreased supply. This imbalance significantly upsets the natural equilibrium that would be achieved, with the result being inefficiently high levels of corn purchased by ethanol refiners and inefficiently low amounts of corn going to feed and food uses. With too little corn to go around and at too high of prices, corn-based food production—especially food animal production—decreases, and the price of these foods increases.

A byproduct of ethanol production is a substance called dried distillers grain with solubles (DDGS). DDGS is returned to use in animal feed, but it can be used only in limited proportions for certain species and cannot wholly replace corn in animal feed. In particular, DDGS cannot substitute for corn in the diets of non-ruminants like poultry, which cannot break down the fiber in DDGS. Because DDGS can be substituted for corn to a limited degree in some species (but not in poultry production), the price of DDGS tracks that of corn; as corn prices increase, so do DDGS prices. 42/ Even taking into account reclaimed DDGS, 30 percent of U.S. corn production is devoted solely to ethanol. Moreover, although DDGS helps offset to a small extent corn consumed by ethanol production, its overall effect is very small, is limited to certain species, and does little to reduce the price pressures caused by the RFS.

ii. The RFS Requirement Will Drive Up Corn Prices, Raising Food Costs and Reducing Food Supplies

Reserving more than 40 percent of the corn crop for ethanol production in the face of significantly reduced yields will inevitably increase the cost of food, especially the cost of poultry and livestock. Numerous economic studies have demonstrated that the RFS will significantly increase the price of corn in the coming year.

An August 2012 report prepared for the Farm Foundation by three Purdue University economists evaluates how an EPA waiver of the ethanol mandate would affect the corn and ethanol markets. 43/ The authors found that reducing the amount of ethanol blended into gasoline in 2013 by even 6.05

40/ *See* Elam at 23,

41/ *See* Purdue at 3 ("[T]here has been an 8% fall in ethanol production over the past even weeks as the higher corn price puts pressure on ethanol margins. . . . Adjustments might have been greater in the absence of the mandate.").

42/ EPRINC at 6.

43/ See Purdue.

BG—about a 44 percent reduction— would reduce corn prices by $2.00 per bushel, a nearly 25 percent reduction. 44/

The authors modeled five scenarios, determining the expected price of corn under various drought conditions and various ethanol blending levels:

1. Full 2013 RFS before the drought
2. Full 2013 RFS (13.8 BG ethanol requirement) with the drought
3. 11.8 BG ethanol requirement, with the drought
4. 10.4 BG ethanol requirement, with the drought
5. 7.75 BG ethanol requirement, with the drought.

The authors selected these ethanol requirements because they reflected levels that might be reached through the use of RINs, a partial waiver of 25 percent of the ethanol requirement, or both, but "[f]or this analysis, it does not matter whether the reduced blending levels result because of the use of RINs or a partial waiver." 45/ Indeed, the ethanol production simply reflects levels selected by the authors to demonstrate the effect decreased ethanol production would have on corn prices. With this in mind, the third, fourth, and fifth scenarios reflect the corn prices that would result from decreasing ethanol levels 2 BG (14 percent), 3.8 BG (25 percent), or 6.06 BG (44 percent), respectively, from the 13.8 BG level required by the RFS. 46/

The authors modeled three drought scenarios—stronger, median, and weaker droughts. USDA crop yield estimates released since the authors wrote their paper indicate the corn crop will fall directly between the strong and median drought scenarios. 47/ The authors' model revealed that corn production would respond to reduced ethanol use by decreasing just slightly, while corn prices would drop by $1.99 (23 percent) if ethanol production decreased by 44 percent from the full RFS requirement. The authors' original results are reproduced in Table 1. 48/

44/ The authors based their original analysis on three corn production scenarios. Through correspondence with NCC, the authors have provided an updated analysis using the September 2012 USDA projected corn production of 10.73 billion bushels. The updated numbers are consistent with the findings from the original paper. The authors' approach of modeling the effects of a waiver of the RFS is the same as demonstrating the harm caused by the implementation of the RFS in the first place because the waiver scenarios reflect what would have occurred but for the RFS mandates.

45/ Purdue at 7.

46/ The most relevant comparison is between the projected price of corn with the full RFS in place in light of the drought and the projected price of corn with 7.75 BG ethanol production (*i.e.*, between the second and fifth scenarios). For completeness, all scenarios are shown in the table that follows.

47/ Indeed, the expectation is that USDA's next estimates will project even lower corn production.

48/ *Id.* at 8.

Table 1: RFS Waiver Effect Simulations from Purdue Study

Description	**Expectation Before Drought**	**Drought with 13.8 BG Ethanol**	**Drought with 11.8 BG Ethanol**	**Drought with 10.4 BG Ethanol**	**Drought with 7.75 BG Ethanol**
Stronger Drought:					
Corn production (Bil. bu.)	14.65	10.50	10.45	10.42	10.35
Corn used for ethanol	5.11	5.11	4.37	3.85	2.87
Domestic food and feed use	6.72	3.96	4.59	5.03	5.58
Exports	1.82	1.43	1.49	1.53	1.63
Corn price ($/bu.)	5.26	8.57	7.89	7.45	6.58
Median Drought:					
Corn production (Bil. bu.)	14.65	11.00	10.95	10.92	10.85
Corn used for ethanol	5.11	5.11	5.11	3.85	2.87
Domestic food and feed use	6.72	4.39	5.02	5.45	6.25
Exports	1.82	1.49	1.56	1.62	1.73
Corn price ($/bu.)	5.26	7.81	7.14	6.67	5.80
Weaker Drought					
Corn production (Bil. bu.)	14.65	11.50	11.45	11.42	11.35
Corn used for ethanol	5.11	5.11	5.11	3.85	2.87
Domestic food and feed use	6.72	4.81	5.42	5.84	6.62
Exports	1.82	1.58	1.66	1.72	1.86
Corn price ($/bu.)	5.26	7.02	6.36	5.89	5.02
Note: The corn yields for these three cases are 120, 126, and 132 bu/ac.					

Revised to reflect USDA's September 2012 estimated 10.73 billion bushel crop production, a reduction in ethanol production by 44 percent reduces corn prices by $2.00 (24 percent) from their full RFS prices, as shown in Table 2. 49/ Put differently, the marginal 44 percent of ethanol production caused by part of the RFS directly increases corn prices by $2.00.

Table 2: Purdue Model with Updated Corn Production Estimates

Description	**Expectation Before Drought**	**Drought with 13.8 BG Ethanol**	**Drought with 11.8 BG Ethanol**	**Drought with 10.4 BG Ethanol**	**Drought with 7.75 BG Ethanol**
Corn Price ($/bu.)	5.26	8.19	11.8	7.06	6.19

49/ In September 2012, USDA estimated U.S. corn production at 10.73 billion bushels. As the corn production forecasts have steadily decreased in the last three USDA reports, it is likely that corn production estimates will continue to shrink as we move further into 2012.

A decrease in the price of corn by $2.00 per bushel would significantly alleviate pressures on both consumers at the grocery store and the food, livestock, and feed industries. Given the vital role of corn in U.S. food production, as the price of corn decreases, so do the prices of meat, poultry, dairy products, and the foods that contain corn-based sweeteners, starches, flours, and oils, as well as substitute products such as wheat and soybeans and any foods made using them.

A marginal decrease in corn price of 24 percent, based on a reduction in the price of corn by $2.00 per bushel, would result in a decrease of approximately 2.4 percent in retail food prices. 50/ USDA estimates that food prices will increase 3–5 percent next year. In other words, less than half of the price increase caused by the RFS requirement is equivalent to half-to-nearly-all of the projected increase in the price of food. Moreover, NCC supports a complete waiver of the 2013 RFS requirement (as compared to the modeled 44 percent reduction in ethanol use), which would reduce corn prices—and thus food prices—even further. 51/

More dramatically, a decrease of $2.00 in the price of corn per bushel is equivalent to a decrease of $71.43 per ton of corn, which results in feed costs that are $32.14 to 47.86 lower per ton. 52/ The broiler industry uses 1.25 billion bushels of corn each year. 53/ Savings of $2 per bushel of corn would amount to $2.5 billion in annual savings to the broiler industry.

As demonstrated, the price of corn, while driven up in recent months by current drought conditions, is forced further upwards by the RFS and increased demand for corn for ethanol production. Numerous studies have recognized the demand for corn by ethanol producers as a major driver of corn and food prices. 54/ A 2011 study demonstrated that the increasing prices of grains in recent

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50/ *See* National Research Council at 133.

51/ Additional studies, including those conducted by the Energy Policy Research Foundation, FarmEcon LLC, and the United Kingdom's Department for Environment Food and Rural Affairs have similarly demonstrated that the RFS causes severe economic harm by driving up corn prices. *See generally* EPRINC; Elam; Chris Durham et al., United Kingdom Department for Environment, Food and Rural Affairs, *Can Biofuels Policy Work for Food Security?: An Analytical Paper for Discussion* (June 2012), http://www.defra.gov.uk/publications/files/pb13786-biofuels-food-security-120622.pdf.

52/ These figures are based on estimates that for every $1 increase in the price of corn per ton, feed costs increase 45-67 cents. There are ostensibly a standardized 56 pounds of corn per bushel and 2000 pounds in a ton. Although a bushel is generally viewed as containing 56 pounds of corn, a bushel is technically a volumetric measurement. As the quality of corn decreases, so does its average weight per bushel. The current year's corn crop is likely to weigh in at 54 pounds per bushel. This would drive up feed prices even more (and the RFS would even further distort market pricing) because livestock and poultry are fed by weight, not volume, meaning more bushels of corn would be required to feed each animal.

53/ This estimate is based on the facts that in 2011 8.34 billion broilers were produced with live weight of 48.28 billion pounds. It requires 106 billion pounds or 53 million tons of feed to produce that quantity of broilers, including broilers, pullets, and breeders. Given that two-thirds of the chicken feed ration is corn and corn by-products, 35.5 million tons or more than 1.25 billion bushels of corn were fed to chickens in 2011.

54/ Donald Mitchell. Word Bank Development Prospects Group, *A Note on Rising Food Prices* (2008), http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf (finding that 70 to 75 percent of the increase in food prices is years can be accounted for by only two factors: speculation by investors and the increase in corn to ethanol conversion. The authors concluded that the underlying upward trend in prices can be attributed to the increased diversion of corn to ethanol, once the spikes in prices caused by speculation are excluded. 55/ In particular, the study "suggests that there has been a direct relationship between the amount of ethanol produced and (equilibrium) food price increases." 56/ The RFS, which establishes mandates for the use of ethanol in the nation's fuel supply, is the major force behind the diversion of corn to ethanol production, and the resulting increases in corn price.

Not only has the price of corn increased overall with implementation of the RFS, but the number of spikes in corn prices has also increased. Corn price volatility has more than doubled since 2007. 57/ This instability puts pressure on the food and feed industries as companies try to make production decisions for the future and injects substantial uncertainty into the market. Uncertainty leads to further speculation, so tightening markets makes the situation even worse. Research conducted by the United Kingdom Department for Environment, Food and Rural Affairs (DEFRA) shows that a 50 percent waiver of the U.S. biofuels mandate in the same year as a spike in the global price of course grain could reduce the magnitude of a hypothetical spike in prices by 40 percent. 58/ A 75 percent waiver would result in a 55 percent reduction in the size of the spike. 59/ These results occur because removing U.S. support for biofuels makes the entire demand side of the grain market responsive to price, compared to just the food and feed components of demand, so demand from biofuels producers would contract along with demand in the food and feed markets. When the burden of the high demand for corn is shared, there is no driver of such high prices in the food and

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due to increased demand for biofuels); Keith Collins, *The Role of Biofuels and Other Factors in Increasing Farm and Food Prices: A Review of Recent Development with a Focus on Feed Grain Markets and Market Prospects* (2008) (using a mathematical simulation to estimate that about 60 percent of the increase in corn prices from 2006 to 2008 may have been due to the increase in maize used in ethanol); John Lipsky, First Deputy Managing Director, International Monetary Fund, Commodity Prices and Global Inflation, Remarks and the Council on Foreign Relations (2008) (estimating that the increased demand for biofuels accounted for 70 percent of the increase in corn prices); Colin Carter et al., *The Effect of the U.S. Ethanol Mandate on Corn Prices*, UC Davis, http://agecon.ucdavis.edu/people/faculty/aaronsmith/docs/Carter_Rausser_Smith_Ethanol_Paper_submit.pdf (estimating that 2010 corn prices were 50 percent greater in log terms than they would have been if U.S. ethanol production stayed at its 2005 level, and that average prices over the period from 2006 to 2010 were 30 percent greater than they would have been had the increase in ethanol production not occurred).; Randy Schnepf and Brent D. Yacobucci, Renewable Fuel Standard (RFS): Overview and Issues (Jan. 23, 2012), http://www.fas.org/sgp/crs/misc/R40155.pdf (finding that "corn prices have trended steadily upward in direct relation to the added growth in demand from the ethanol sector").

55/ Marco Lagi et al., *The Food Crises: A Quantitative Model of Food Prices Including Speculators and Ethanol Conversion* (2011), http://necsi.edu/research/social/food_prices.pdf.

56/ *Id.* at 19.

57/ Elam at 2.

58/ Durham, *supra* note 51, at 2. Notably, the European Commission recently announced plans to limit crop-based biofuels to 5 percent of transport fuel due to concerns about diverting too much of the corn supply from food to fuel. Charlie Dunmore, *Exclusive: EU to Limit Use of Crop-Based Biofuels – Draft Law*, Reuters (Sept. 10, 2012).

59/ *Id.* at 5.

feed markets. Thus, a waiver of the RFS would significantly relieve producers and consumers of the adverse effects and uncertainty of corn price volatility.

As has historically occurred when the price of corn increases, the current increase in corn price will result in overall inflation in the price of food. The USDA's Economic Research Service has predicted that the increase in the price of corn will first affect the price of beef, pork, poultry, and dairy, while "[t]he full effects of the increase in corn prices for packaged and processed foods (cereal, corn flour, etc.) will likely take 10-12 months to move through to retail prices." 60/

Increased costs of corn affect the entire production chain from farm to table. As processing plants find themselves unable to keep pace with the increasing costs of grain, the growers and farmers who produce poultry and livestock suffer. And when poultry processing plants shutter, the economic effects ripple through the entire local community, reaching those employed both directly and indirectly by the plant. In total, the chicken industry directly employed about 251,100 employees in 2011 and indirectly generated an additional 759,150 jobs in the supplier and ancillary industries, including feed mills, hatcheries, and trucking. 61/ Thus, the total direct and indirect employment by the U.S. chicken industry in 2011 was about 1,010,250 workers, producing wages of $47.3 billion and generating $197.6 billion in economic activity. At the local level, a single processing plant is supported by about 300 farm families. The direct effect of the increased price of corn is to put local farmers and workers employed by the chicken industry out of business.

Short-term spikes in corn prices are particularly devastating for poultry and livestock producers due to their longer production cycles and inflexible animal diets. 62/ Livestock and poultry producers face a production lag that makes it difficult to adjust quickly to increased feed costs by reducing animal numbers. For example, the time between breeding parent stock to retail sales of fresh product from the resulting offspring ranges from 10 weeks for broiler meat to about 10 months for milk and pork to about 30 months for beef. Thus, production decisions for broiler products consumed today were made nearly three months ago (more than two years ago for beef products), leaving livestock and poultry producers unable to respond to price increases in the interim. Livestock and poultry producers are thereby held captive to increasingly high corn prices.

Further, while livestock such as cattle can switch (in part) to other diets when the cost of grains increases, poultry and swine are more reliant on high-energy grains and have a limited ability to use other energy sources. For example, during the two years from 2006 to 2008 when feed costs increased by two-thirds, resulting in an 80 percent increase in total live-production cost, the ratio of corn in broilers' diets held constant. Over those two years, the cumulative effect of the increased feed costs to the broiler industry exceeded $7.8 billion. 63/ Poultry producers, with nearly three-month production lags and long-term growing contracts, cannot meaningfully adjust to the rapid

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60/ USDA, Economic Research Service, *U.S. Drought 2012: Farm and Food Impacts*, http://www.ers.usda.gov/newsroom/us-drought-2012-farm-and-food-impacts.aspx.

61/ The Poultry and Egg Industry Economic Contribution Study: 2012, http://chicken.guerrillaeconomics.net/public/res/Poultry%20Impact%20Methodology.pdf.

62/ National Research Council at 135-36.

63/ M. Donohue and D.L. Cunningham, *Effects of Grain and Oilseed Prices on the Costs of U.S. Poultry* Production, 18 J. APP. POULTRY RES. 325-337 (2009).

changes in feed prices caused by the RFS. Both poultry and livestock producers are severely harmed by increases in the price of their primary feedstock.

The U.S. chicken industry has suffered in the years since the implementation of the RFS, in contrast to the industry's average annual growth rate of 4.0 percent and historical resiliency even during difficult economic times. In 2009, U.S. broiler production decreased by 3.8 percent, the largest decrease since 1970. The years 2011 and 2012 each saw a 1 percent decrease in production, representing the first time in this period that the broiler industry has seen two consecutive years of negative growth. These recent trends demonstrate that an historically resilient industry has seen the greatest decrease in growth (indeed, it has shrunk) in more than forty years during the implementation of the RFS, when it has seen demand for one of its primary inputs drastically and artificially increased. Because of the importance of corn in so many aspects of food production, the entire food industry—and ultimately, the consumer—is suffering because of the RFS.

B. The RFS Does Not Meaningfully Reduce Retail Gasoline Prices

The RFS causes this severe harm to the food industry without meaningfully reducing prices at the gas pump. An oft-touted study concluding that ethanol, despite making up only 6.7 percent of the energy content of gasoline sold in the U.S., 64/ reduced average gas prices by $1.09 has been thoroughly debunked as methodologically unsound. Indeed, more recent analyses have found that ethanol use may even increase fuel costs by $0.10 per gallon, or $14.5 billion annually, and that increased ethanol production has had no statistically significant effect on gasoline prices or refiner margins. 65/

The Center for Agricultural and Rural Development at Iowa State University (CARD) released a now well-traveled report indicating that increased ethanol production under the RFS decreased gasoline prices by $0.89 in 2010 and $1.09 in 2011. 66/ Subsequent studies have thoroughly refuted the statistical and econometric methodology underlying the CARD report. The CARD study relied on several key, fundamentally flawed assumptions that failed to reflect the reality of the refining industry. 67/

First, the authors did not adjust for changes in refining capacity and held ethanol use constant at its 1.6 BG level for the entire period from 2000 to 2011. 68/ Refining capacity and actual ethanol output

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64/ Elam at 14.

65/ *Id.* at 2.

66/ Xiaodong Du and Dermot J. Hayes, *The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to 2012,* Working Paper 12-WP 528, May 2012, http://www.card.iastate.edu/publications/dbs/pdffiles/12wp528.pdf.

67/ The econometric model used in the CARD study has been thoroughly criticized and refuted by Knittel & Smith. They show that the CARD model makes incorrect assumptions about the refining industry, uses an inaccurate dependent variable as its measure for the effect of ethanol production, and suffers from significant autocorrelation. Knittel & Smith use more refined models to demonstrate a slight, if any reduction in gasoline prices due to ethanol production. Christopher R. Knittel & Aaron Smith, *Ethanol Production and Gasoline Prices: A Spurious Correlation* (July 12, 2012), http://web.mit.edu/knittel/www/papers/knittelsmith_latest.pdf.

68/ EPRINC at 11.

have increased significantly during that period, however. 69/ Although much of that increased production is a result of the market distortion caused by the RFS, refiners would be expected to increase ethanol use over this 11-year period as gasoline production increased, especially as ethanol was phased in as an oxygenate to replace MTBE. The authors' assumptions, though, created a shortage of gasoline and increase in imports in the model because they did not let production increase as it naturally would. 70/ This artificial gas shortage led to an increase in the "crack spread," which the CARD authors used to proxy the increase in gasoline prices. 71/ Economic models of the refining industry, however, commonly incorporate changes in output, product mix, and capital structure when modeling the refining industry. 72/ The CARD study thus injected into its model an artificial gas shortage, which explains the questionable result. 73/

Moreover, ethanol production increased smoothly during the period in the CARD study, creating significant challenges in identifying and eliminating spurious results in a statistical regression analysis. 74/ When an independent variable in a statistical model steadily increases, with few fluctuations, it becomes difficult to tell whether the independent variable is actually related to the dependent variable or is simply increasing along with it due to unrelated factors. Two researchers, Knittel and Smith, demonstrate that, because of this problem, the same models using ethanol production as independent variables also show a "relationship" between ethanol production and completely unrelated factors, such as U.S. and European unemployment. 75/

Instead, more accurate models demonstrate little or no statistically significant effect of ethanol production on gas prices. 76/ In assessing the CARD study, the Energy Policy Research Foundation showed that reducing ethanol production would not raise fuel prices. 77/ In particular, the study showed that if ethanol output had remained constant at the year 2000 level (*i.e.*, if there were no RFS), refiners could have made up for the shortfall without importing or even refining "a single additional barrel of crude oil." 78/ The RFS has increased ethanol production by about 400,000 barrels per day since 2000. A "remarkably small operational adjustment" in refineries' product mix—a 1.8% increase in gasoline production—could have covered an ethanol shortfall of 400,000 barrels per day in 2011. 79/ This result makes intuitive sense; ethanol makes up a very small percentage of gasoline, by energy contribution or by volume. As the CARD study further

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69/ *Id.*
70/ *Id.* at 12.
71/ The crack spread is the weighted average price of gasoline and distillate fuel oil (the main refinery products) less the price of crude oil. As such, it is a rough estimate of refiner margins, although it does not capture the full costs of producing refined products. Elam at 10.
72/ EPRINC at 12.
73/ Even the authors of the CARD study recognize that "the[] results may be questionable" because of issues with their statistical model. *Id.* at 5.
74/ *Id.* at 9.
75/ *Id.* at 23–24.
76/ EPRINC at 18.
77/ *See id.*
78/ *Id.* at 14.
79/ *Id.*

demonstrates, adding a small amount of a less efficient fuel to gasoline would have dramatically lowered gas prices only under highly unreasonable constraints.

Moreover, a study conducted by FarmEcon LLC after the CARD study and using more realistic models found that the increased ethanol production from 2000 through February of 2012 had no statistically significant effects on gas prices. 80/ The author ran four different models, using different measures of gas prices—gasoline prices, the crack spread, the gasoline crack ratio, 81/ and the gasoline crack spread. 82/ The models explained a high percentage of the historical changes in the price measures, demonstrating the models were statistically robust. 83/ In each model, though, the increase in ethanol production did not have a statistically significant effect on the price measure. In some cases, the author found increased ethanol production actually increased the price measure, although in a statistically insignificant manner. 84/ From these models, the author concluded "it is highly unlikely that increasing ethanol production depressed wholesale gasoline prices or refiner margins." 85/

As these studies demonstrate, adding a more expensive fuel source to the U.S. fuel supply at relatively small levels—6.7 percent by energy—is not going to reduce U.S. gasoline prices by nearly 25 percent. 86/ Indeed, it is much more plausible that ethanol use increases U.S. gasoline prices, which should be expected when the markets for fuel inputs and corn use are disrupted. Moreover, as demonstrated in the FarmEcon study, a significant portion of the ethanol produced under the RFS is exported because it is too costly an input to use in gasoline and there is no domestic market for high-ethanol fuels, further demonstrating that increased ethanol use in the gasoline supply has little effect on U.S. fuel prices. 87/

Given the severe effect the RFS has on corn prices—and all the end users of corn, including the broiler industry—combined with its negligible and possibly harmful effects on motor fuel prices, the RFS will, and does, cause severe economic harm to the U.S. economy. As such, the 2013 ethanol blending requirement should be waived.

III. A Waiver Will Directly Relieve the Harm Caused by the RFS by Lowering the Price for Corn

Waiving the 2013 RFS requirement will directly relieve the harm caused by the program. Without the RFS in place, ethanol production would drop below even the 7.75 BG level modeled in the

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80/ Elam at 9.

81/ The gasoline crack ratio is the ratio of gasoline prices to crude oil prices. *Id.* at 11.

82/ The gasoline crack spread is the difference between the price of a gallon of gasoline and a gallon of crude oil. *Id.* at 11.

83/ *Id.* at 10–11.

84/ *Id.* at 10–11.

85/ *Id.* at 12.

86/ In 2011, the average national price of a gallon of gasoline was $3.52. U.S. Energy Information Administration, *2011 Brief: U.S. Average Gasoline and Diesel Prices over $3 per Gallon Throughout 2011*, Jan. 13, 2012, http://www.eia.gov/todayinenergy/detail.cfm?id=4570. If they were $1.09 higher, the average price would be $4.61, indicating an alleged decrease of 23.6 percent.

87/ *Id.* at 4–5.

Purdue study. The Energy Policy Research Foundation has determined that, without the RFS, ethanol would be blended into gasoline only to the extent necessary as an oxygenate, which is about 400,000 barrels per day, or 6.1 BG annually. 88/ Ethanol production would decrease because, as explained above, while ethanol is useful as an oxygenate, its poor energy levels per gallon relative to gasoline make it too expensive to use solely as a fuel source. 89/ Refiners and blenders would use only the amount of ethanol necessary to replace MTBE as an oxygenate.

Supporters of ethanol blending often claim that a short-term waiver would not decrease ethanol production because refiners would be unwilling to switch blending processes in light of the impending reinstatement of the RFS. First, that argument simply makes the case for a longer-term waiver to properly relieve the economic harm caused by the RFS.

Second, the RFS is saturating the ethanol market, and the lowest-value uses of ethanol will decrease after a waiver. As noted, the U.S. exports a significant amount of corn ethanol each year—1.2 BG in 2011. 90/ If it made economic sense to blend this ethanol into the U.S. fuel supply, refiners would not be exporting it. A waiver of the RFS would cause corn use to shift away from this and other lower-value uses toward higher-value use in food and animal feed.

Third, the Energy Policy Research Foundation has demonstrated that the predicted decrease in ethanol use in gasoline could be covered by shifting production from less refined petroleum products like diesel back to gasoline without requiring even one additional barrel of crude oil to be consumed. 91/ As demonstrated by the Energy Policy Research Foundation, the RFS has not caused refiners to decrease the amount of crude oil imported, but rather to change the end uses of that crude oil, producing slightly less gasoline and slightly more diesel. 92/ These production shifts are low cost and, because ethanol displaces such a small percentage of gasoline anyway, would cause minimal disruption, greatly increasing the likelihood refiners would shift to the most cost-effective production process.

Therefore, waiving the RFS requirement would lead directly to a decrease in corn ethanol production, in turn causing corn prices to drop. Indeed, the European Commission has already decided to limit the amount of food-crop-based biofuels in motor fuel to 5 percent to reduce pressure on food commodity prices and out of concern about emissions and greenhouse gases. 93/ If EPA followed suit and waived the 2013 ethanol blending requirement, more corn would be available for food and feed, and food prices would in turn decrease significantly. The refining industry would

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88/ EPRINC at 10. A barrel contains 42 gallons. Elam at 10.

89/ Ethanol provides only 67 percent of the energy contained in an equal volume of gasoline. Ethanol would have to sell at 67 cents to the dollar against gasoline for its in gasoline solely as a fuel source to be economical. When the decreased fuel efficiency of ethanol (because each gallon of ethanol provides less energy) is considered, which could raise issues with meeting fuel-efficiency standards and pollution requirements, ethanol becomes an even less appealing substitute for gasoline and may require an even greater discount before used widely in fuels.

90/ Elam at 4.

91/ EPRINC at 13.

92/ *Id.*

93/ Charlie Dunmore, *Exclusive: EU to Limit Use of Crop-Based Biofuels – Draft Law*, Reuters (Sept. 10, 2012).

switch back to a more efficient production mix, and gas prices might even decrease slightly. In short, waiving the RFS would relieve the economic harm it is causing.

IV. Conclusion

In sum, the RFS is causing severe economic harm to the U.S. economy, and the 2013 requirement must be waived. EPA posed several questions in its *Federal Register* notice, the answers to all of which demonstrate the need for a complete waiver of the 2013 RFS requirement: [94]/

1. Requiring that more than 40 percent of the nation's corn supply be diverted to produce 13.8 BG of ethanol will raise corn prices by more than $2.00 per bushel—at least 24 percent—raising the cost of feed and food, which will be felt by every American consumer. Overall food prices will increase by more than 2 percent solely because of the RFS. Not only will the 2013 blending requirement fail to reduce gas prices, it will actually slightly increase gas prices. The 2013 RFS requirement forces consumers to pay more at the grocery store register and at the gas pump.
2. Waiving the RFS would directly relieve the harm caused. Ethanol is a poor motor fuel, and refiners would switch to cheaper inputs. Ethanol production will drop by 50 percent, causing a more than $2.00 decrease in the price of a bushel of corn.
3. An RFS waiver would decrease the price of corn by more than $2.00, reduce the overall cost of food by more than 2 percent, decrease the artificially inflated demand for ethanol, and not affect consumer gasoline supply or prices.
4. Absent an RFS, about 400,000 barrels per day of ethanol—about 6.1 BG annually—would be blended into the fuel supply. That would represent a 50 percent decrease in the amount of ethanol used in motor fuel.
5. To have the greatest effect, the RFS should be waived in its entirety for a significant period of time. At a minimum, EPA should waive the full requirement for a full year beginning January 1, 2013.

Viewed together, these factors demonstrate the RFS must be waived to relieve the severe economic harm the RFS is causing. The corn supply is under tremendous pressure due to the drastically decreased yields caused by the year's drought. Given the conditions of the country's corn supply—and its critical importance to feeding the nation—it is irresponsible to divert more than 40 percent of it to use as a second-rate motor fuel. The RFS should be waived in full to remedy this harm.

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[94]/ We respond in order to the questions posed in Part V of the August 30, 2012 *Federal Register* notice. *See* 77 Fed. Reg. at 52716.

NCC appreciates the opportunity to present these comments. Please do not hesitate to contact me if I can provide any additional information.

Sincerely,

Michael Brown
President, National Chicken Council

Attachments:

- Thomas E. Elam, President, FarmEcon LLC, *The RFS, Fuel and Food Prices, and the Need for Statutory Flexibility* (July 16, 2012)
- Wallace Tyner, Farzad Taheripour and Chris Hurt, *Potential Impacts of a Partial Waiver of the Ethanol Blending Rules* (Aug. 16, 2012)
- Energy Policy Research Foundation, Inc. (EPRINC), *Ethanol's Lost Promise: An Assessment of the Economic Consequences of the Renewable Fuels Mandate* (Sept. 14, 2012)
- Chris Durham et al., United Kingdom Department for Environment, Food and Rural Affairs, *Can Biofuels Policy Work for Food Security?: An Analytical Paper for Discussion* (June 2012)
- Christopher R. Knittel & Aaron Smith, *Ethanol Production and Gasoline Prices: A Spurious Correlation* (July 12, 2012)
- E-mail from Wallace E. Tyner, Purdue University, to William Roenigk, National Chicken Council, Sept. 12, 2012.

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The RFS, Fuel and Food Prices, and the Need for Statutory Flexibility

July 16, 2012

Dr. Thomas E. Elam
President, FarmEcon LLC

The information contained herein has been taken from trade and statistical services and other sources believed to be reliable. FarmEcon LLC makes no warranty, express or implied, that such information is accurate or complete and it should not be relied upon as such. Funding for this study was provided by a coalition of food producing interest groups.

The RFS, Fuel and Food Prices, and the Need for Statutory Flexibility

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Executive Summary

Current U.S. biofuels policy contains escalating corn-based ethanol blending requirements (the Renewable Fuel Standard - or RFS) that do not automatically adjust to energy and corn market realities. That same policy contains cellulosic ethanol requirements that do not reflect the fact that the biofuels industry, despite decades of effort and large subsidies, has failed to develop a commercially viable process for converting cellulosic biomass to ethanol.

Corn-based ethanol blending requirements have pushed corn prices, and thus ethanol production costs, so high that the market for ethanol blends higher than 10 percent is essentially non-existent. That same policy has also destabilized corn and ethanol prices by offering an almost risk-free demand volume guarantee to the corn-based ethanol industry. Domestic and export corn users other than ethanol producers have been forced to bear a disproportionate share of market and price risk.

Increases in ethanol production since 2007 have made little, or no, contribution to U.S. energy supplies, or dependence on foreign crude oil. Rather, those increases have pushed gasoline supplies into the export market. Gasoline production and crude oil use have not been reduced. If the RFS is made more flexible, and ethanol production shrinks due to market forces, we can easily replace ethanol with gasoline currently being exported.

This paper will argue that it is time to reform the current RFS. Corn users other than the ethanol industry need assurance of automatic market access in the event of a natural disaster and a sharp reduction in corn production. Ethanol producers should bear the burden of market adjustments, along with domestic food producers and corn export customers. Ethanol prices should reflect the fuel's energy value relative to gasoline, not a corn price that is both inflated and destabilized by the inflexible RFS.

Finally, the RFS schedule should be revised to reflect the ethanol industry's inability to produce commercially viable cellulosic fuels. Policy should reflect reality when that reality does not reflect substantial and undeniable barriers to achieving policy goals.

Key Points

- Current ethanol policy has increased and destabilized corn and related commodity prices to the detriment of both food and fuel producers. Corn price volatility has more than doubled since 2007.
- Following the late 2007 increase in the RFS, food price inflation relative to all other goods and services accelerated sharply to twice its 2005-2007 rate.
- Post-2007 higher rates of food price inflation are associated with sharp increases in corn, soybean and wheat prices.
- On an energy basis, ethanol has never been priced competitively with gasoline.
- Ethanol production costs and prices have ruled out U.S. ethanol use at levels higher than E10. As a result, we exported 1.2 billion gallons of ethanol in 2011.
- Due to its higher energy cost and negative effect on fuel mileage, ethanol adds to the overall cost of motor fuels. In 2011 the higher cost of ethanol energy compared to gasoline added approximately $14.5 billion, or about 10 cents per gallon, to the cost of U.S. gasoline consumption. Ethanol tax credits (since discontinued) added another 4 cents per gallon.
- Using four different measures of gasoline prices and oil refiner margins, from 2000 through 2011, there was no statistically significant effect of increased ethanol production on gasoline prices or oil refiner margins.

  - All four of these statistical models showed a weak, statistically insignificant, positive association between increased ethanol production and gasoline prices and oil refiner margins.
  - Factors that do account for gasoline prices and refining margins include: crude oil prices, crude oil inventories, gasoline inventories, net gasoline exports (exports minus imports), seasonality, and supply disruptions caused by hurricane Katrina, refinery outages, and methyl tertiary butyl ether (MTBE) gasoline additive withdrawal.
  - A similar model from Iowa State University found a negative effect of increased ethanol production on refiner margins. That model used flawed methodology. Projected 2011 effects are unrealistic.
- In the U.S., the January 2007, through February 2012, increase in ethanol production had no effect on: 1) gasoline production; 2) crude oil imports; 3) crude oil consumption; or 3) refinery utilization.
- From January 2007, through February 2012, increased ethanol production displaced gasoline in the U.S. fuel supply, but did not cause reduced gasoline production. The displaced gasoline was exported. Gasoline consumption declined by more than the ethanol displacement, further boosting gasoline exports. In effect, the 2007 to 2011 increase in ethanol production has been exported.
- Declining U.S. oil imports are being caused by increased U.S. crude oil production, and higher refinery yields, not increased ethanol production.
- Adoption of market-based adjustments to the RFS would not affect U.S. fuel supplies, but tend to reduce the volatility and level of corn prices to the benefit of both food and fuel producers.
- Given the realities of cellulosic biofuels, the RFS schedule should be amended to reflect the lack of technological progress in this area, and potential risks to the environment.

Ethanol Prices and Production Costs

Supporters of current ethanol policy have claimed that ethanol is saving American motorists money. That claim is partially based on the fact that ethanol typically sells for less per gallon than gasoline. The problem with that claim is that engines do not run on gallons, they run on energy. On an energy basis gasoline and ethanol are very different fuels.

Earlier in the modern history of ethanol use in motor fuels its main purpose was for a combination of octane enhancement and as a fuel oxygenator. In more recent times, with the dramatic increase in ethanol production, those limited markets have become saturated. To go beyond use as an additive, and compete with gasoline as a fuel, ethanol must be priced competitively based on its energy content. This section will show that ethanol continues to be priced at a premium that prevents its widespread use beyond the universally authorized E10 (90% gasoline, 10% ethanol) blend level. The fact that substantial amounts of ethanol were exported in 2011 when the E10 market became saturated supports that fact.

Ethanol's value as a fuel is established by its energy content relative to competing fuels. Despite its higher octane rating, gallon of ethanol has only 67 percent of the net energy of a gallon of gasoline[1]. As a result, in current gasoline engine technology, fuel mileage per gallon declines as ethanol content increases. Fuel mileage per BTU is approximately equal between gasoline and ethanol. This fact was born out in a tightly controlled test performed by Oak Ridge National Laboratory and the National Renewable Energy Laboratory[2]. To quote from that study (page 3-1):

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[1] Ethanol contains 76,100 BTUs per gallon compared to 114,100 for 87 octane gasoline.

[2] National Renewable Energy Laboratory. "Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1 – Updated." NREL/TP-540-43543. February 2009.

"The following trends from E0 to E20 were found to be statistically significant. Fuel economy decreased (7.7% on average), consistent with the energy density reduction associated with ethanol blending (in limited tests, this trend was observed to continue to E30)."

Ethanol must sell at a significant discount to gasoline to achieve equal fuel cost per mile. If ethanol blends higher than 10 percent are not competitively priced, the result will be failure of those fuels to achieve significant sales. That has been the fate of E85. According to recent Department of Energy statistics, ethanol blends of more than 55 percent account for only 2,000 barrels per week out of total gasoline production of about 8.7 million barrels per week. Ethanol blends under 55 percent, almost entirely E10, account for about 95 percent of U.S. gasoline production[3]. There is little, or no, room for E10 to grow further, and E85 cannot grow due to its high cost. E15 will likely suffer a similar fate.

The Nebraska Energy Office publishes monthly averages of 87 octane unleaded gasoline and ethanol prices at Omaha fuel terminal rack locations[4]. These averages represent ethanol prices near the center of U.S. ethanol production. They are among the lowest ethanol and gasoline prices in the country. This comparison is thought to be representative of relative prices across much of the United States.

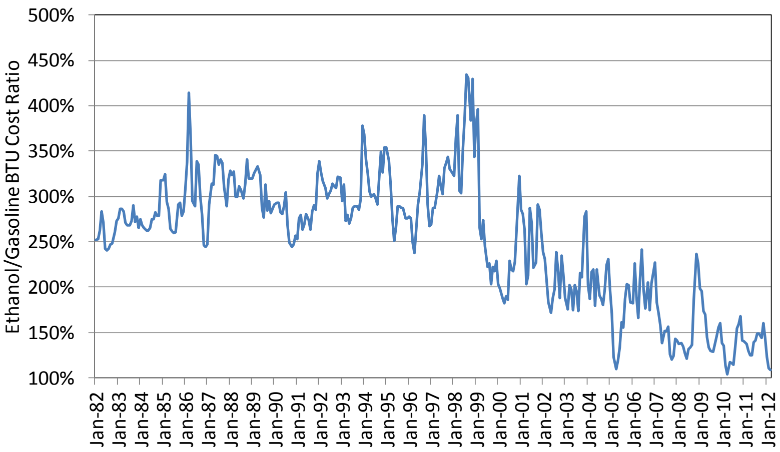
From January 1982, until March 2012, ethanol has never been priced at energy parity with 87 octane unleaded gasoline. The relative ethanol price has declined since 2000 as the octane and oxygenator markets have become saturated. However, since the current RFS was adopted in late 2007, ethanol energy has remained at a 44 percent average premium to gasoline at Omaha blending locations.

Key Point:

Ethanol is an expensive fuel. Compared to 87 octane unleaded gasoline at Omaha, Nebraska fuel terminals the cost of ethanol per gallon of gasoline energy has been higher than gasoline every month since 1982. Higher relative values prior to 2007 reflect an ethanol octane enhancement and oxygenator value premium. Recent declines in the ratio reflect a spike in wholesale gasoline prices.

Ethanol Price as Percent of 87 Octane Gasoline Energy

Omaha, Nebraska, January 1982 to March 2012



In 2011, the United States exported 1.2 billion gallons of ethanol. A major reason was that ethanol's energy is more expensive than gasoline, and thus E85 cannot be priced competitively in the U.S. market.

Another way to look at the ethanol price premium compared to gasoline is ethanol's price difference per gallon of gasoline energy. As the next chart shows, the energy-equivalent per gallon price difference has declined only slightly since the 1980s. Since the current RFS was enacted in late 2007, the average price

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[3] Department of Energy. Weekly Refiner & Blender Net Production, 4 Week Average. Found at http://www.eia.gov/dnav/pet/pet_pnp_wprodrb_dcu_nus_w.htm. Accessed 5/10/2012.

[4] Nebraska Energy Office. Ethanol and Unleaded Gasoline Average Rack Prices. Found at http://www.neo.ne.gov/statshtml/66.html, Accessed 5/7/2012.

difference was $0.95 per gallon premium for ethanol energy versus gasoline energy. From January, 1982 until December 2007, the average was a $1.25 per gallon premium for ethanol energy. Again, ethanol energy has not been priced competitively with gasoline since 1982.

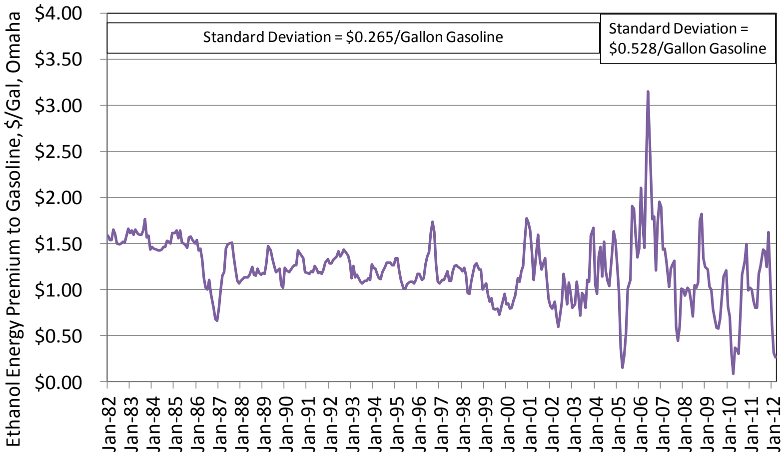
Not only has the ethanol energy price premium remained at high levels, the volatility of the premium has doubled. The standard deviation of the ethanol energy premium was $0.265 per gallon from 1982 to mid-2005, when the first RFS was enacted. Since then the standard deviation was $0.528 per gallon. A recent journal article by Bruce A. Babcock and Lihong Lu McPhaila shows that the RFS is a major cause of this increased volatility for both ethanol and corn prices[5].

Key Point:

Ethanol is an expensive fuel. Since 1982, relative to 87 octane gasoline, ethanol energy has been priced at about a $1.30 higher per gallon of gasoline energy. That premium has declined slightly since 2007, but remains nearly as high on average as it was prior to the current RFS. Since the original 2005 RFS, the volatility of the price premium has doubled.

Ethanol Price Premium/Gallon Gasoline Energy

Omaha, Nebraska, January, 1982 to March, 2012



The impact of this increased volatility on fuel markets is difficult to understate. Gasoline blenders and their retail customers who might want to sell E85 have been discouraged by the state of flux in gasoline versus ethanol pricing. This pricing instability has likely been a detriment to installation of E85 fueling stations and flex-fuel auto purchases. As will be shown later, much of this increased volatility can be traced back to the impact of the inflexible RFS on corn use, corn inventories, and corn prices.

The most significant ethanol production cost is corn. Since the first RFS schedule in 2005, the corn cost in a gallon of ethanol has increased from about 50 percent to more than 80 percent of total ethanol production costs. Corn costs for ethanol producers have also been much more volatile. The increased volatility of corn costs is directly attributable to large increases in mandated corn use for ethanol production, resulting lower corn stocks, and increased corn price volatility.

Increases in corn prices since 2005 are primarily the result of both higher mandates for corn-based ethanol production and higher energy prices. Each played a significant role, and they reinforced each other in their corn price effects. Absent the RFS mandates and higher oil prices, corn prices would be much lower today. How much each of the driving forces affected corn prices and ethanol production is debatable, but there is no doubt that both were important.

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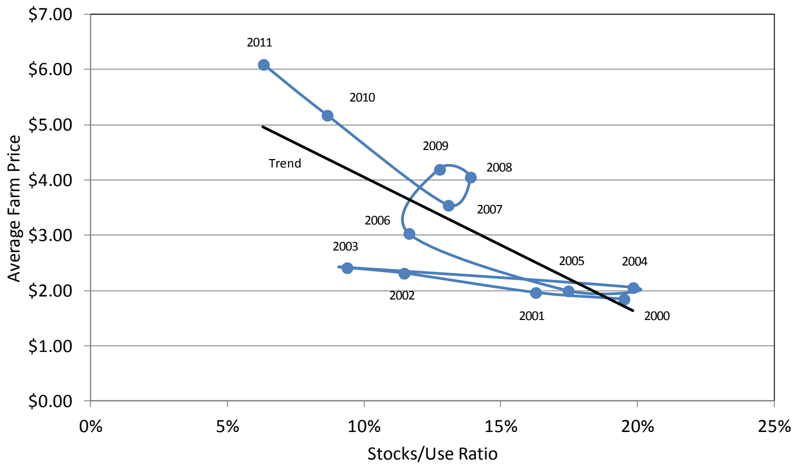
[5] Bruce A. Babcock and Lihong Lu McPhaila. Impact of US biofuel policy on US corn and gasoline price variability. Energy. Volume 37, Issue 1. January 2012.

The next chart shows the 2000-2011 crop year average farm level corn prices versus the ratio of ending stocks-to-use. Clearly, as the stocks-to-use ratio declines there is a tendency for corn prices to rise.

Key Point:

The increased demand for corn that has been partially the result of the inflexible RFS has caused corn stocks to decline to near-record low levels relative to total corn use. Tighter stocks have caused higher corn prices for all users, including ethanol producers.

Season-Average Corn Price vs. Stocks-to-Use Ratio
(Year is Year of Harvest, Black Line is Trend))

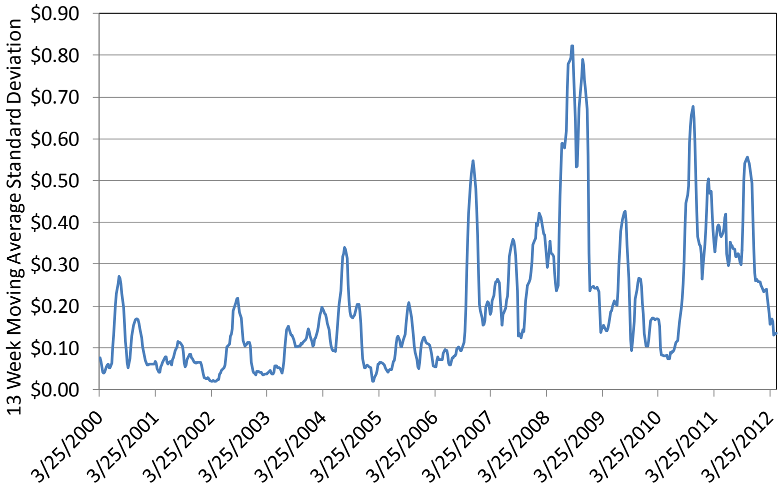


Less obvious than the increase in corn prices has been in the increase in their volatility. The next graph shows the 13 week standard deviation of weekly Central Illinois elevator corn bids. The volatility obviously increases markedly after the 2007 RFS. This higher volatility has increased business risks for all corn users. The result has been the bankruptcy of a number of ethanol companies and food producers.

13 Week Standard Deviation of Central IL Elevator Corn Bids

Key Point:

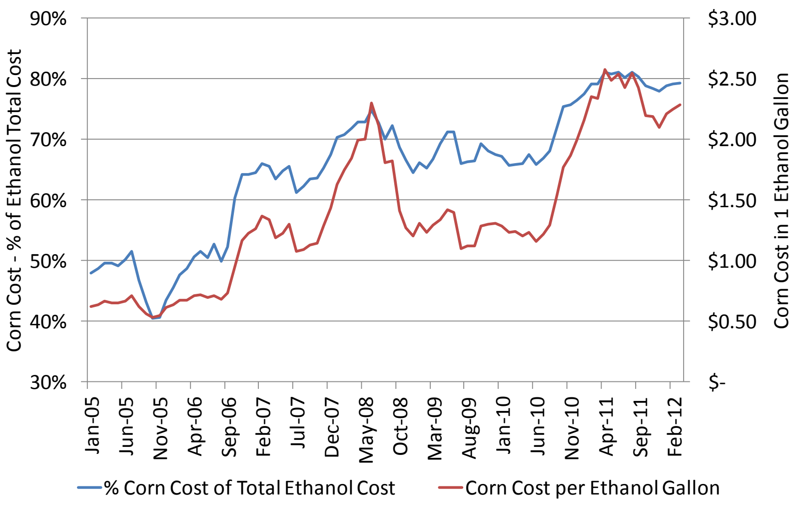
Tighter stocks shown in the chart above have also caused much higher corn price volatility for all users, including ethanol producers. This higher volatility has substantially increased business risks, resulting in a number of bankruptcies of ethanol and food producers.



The impact of higher corn prices on ethanol production costs is shown in the following chart. Prior to the RFS, corn accounted for about a $0.60 cost per gallon of ethanol. The corn cost per gallon is now in the $2.00 to $2.50 range. Looking at the cost of just the corn used in ethanol per 100,000 BTUs of fuel energy produced, that cost is currently in the $2.65 to $3.30 range. This is roughly comparable to recent wholesale prices for 87 octane unleaded gasoline. Past costs for the corn used in ethanol have been substantially higher than the recent relationship.

Key Point:

Higher corn prices have increased the cost of ethanol production. Corn now represents about 80 percent of the cost of ethanol versus 40-50 percent prior to the RFS. Higher ethanol prices are acting as a choke point on use of ethanol at blends higher than 10 percent.


Corn Cost Impact on Ethanol Production Cost[6]

Corn Prices and Food Production Costs

Corn is one of the key commodities used in U.S. food production. It enters the food chain via a wide range of products, but meat, poultry and dairy are the major users. Ranked by wholesale value of primary commodities, corn dwarfs the second and third ranking commodities, soybean products and wheat. Distiller's Grains (DGs), an animal feed by-product of ethanol production, are included with corn to arrive at the total value of corn used for U.S. food production.

Top Three U.S. Food Production Commodities, by Value, 2011/2012 Crop Year[7]

Commodity	Units	Domestic Food Production Use	Price	Value/Cost, $ Million
Corn				
Corn as Grain	Bushels	5,955	$6.05	$36,028
DGs from Corn	Tons	33.5	$200	$6,700
Total Corn				$42,728
Soybeans				
Soybean Meal	Tons	30,900	$360	$11,124
Soybean Oil	Million Pounds	14,000	$0.54	$7,490
Total Soybeans				$18,614
Wheat	Bushels	1,110	$7.25	$8,048

Not only is corn important on its own, corn prices also influence wheat, soybeans and other important commodities. As corn prices have risen, so have prices of the other two major commodities. Increases in

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[6] Source: Iowa State Ethanol Plant Profitability Model. Found at http://www.extension.iastate.edu/agdm/energy/xls/d1-10ethanolprofitability.xls. Accessed 5/10/2012

[7] USDA. World Agricultural Supply and Demand Estimates. May, 2012. DGs are estimated based on ethanol production and exports.

prices of these three major food production items have driven costs of U.S. food production significantly higher since the first RFS was introduced in 2005.

Cost of Corn, Soybean Products and Wheat Used In U.S. Food Production[8]

Corn Crop Years 2005-2011

Commodity	2005	2006	2007	2008	2009	2010	2011	% Increase 2005-2011
Corn								
Corn as Grain	$12,310	$17,017	$24,940	$21,039	$18,194	$24,828	$36,028	193%
DDGS from Corn	$879	$1,653	$3,069	$2,869	$3,173	$5,982	$6,700	662%
Total Corn	$13,189	$18,671	$28,009	$23,908	$21,366	$30,809	$42,728	224%
Soybeans								
Soybean Meal	$5,782	$7,059	$11,138	$10,181	$9,537	$10,444	$11,124	92%
Soybean Oil	$3,845	$4,947	$7,985	$4,656	$5,081	$7,578	$7,490	95%
Total Soybeans	$9,626	$12,006	$19,123	$14,837	$14,618	$18,022	$18,614	93%
Wheat	$3,677	$4,507	$6,234	$8,034	$5,206	$6,088	$8,048	119%
Total Cost	**$26,492**	**$35,183**	**$53,365**	**$46,779**	**$41,191**	**$54,919**	**$69,389**	**162%**
Cumulative Increase		**$8,692**	**$35,565**	**$55,852**	**$70,551**	**$98,979**	**$141,877**	

By 2011, the annual cost of the three commodities to U.S. food producers had risen from $26.5 billion in 2005 to $69.4 billion. The cumulative cost increase over the 2005-2011 was $141.9 billion.

It should then come as no surprise that the cost of food has increased much faster than overall inflation since 2005. The following table shows consumer level price inflation for selected food categories, and all items other than food, between calendar years 2005 and 2011. The time periods are before and after the 2007 RFS came into force. Overall price inflation of items other than food, even including energy, declined dramatically after December, 2007. The decrease was largely due to the 2008-2009 recession. In 2005 to 2007, food prices were increasing slower than all items other than food.

U.S. Price Inflation, Food and All Items Other than Food[9]

Before and After the 2007 RFS

From:	January-2005	January-2008	Rate
CPI Category and Ratio To:	December-2007	December-2011	Change
All CPI Items Other Than Food (Includes Energy)	10.5%	6.2%	-41.1%
All Food	9.6%	11.3%	17.8%
Cereals and Bakery Products	9.4%	16.6%	76.6%
Meats, Poultry, Fish, and Eggs	8.2%	14.6%	78.8%
Fats and Oils	5.0%	27.2%	444.5%
Ratios to All Items Other Than Food			
All Food to All Items Other Than Food	91.7%	183.2%	99.9%
Meats, Poultry, Fish, and Eggs to All Items Other Than Food	78.0%	236.6%	203.4%
Cereals and Bakery Products	90.0%	269.7%	199.8%
Fats and Oils to All Items Other Than Food	47.7%	441.2%	824.2%

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[8] USDA. World Agricultural Supply and Demand Estimates. Various issues, 2005-2012. Value is domestic use times price.

[9] Bureau of Labor Statistics. Consumer Price Index Database. Found at http://www.bls.gov/cpi/data.htm. Accessed 5-10-2012.

However, post-RFS food price inflation accelerated, even in the face of the recession. The grain and soybean-intensive food categories of cereals and bakery products, meats, poultry, fish and eggs, and fats and oils all increased at a much faster rate than overall food prices, and all items other than food.

The rapid increase in those three categories should come as no surprise. They all make heavy use of the three basic commodities shown in the table above. Ethanol from corn and biodiesel from soybean oil are both targeted by the 2007 RFS fuel blending mandates. Wheat and soybean prices have risen with corn due to the potential for corn to take wheat and soybean acreage, and the potential for wheat to substitute for corn in animal feeding.

The last four lines of the preceding table compare Consumer Price Index (CPI) food categories to all items other than food for the two sub-periods. Prior to the 2007 RFS, all four food categories had price inflation that was less than all items other than food. After 2007, all of the three food categories were increasing much faster than the all items other than food index. After 2007, all-food inflation increased about doubled relative to all items other than food before 2007. Fats and oils, which had been increasing at only 47.7 percent of the all items other than food, accelerated to an astounding 444.5 percent relative rate after 2007. The acceleration in this category's rate relative to the pre-RFS rate was an incredible eight-fold.

Some studies have shown little or no contemporaneous, month-to-month, relationship between corn prices and consumer food prices. However, the effects are not month-to-month or limited to corn, but cumulative and spread across other basic commodities. Post-2007 food prices, especially categories that make heavy use of corn, wheat and soybean products, accelerated much faster than overall inflation. The 2008-2009 recession had little negative effect on longer term food prices because those were being pushed up by the artificial demand of RFS mandates that increased faster than the ability to produce corn, wheat and soybeans.

In addition, ethanol production costs and ethanol prices were also increased by the 2007 RFS. The result was that ethanol has been priced out of all blends, except E10. Thus, the United Sates is producing surplus ethanol that cannot be sold here, and is having to export surplus ethanol!

Has Increased Ethanol Production Affected Gasoline Prices?

A recent Iowa State working paper[10] claimed to show that increased ethanol production lowered the average 2011 gasoline price by $1.09 per gallon. To get that result the authors used an indirect, convoluted, calculation based on a highly dubious statistical model.

With a more direct approach using actual (not the deflated data used in the Iowa State study) energy prices, several statistical models were estimated. All show that increased ethanol production from January 2000 through February 2012 had no statistically significant effect on gasoline prices or oil refiner margins. Furthermore, simple trends of gasoline energy equivalent ethanol production and U.S. gasoline exports show that increased ethanol production since 2007 has added nothing to the U.S. fuel supply. Rather, the increase in ethanol production has simply shifted U.S. gasoline production from domestic use to exports.

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[10] Xiaodong Du and Dermot J. Hayes. The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to 2012, Working Paper 12-WP 528. Center for Agricultural and Rural Development. Iowa State University. May 2012.

It will also be shown that with no impact on gasoline prices, the lower energy content of ethanol has actually increased the cost of U.S. automobile motor fuel.

Statistical Models

To estimate an impact of ethanol production on gasoline prices or oil refiner margins, an approach similar to the Iowa State paper was taken. Several models were used. All of the models are based on monthly data for January 2000 through February 2012. All energy data are from the U.S. Department of Energy, Energy Information Administration.

Model 1: Gasoline Prices, Crude Oil Prices, Ethanol Production and Other Related Factors:

The New York harbor conventional gasoline, regular grade, monthly average price (cents per gallon) was explained using the following factors:

1. U.S. Crude Oil Composite Acquisition Cost by Refiners (Dollars per Barrel)
2. U.S. Fuel Ethanol Production (Thousand Barrels)
3. U.S. Percent Utilization of Refinery Operable Capacity (Percent)
4. U.S. Ending Stocks Excluding Strategic Reserves (Thousand Barrels)
5. U.S. Motor Gasoline Ending Stocks (Thousand Barrels)
6. Net Gasoline Exports (Exports-Imports, Thousand Barrels)
7. Monthly Seasonal Effects
8. Katrina Effect, September to October 2005
9. MTBE Effect, April to August 2006
10. 2007 Refinery Outages Effect, March to July 2007

Except for ethanol production and net gasoline exports, all of the factors were statistically significant. The model shows that ethanol production had a positive, but statistically insignificant, effect on gasoline prices. The estimated equation explained 98.8 percent of the variation in gasoline prices. Crude oil prices were by far the leading driver of gasoline prices.

The model shows that increasing ethanol production was very weakly associated with higher, not lower, gasoline prices. While interesting, the model really shows that increasing ethanol production did not depress, or increase, gasoline prices. Crude oil prices are the major driver.

Detailed results for all four models are in the appendix to this study.

Model 2: 3:2:1 Crack Spread, Crude Oil Prices, Ethanol Production and Other Related Factors:

This model closely resembles the Iowa State paper 3:2:1 crack spread model. There are two major differences. The Iowa State paper deflated the crack spread by the Producer Price Index (PPI) of crude energy material. This version uses the actual, non-deflated, crack spread. The Iowa State model also did not include crude oil prices as a driver of the margin, or the MTBE and refinery outage events.

The “Crack Spread” is a common measure of refiner margins above the cost of crude oil. It is the weighted value of two major refiner products, gasoline and distillate fuel oil, minus crude oil cost. It is the value of 2 barrels (84 gallons) of gasoline, 1 barrel (42 gallons) of distillate fuel oil, versus the total value of the price of three barrels of crude oil. For February 2012 the crack spread was:

Gasoline Value: $3.044/gallon x 42 gallons per barrel x 2 barrels = $255.70
+ Fuel Oil Value: $3.196/gallon x 42 gallons per barrel x 1 barrel = $134.23
- Crude Oil Value: $107.19/barrel x 3 barrels = $321.57
= $68.36 per 3 barrels of crude oil; or $22.79 per barrel of crude oil, the value used in the model.

The variables used to explain the crack spread are the same as used in Model 1. The results are also almost the same. Ethanol production had a positive, but statistically insignificant, effect on the crack spread. Net gasoline exports were statistically significant, but just above the threshold level. Except for ethanol production, all of the variables had the expected direction of influence on the crack spread.

The model explained 74 percent of the variation in the crack spread.

Model 3: Gasoline Crack Ratio, Crude Oil Prices, Ethanol Production and Other Related Factors:

This model closely resembles the Iowa State paper crack ratio model. The "Gasoline Crack Ratio" is the ratio of the price of gasoline to the price of crude oil. For February 2012, the crack ratio was:

Gasoline Price: $3.044/gallon x 42 gallons per barrel = $127.85
Crude Oil Price: $107.19/barrel
Gasoline Crack Ratio = $127.85/$107.19 = 1.193

The variables used to explain the gasoline crack ratio are the same as used in Model 1. Except for ethanol production and net gasoline exports, all of the factors were statistically significant and had the expected direction of influence. The estimated equation explained 68 percent of the variation in the gasoline crack ratio.

While it was not statistically meaningful, the model also shows that increasing ethanol production was actually associated with higher, not lower, gasoline prices. While interesting, the model really shows that increasing ethanol production was not statistically important to gasoline prices.

Model 4: Gasoline Crack Price Spread, Crude Oil Prices, Ethanol Production and Other Related Factors:

The "Gasoline Crack Price Spread" is defined as the difference between the value of a gallon of gasoline and the value of a gallon of crude oil. For February 2012, the gasoline crack price spread was:

Gasoline Price: $3.044/gallon
Crude Oil Price: $107.19/barrel/42 = $2.552/gallon
Gasoline Crack Price Spread = $3.044 - $2.55 = $0.492/gallon

This price spread is a rough measure of the gasoline gross margin above crude oil costs. It is not refiner profits, only crude oil costs are included.

The variables used to explain the gasoline crack price spread are the same as used in Model 1. Except for ethanol production and net gasoline exports, all of the factors were statistically significant and had the expected direction of influence. The estimated equation explained 64 percent of the variation in the gasoline crack price spread.

While it was not statistically meaningful, the model again shows that increasing ethanol production was actually associated with higher, not lower, gasoline prices. The model shows that increasing ethanol production was not statistically important to gasoline prices.

Conclusions

Four different measures of gasoline prices and oil refiner margins were used to model the effect of increasing ethanol production on those prices and margins. The monthly data used spanned January 2000 through February 2012. In all four attempts increasing ethanol production showed a positive, but statistically insignificant, effect on wholesale gasoline prices or refiner margins.

The overall conclusion is that increasing ethanol production over the 2000-2012 period tested had no significant effect on wholesale gasoline pricing or refiner margins. The fact that all four models showed a positive, but statistically insignificant, effect indicates that it is highly unlikely that increasing ethanol production depressed wholesale gasoline prices or refiner margins.

In one of the models, net gasoline exports did show a weakly significant negative effect on refiner gasoline margins. Increased ethanol production has caused gasoline exports to increase. That might be an indication of an indirect negative gasoline price effect, but the results are not consistent across the models. If there is an effect, it is contradicted by the weak positive effects of increasing ethanol production on gasoline prices and refiner margins.

Why Do These Results Differ from Iowa State's Paper?

There are several items that contribute to the differences between the Iowa State results and these.

For the 3:2:1 Crack Spread version there are three major differences. The Iowa State version deflated the spread by a Producer Price Index (PPI) for crude energy materials. This study did not deflate the crack spread, but used actual data. This study also included crude oil price effects, an important variable.

The deflation of the crack spread may have produced a spurious result in the Iowa State version. Their model showed a statistically significant negative effect of increasing ethanol production on the spread. However, deflating that spread by the cost of energy materials causes it to not increase as fast as the actual raw data. Thus, with the crack spread increases held down in a time of increasing ethanol production and energy costs, there is a measured negative effect, even if one does not exist in the actual, non-deflated, data.

A second major difference is that the models in this paper included crude oil prices as a variable to explain the crack spread. The reason is that oil refineries use some oil in their processing. As crude oil prices increase, the crack margin should also increase to cover those higher costs. The model results confirm this effect. The effect of crude oil cost is positive, highly significant, and contributes to the different model results.

Finally, all of this paper's price and margin models include the effects of major March-July 2007 refinery outages that caused petroleum product prices and margins to increase over those months. The effect is statistically significant. Also included is an April-August 2006 gasoline price and margin increase associated with the withdrawal of the MTBE additive in several areas of the country. The effect is statistically significant. Neither of these market disruptions was considered in the Iowa State paper.

Using a more complete model, and actual prices and refiner margins, the effects of increased ethanol production on gasoline prices and oil refiner margins shown in the Iowa State model disappear.

Other Iowa State Paper Issues

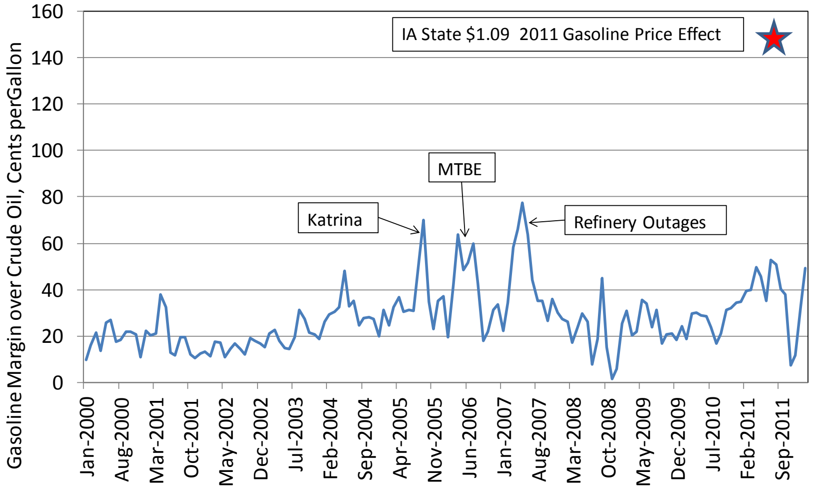
There are several other issues with the Iowa State paper's results. The Iowa State 3:2:1 crack spread model uses a deflated spread to estimate the impact of increasing ethanol production. They then use that result to project an actual price difference for gasoline. Mixing deflated model results and actual non-deflated price data is statistically problematic.

More significantly, the Iowa State authors do not seem to realize that their extrapolated $1.09 per gallon increase in gasoline price relative to the crude oil price would cause major changes in supply-side market behavior. The 2000-2011 average gasoline crack price spread was 27.8 cents per gallon. The 2011 margin averaged 37.1 cents. A $1.09 increase in that margin would lead to refineries quickly increasing gasoline production and reducing gasoline exports. The increase in gasoline supply available to the U.S. market would largely, likely entirely, wipe out the higher gasoline price.

Key Point:

The Iowa State finding that 2011 gasoline prices would have been $1.09 higher without ethanol production increases is out of line with historical prices and the fact that we are producing large gasoline exports. The actual 2011 gasoline premium to crude oil was 37.1 cents/gallon. An added $1.09 makes that margin $1.46.

Gasoline Price Margin over Crude Oil Price, 2000-February, 2011



Put simply, a $1.09 gasoline price increase in 2011 would have never happened. There is enough U.S. and global spare capacity to produce more gasoline, or the United States could export less, and bring gasoline prices down relative to crude oil.

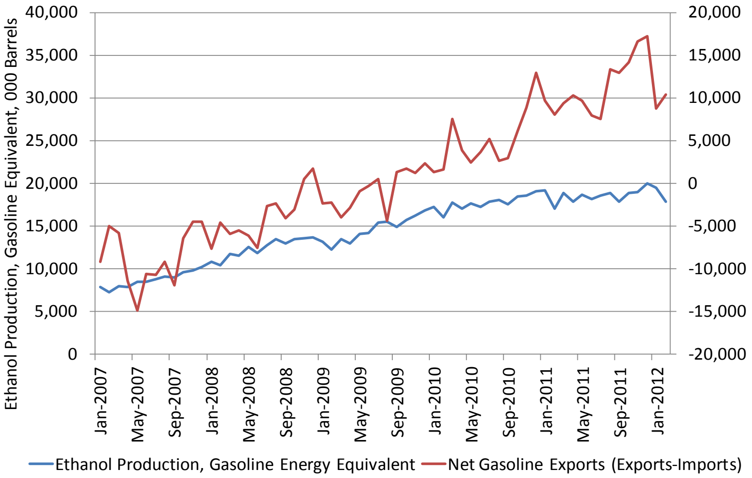
Has Increased Ethanol Production Increased U.S. Energy Supplies?

Another fact that supports the lack of impact of increased ethanol production on gasoline prices is that more ethanol production has not added to the U.S. energy supply. Rather, ethanol has displaced some U.S. gasoline consumption, but not production. The gasoline that was displaced from 2007 to 2011 was exported (next chart). In recent years the United States is also producing more ethanol than can be sold in the U.S. market, and ethanol exports increased to 1.2 billion gallons, 8.6 percent of production, in 2011.

Monthly Ethanol Production (Gasoline Energy Equivalent) and Gasoline Exports

Key Point:

The entire increase in ethanol production since 2007 has simply displaced U.S. gasoline consumption, not added to the domestic energy supply. All of the energy produced by the added ethanol has left the country in the form of higher gasoline exports and reduced gasoline imports.



In the chart above ethanol production was corrected for the fact that ethanol has only 67 percent of the energy in gasoline. Net gasoline exports are calculated as exports minus imports. Until about 2009 the U.S. was a net gasoline importer, thus the negative exports until then.

How can the ethanol industry claim that they are adding to the U.S. liquid fuel supply, or affecting prices, when ethanol has had no affect at all on domestic energy supply?

The ethanol industry has claimed that “Ethanol is now 10 percent of the U.S. motor fuel supply.” This is a very misleading statement.

In 2011, about 95 percent of U.S. gasoline was sold as E10, containing 10 percent ethanol by volume, but only 6.7 percent by energy content. Measured by volume, and for gasoline alone, the claim is very close to the fact. That is far from the whole story. A gallon of ethanol is not a gallon of gasoline, and gasoline is a far cry from the entire U.S. liquid fuels supply.

Gasoline is not the only liquid fuel used in the United States. According to the U.S. Department of Energy, 2011 U.S. total liquid fuel consumption was about 6.46 billion barrels. Gasoline-equivalent ethanol consumption was about 199 million barrels (table below). U.S. ethanol energy consumption was only 3.1 percent of U.S. liquid fuel consumption, not 10 percent. On a global scale, U.S. ethanol energy production contributed well under 1 percent of global liquid fuels consumption.

U.S. Ethanol Production Versus U.S. and Global Liquid Fuels Consumption

Item	2011, 000 Barrels
U.S. Ethanol Consumption, Gasoline Equivalent	198,751
Total U.S. Liquid Fuels Consumption	6,456,850
Ethanol Percent of U.S. Liquid Fuels	3.1%
U.S. Ethanol Production, Gasoline Equivalent	222,512
Global Liquid Fuels Consumption	32,090,800
Ethanol Percent of Global Liquid Fuels	0.69%

Does Ethanol Save Motorists Money?

The ethanol industry claims that increased use of ethanol is saving motorists' money. We have already shown that higher ethanol production has had no effect on gasoline prices. That claim is also based in part on the fact that ethanol now typically sells for less per gallon than gasoline. Once again, a gallon of ethanol displaces only 0.67 gallons of gasoline. On an equal energy basis, a gallon of ethanol has never sold for less than a gallon of gasoline.

The next table shows that the 2011 ethanol price premium added about $14.5 billion to motorists' fuel bills. In addition, more than $5.7 billion was paid in direct subsidies in the form of a $0.45 per gallon tax credit (now expired).

The total 2011 motorist and taxpayer cost of U.S. ethanol consumption more than $20 billion. Fortunately that cost will decline this year with the expiration of the ethanol tax credit on January 1, 2012. Still, motorists continue to pay significantly more for fuel than they would if ethanol was not included in gasoline, or was priced at energy parity with gasoline.

2011 Wholesale Level Cost of U.S. Ethanol Consumption[11]

Item	2011
Gasoline Average Price per Gallon	$2.90
Ethanol Average Price per Gallon, Gasoline Equivalent	$4.03
Ethanol Price Premium per Gallon	$1.13
Billion Gallons of Ethanol Consumed	12.79
Ethanol Cost to Motorists, $Billion	$14.49
Tax Credit Costs, $Billion	$5.76
Total Motorist and Taxpayer Cost, $Billion	$20.24
Actual Ethanol Average Price per Gallon	$2.70

Has Increased Ethanol Production Reduced U.S. Crude Oil Imports?

One claim made by the ethanol Industry is that ethanol substantially reduces U.S. oil imports. On the surface, that may seem obvious. The logic is that ethanol replaces gasoline, and if less gasoline is consumed we need to import less oil. The real world is not that simple. Increased ethanol production since 2007 has not replaced U.S. crude oil imports. Rather, since 2007, increased ethanol production has increased gasoline exports.

The Renewable Fuels Association claims that 2011 ethanol production reduced U.S. oil imports by 485 million barrels[12]. However, on an energy basis the U.S. consumed only 199 million barrels of ethanol last year. How can 199 million barrels replace 485 million barrels?

The claim is based on the theory that for every barrel of ethanol production there is no need to import the crude oil used to produce a barrel of gasoline. Since a barrel of crude oil yields about half a barrel of gasoline, the theory is that a barrel of ethanol actually replaces more than one barrel of crude oil

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[11] Sources: Ethanol and gasoline prices are from the Nebraska Energy Office. Ethanol consumption is from the Department of Energy, Energy Information Administration.

[12] http://ethanolrfa.org/pages/ethanol-facts-energy-security, Accessed May 19, 2012

imports. The first problem with this theory is that if the U.S. did reduce crude oil imports, there would less production of crude oil-based fuels other than gasoline. The U.S. would then need to import those other fuel products. So, about half of the 485 million barrel claim makes no contribution to reducing dependency on imported petroleum. It does not matter if it is imported crude oil or refined products, both represent dependency on "foreign oil."

A second problem is that a barrel of ethanol actually replaces only 0.67 barrels of gasoline. U.S. fuel ethanol use in 2011 was about 297 million barrels. That is the energy of 199 million barrels of gasoline, and the most gasoline that fuel ethanol could have replaced.

If there is any replacement of crude oil and refined product imports, the actual maximum reduction in foreign dependency is about 40 percent of the claimed amount. Even that claim may not be true if U.S. gasoline production did not decline in line with the increase in gasoline energy equivalent ethanol production. Data from the Department of Energy can show if U.S. gasoline production declined, or not. If gasoline production declined, it is also expected that there would be declines in the other major refinery production stream, distillate fuel oil used to make diesel, heating oil and jet fuel.

The next table summarizes 2007 to 2011 U.S. production and use for gasoline, ethanol, distillate fuel oil and crude oil use. U.S. finished gasoline production, net of the ethanol it includes, has increased, not declined, since 2007. Since gasoline consumption declined, exports have increased more than production. That means that the U.S. demand for the oil needed for gasoline production has not declined at all. Use of crude oil did decline slightly, but that was due to increased refinery fuel yields coupled with increased U.S. crude oil production, not refined product supply reductions.

U.S. Gasoline and Ethanol, Production, Trade and Consumption, 2007-2011[13]

Year	Finished Gasoline Production - Ethanol Used (Thousand Barrels)	Gasoline Net Exports (Thousand Barrels)	Gasoline Production - Net Exports (Thousand Barrels)	Ethanol Used for Blending (Thousand Barrels, Gasoline Equivalent)	Gasoline Production - Net Exports + Ethanol Used (Thousand Barrels, Gasoline Equivalent)	U.S. Refinery and Blender Net Production of Distillate Fuel Oil (Thousand Barrels)	U.S. Refinery and Blender Net Input of Crude Oil (Thousand Barrels)
2007 Actual	2,914,011	(104,248)	3,018,259	91,524	3,109,783	1,508,530	5,532,097
2008 Actual	2,938,589	(47,541)	2,986,130	127,356	3,113,486	1,571,539	5,361,287
2009 Actual	2,965,771	(10,210)	2,975,981	161,440	3,137,421	1,477,534	5,232,656
2010 Actual	3,020,517	58,954	2,961,563	191,542	3,153,105	1,541,503	5,374,094
2011 Actual	3,001,065	136,544	2,864,521	198,751	3,063,272	1,637,771	5,413,999
2007-11 Change	**87,054**	**240,792**	**(153,738)**	**107,227**	**(46,511)**	**129,241**	**(118,098)**

From 2007 to 2011, actual U.S. gasoline production and gasoline net exports both increased. Gasoline supplied to the U.S. market declined, ethanol use increased, and on balance total gasoline and ethanol (on an energy basis) declined. In 2011 an additional 19 million barrels of ethanol (gasoline energy equivalent) was exported. On balance, all the gasoline displaced by ethanol, plus a significant amount of ethanol, was exported. Crude use declined, but not due to refined product production reductions.

A major factor in reduced crude oil imports was increased total refiner fuel yield. As shown in the next table, the total yield increased from 71.6 percent in 2007 to 73.9 percent in 2011. Refiners reduced gasoline yields slightly due to its declining consumption. Versus 2007 yields, that small yield increase saved 125 million barrels of 2011 crude oil use.

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[13] These estimates use definitions that are different from the U.S. Department of Energy

Refinery Yields, Two Major Products

Year	Gasoline Yield	Distillate Fuel Oil Yield	Total Gasoline and Distillate Fuel Oil Yield
2007	45.5%	26.1%	71.6%
2008	44.2%	27.8%	72.0%
2009	46.1%	26.9%	73.0%
2010	45.7%	27.5%	73.2%
2011	45.0%	28.9%	73.9%

But, why did oil refiners continue to produce more gasoline when ethanol production was increasing? Gasoline is not the only important fuel produced from crude oil. Diesel, aviation and heating fuels made from distillate fuel oil are also very important to refiners. Total demand for those products was increasing from 2007 to 2011. Ethanol cannot replace any of those other refinery products.

To meet the demand for fuels other than gasoline, and keep refineries running at efficient rates, oil companies had to maintain crude oil use even as ethanol and gasoline supplies grew. With U.S. gasoline demand on the decline, and ethanol adding to the gasoline supply, refiners simply started to export more gasoline to balance their total fuels supply and demand.

The next table is what might have happened if ethanol production and use had not increased after 2007. The only changes are a reduction in gasoline exports and increase in domestic use. Crude oil use does not change. Gasoline exports move from net imports to significant net exports even if ethanol production is held flat.

In summary, the theory that increased ethanol production would reduce U.S. dependence on crude oil imports does not stand up to the facts. It is true that somewhere in the world our 2011 ethanol production may have displaced crude oil and gasoline production, but not here in the United States!

U.S. Gasoline and Ethanol Production, Trade and Consumption, 2077 - 2011
No Ethanol Production Increase Scenario

Year	Finished Gasoline Production - Ethanol Used (Thousand Barrels)	Gasoline Net Exports (Thousand Barrels)	Gasoline Production - Net Exports (Thousand Barrels)	Ethanol Used for Blending (Thousand Barrels, Gasoline Equivalent)	Gasoline Production - Net Exports + Ethanol Used (Thousand Barrels, Gasoline Equivalent)	U.S. Refinery and Blender Net Production of Distillate Fuel Oil (Thousand Barrels)	U.S. Refinery and Blender Net Input of Crude Oil (Thousand Barrels)
2007	2,914,011	(104,248)	3,018,259	91,524	3,109,783	1,508,530	5,532,097
2008	2,938,589	(83,373)	3,021,962	91,524	3,113,486	1,571,539	5,361,287
2009	2,965,771	(93,170)	3,045,897	91,524	3,137,421	1,477,534	5,232,656
2010	3,020,517	(41,064)	3,061,581	91,524	3,153,105	1,541,503	5,374,094
2011	3,001,065	29,317	2,971,748	91,524	3,063,272	1,637,771	5,413,999
2007-2011: No Increase in Ethanol Production	**87,054**	**133,565**	**(46,511)**	**-**	**(46,511)**	**129,241**	**(118,098)**
Actual 2007-2011 Change	**87,054**	**240,792**	**(153,738)**	**107,227**	**(46,511)**	**129,241**	**(118,098)**
Difference	**-**	**(107,227)**	**107,227**	**(107,227)**	**-**	**-**	**-**

In fact, one way to look at what happened is that the RFS has forced almost all of the 2007-2011 ethanol production increase to be used in the U.S. In a very real sense, all of the energy contained in the 2007-2011 ethanol production increase was actually exported in the form of gasoline! We could have exported all of that increased ethanol production, still increased gasoline net exports, and had exactly the same gasoline energy supply for domestic use, with no increase in crude oil use or imports!

In other words, the 2007-2011 increase in ethanol production increased the global energy supply, but that energy was exported from the U.S. Increased ethanol production since 2007 has not increased U.S. motor fuel consumption, or reduced crude oil use or imports. That helps make sense out of the statistical model results that show no impact of increasing ethanol production in gasoline prices.

Statutory RFS Adjustments Based on Corn Market Conditions

In the post-RFS era grain and soybean prices have reached record-high prices, and volatility levels are the highest seen in modern history. Such an outcome is to be expected given the fixed nature and size of the RFS blending mandates versus forces of nature that largely determine biofuel feedstock production.

Consequences of high, volatile, grain and soybean prices have been detrimental to both the food and ethanol fuel sectors, and the overall economy. As was pointed out earlier, since 2007 food price inflation has accelerated to double the pre-2007 rate relative to non-food prices. Higher food prices have acted on a drag to post 2007 economic growth and recovery from the 2008-2009 recession.

The effects of the fixed RFS can be seen in the next table that details the 2005 to 2012 corn supply and use situation. The 2007 RFS promise of guaranteed ethanol use helped drive corn used for ethanol from 1.6 billion bushels in the 2005/2006 crop year to 5.0 billion in 2011/2012. That increase in ethanol use forced higher prices and significant rationing of corn among feed users and export customers.

Feed use of corn declined from 6.2 billion bushels in 2005/2006, to only an estimated 4.6 billion in 2011/2012. Part, but not all, of the decline in corn feeding was offset by the increase in distillers' grains that are a by-product of ethanol production.

There are no official USDA estimates of distillers' grains production or stocks, but export data are available. To estimate distillers' grain feed use a standard yield of 17 pounds of 10 percent moisture distillers' dried grains with solubles (DDGS) per bushel of corn used for fuel ethanol production was assumed. That production volume was then factored up to from 10 percent to 14 percent moisture, the standard for corn. That supply was assumed to substitute for corn on a 1:1 basis. That is, 56 pounds of 14 percent moisture DDGS was assumed to replace one bushel of corn. Exports were subtracted from production to obtain domestic supply. DDGS has no use other than feeding, and inventory data are not available, so the entire domestic supply was assumed to be fed in the year of production.

Even with the add-back of DDGS, total feed use of corn plus DDGS declined from about 6.6 billion bushels in 2005/2006, to an estimated 5.8 billion bushels in 2011/2012.

Corn exports declined from about 2.1 billion bushels in 2005/2006 to an estimated 1.7 billion bushels in 2011/2012.

Both of these declines in use are the result of corn prices increasing from $2.00 for the 2005/2006 crop year to more than $6.00 in 2011/2012. Higher corn prices (and associated increases in wheat and soybean product prices) have dramatically raised the costs of producing meat and poultry.

USDA Corn Production, Supply and Demand Estimates[14]

Item	2005/ 2006	2006/ 2007	2007/ 2008	2008/ 2009	2009/ 2010	2010/ 2011	2011/2012 Proj.
Area Planted (Mill. Ac.)	81.8	78.3	93.5	86.0	86.4	88.2	91.9
Area Harvested (Mill. Ac.)	75.1	70.6	86.5	78.6	79.5	81.4	84.0
Yield (Bu/Ac.)	148.0	149.1	150.7	153.9	164.7	152.8	147.2
Beg. Corn Stocks (Mill. Bu.)	2,114	1,967	1,304	1,624	1,673	1,707	1,128
Corn Production (Mill. Bu.)	11,114	10,535	13,038	12,092	13,092	12,447	12,358
Corn Imports (Mill. Bu.)	9	12	20	14	8	28	20
Total Corn Supply (Mill. Bu.)	13,237	12,514	14,362	13,729	14,773	14,182	13,506
Corn Feed Use (Mill. Bu.)	6,155	5,598	5,938	5,182	5,125	4,793	4,550
Corn+DDGS Feed Use	6,612	6,195	6,735	6,153	6,238	6,072	5,805
Food/Seed/Ind. Use (Mill. Bu.)	2,981	3,488	4,363	5,025	5,961	6,428	6,405
Fuel Ethanol Use (Mill. Bu.)	1,603	2,117	3,026	3,709	4,591	5,021	5,000
Est. DDGS Prod. (Mill. Bu. Equiv.)	508	670	958	1,175	1,454	1,590	1,583
DDGS Exports (Mill. Bu. Equiv.)	50	73	161	204	340	311	328
DDGS Feed Use (Mill. Bu. Equiv.)	457	597	797	971	1,113	1,279	1,255
Other Food/Seed/Ind. Use (Mill. Bu.)	1,378	1,371	1,337	1,316	1,370	1,407	1,405
Corn Exports (Mill. Bu.)	2,134	2,125	2,436	1,849	1,980	1,835	1,700
Total Corn Use (Mill. Bu.)	11,270	11,210	12,737	12,056	13,066	13,056	12,655
Ending Corn Stocks (Mill. Bu.)	1,967	1,304	1,624	1,673	1,707	1,128	851
U.S. Average Farm Price, Corn, $/Bu.	$2.00	$3.04	$4.20	$4.06	$3.55	$5.18	$6.20
% Corn Production Used for Fuel Ethanol	14%	20%	23%	31%	35%	40%	40%
Corn Ending Stocks to Total Use Ratio	17%	12%	13%	14%	13%	8.6%	6.7%

In the domestic market, the sharp increases in corn prices after 2007 have led to higher prices for foods that make heavy use of corn. Meat and poultry production has been heavily affected. Higher prices for these commodities have forced price rationing among consumers, and per capita consumption has declined to the lowest level since 1990 (next chart).

The post-2007 decline in U.S. meat and poultry consumption is unprecedented. But, so is the current RFS that reduces this industry's access to its basic feedstock, corn. By encouraging the diversion of corn to ethanol production, even in times when corn stocks were dangerously low, the RFS has forced all other users to reduce production to accommodate higher costs. It is no accident that the decline in meat and poultry consumption started in 2008, the first year of the current RFS.

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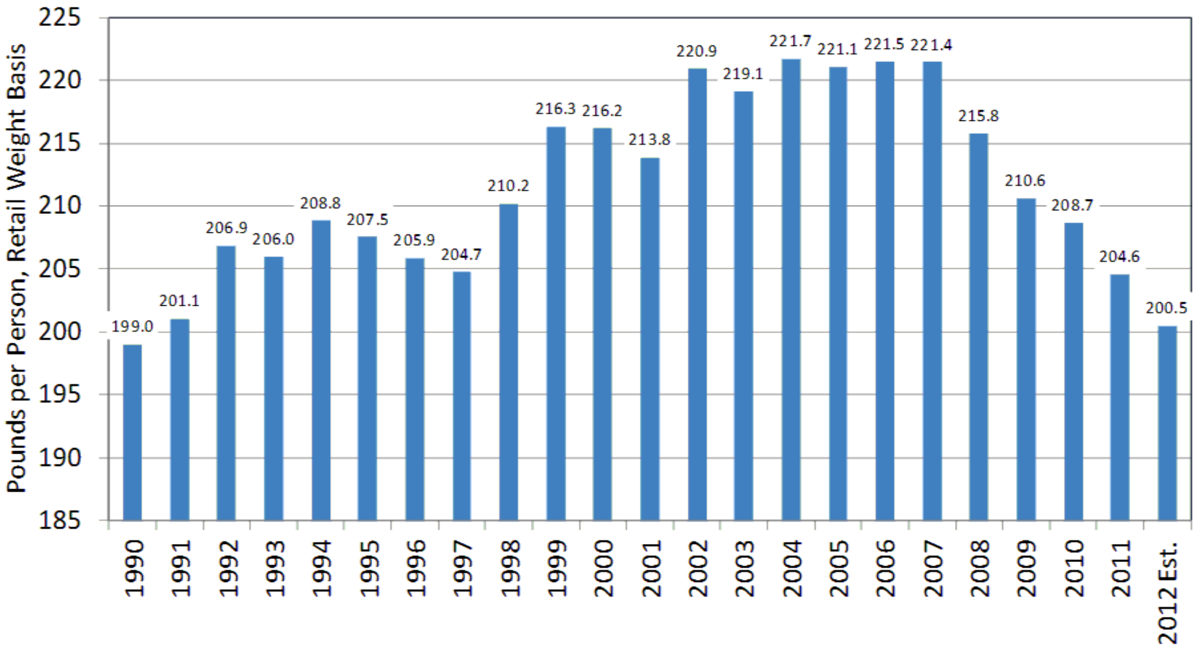
[14] USDA, World Agricultural Supply and Demand Estimates, May 10, 2012. Years are September 1 crop years.

USDA Estimates of Per Capita Total Meat and Poultry Consumption, 1990-2012[15]



Had the RFS contained automatic adjustments to the tight corn stocks since 2007, the corn market could have been allowed to better adjust to the realities of corn production and market demand. The next table contains proposed adjustments to the RFS based on a draft bill prepared by Rep. Bob Goodlatte of Virginia.

Proposed Schedule of RFS Adjustments
Stocks-to-Use Based on the November USDA World Agricultural Supply and Demand Estimates

U.S. Corn Stocks-to-Use Ratio for the Current Crop Year (percent)	Reduction in national quantity of renewable fuel required
Above 10.0	No adjustment
10.0-7.5	10 percent reduction
7.49-6.0	15 percent reduction
5.99-5.0	25 percent reduction
Below 5.0	50 percent reduction

The next table contains estimates of how this adjustment mechanism might have affected corn use and prices had it been in effect for the 2005/2006 through 2011/2012 corn marketing years. Estimates by marketing year are as follows:

2005/2006: No change; the November 2005 Stocks/Use Ratio was well above the upper threshold of 10 percent.

2006/2007: No change; the November 2006 Stocks/Use Ratio was below 10 percent. Corn prices were not yet high enough to materially affect use, and ethanol plants were extremely profitable.

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[15] USDA, World Agricultural Supply and Demand Estimates, May 10, 2012 and prior editions.

2007/2008: No change; the November 2007 Stocks/Use Ratio was above the 10 percent threshold.

2008/2009: The 9 percent November 2008 Stocks/Use Ratio was below 10 percent, and corn prices high enough to materially ration use. The RFS was reduced by 10 percent. Corn prices were also extremely volatile during the year. Major broiler and ethanol producer bankruptcies occurred. Ethanol use was adjusted down by 185 million bushels and corn feed use up by 118 million. The net result is a 67 million bushel increase in ending stocks. The season average price was adjusted downward by a small $0.06 per bushel. Corn prices during the 2008/2009 crop year could have been much less volatile had the lower RFS been in effect.

2009/2010: No change; the November 2009 Stocks/Use Ratio was above the upper threshold of 10 percent. Beginning inventories are slightly higher due to the use effects from the prior year. The season average price was not adjusted for the small impact on stocks/use ratio.

2010/2011: The 6.2 percent November 2010 Stocks/Use Ratio was well below 10 percent, and corn prices high enough to materially ration use. The RFS was reduced by 15 percent. Estimated fuel ethanol use was decreased by 321 million bushels. Estimated feed use was increased by 207 million bushels. The resulting change in the actual stocks-to-use ratio from 8.6 percent to over 10 percent caused the estimated season average corn price to decline by $0.93 per bushel versus the actual corn price.

2011/2012: Even with larger carryover stocks from 2010/2011, the November 2012 stocks-to-use ratio of 6.7% was still well below 10 percent, and corn prices high enough to materially ration use. The RFS was again reduced by 15 percent. Estimated fuel ethanol use was decreased by 200 million bushels. Estimated feed use was increased by 200 million bushels. The stocks-to-use ratio changes from 6.7 percent to 8.1 percent as a result of higher stocks from the prior year. The estimated season average corn price declined by $0.95 per bushel versus the actual corn price.

USDA Corn Production, Supply and Demand Estimates Adjusted for a Flexible RFS

Item	2005/ 2006	2006/ 2007	2007/ 2008	2008/ 2009	2009/ 2010	2010/ 2011	2011/2012 Proj.
Area Planted (Mill. Ac.)	81.8	78.3	93.5	86.0	86.4	88.2	91.9
Area Harvested (Mill. Ac.)	75.1	70.6	86.5	78.6	79.5	81.4	84.0
Yield (Bu/Ac.)	148.0	149.1	150.7	153.9	164.7	152.8	147.2
Beg. Corn Stocks (Mill. Bu.)	2,114	1,967	1,304	1,624	1,740	1,775	1,308
Corn Production (Mill. Bu.)	11,114	10,535	13,038	12,092	13,092	12,447	12,358
Corn Imports (Mill. Bu.)	9	12	20	14	8	28	20
Total Corn Supply (Mill. Bu.)	13,237	12,514	14,362	13,729	14,841	14,250	13,686
Estimated Corn Feed Use (Mill. Bu.)	6,155	5,598	5,938	5,300	5,125	5,000	4,750
Estimated Corn+DDGS Feed Use	6,612	6,195	6,735	6,212	6,238	6,178	5,942
Estimated Food/Seed/Ind. Use (Mill. Bu.)	2,981	3,488	4,363	4,840	5,961	6,107	6,205
Estimated Fuel Ethanol Use (Mill. Bu.)	1,603	2,117	3,026	3,524	4,591	4,700	4,800
Estimated DDGS Prod. (Mill. Bu. Equiv.)	508	670	958	1,116	1,454	1,488	1,520
DDGS Exports (Mill. Bu. Equiv.)	50	73	161	204	340	311	328
Estimated DDGS Feed Use (Mill. Bu. Equiv.)	457	597	797	912	1,113	1,178	1,192
Other Food/Seed/Ind. Use (Mill. Bu.)	1,378	1,371	1,337	1,316	1,370	1,407	1,405
Corn Exports (Mill. Bu.)	2,134	2,125	2,436	1,849	1,980	1,835	1,700
Estimated Total Corn Use (Mill. Bu.)	11,270	11,210	12,737	11,989	13,066	12,942	12,655
Estimated Ending Corn Stocks (Mill. Bu.)	1,967	1,304	1,624	1,740	1,775	1,308	1,031
Estimated U.S. Average Farm Price, Corn, $/Bu.	$2.00	$3.04	$4.20	$4.00	$3.55	$4.25	$5.25
Estimated % Corn Production Used for Fuel Ethanol	14%	20%	23%	29%	35%	38%	39%
Estimated Corn Ending Stocks to Total Use Ratio	17.5%	11.6%	12.8%	14.5%	13.6%	10.1%	8.1%
November WASDE Corn Ending Stocks to Total Use Ratio	21.4%	7.9%	15.1%	9.0%	12.5%	6.2%	6.7%
Required RFS Reduction (%)	0%	10%	0%	10%	0%	15%	15%
Actual Corn-Based Ethanol RFS, Following Year	4.0	4.7	9.0	10.5	12.0	12.6	13.2
Adjusted Corn-Based Ethanol RFS, Following Year	4.0	4.2	9.0	9.5	12.0	10.7	11.2

The RFS, Fuel and Food Prices, and the Need for Statutory Flexibility

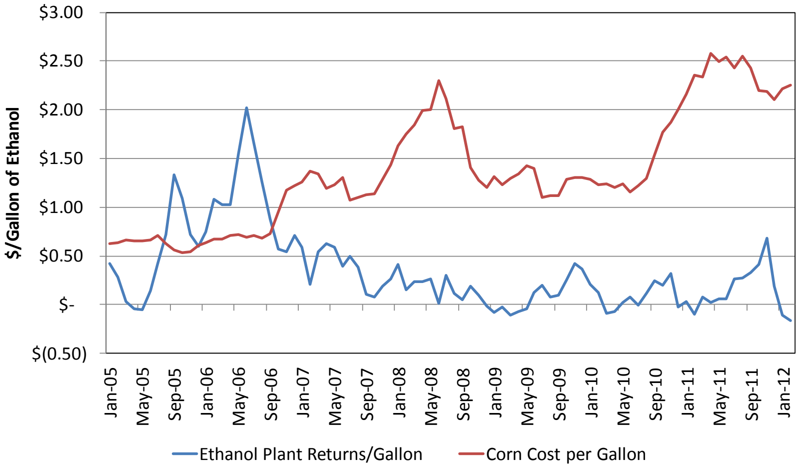
Summary: Even with a more flexible RFS, corn prices would have remained much higher than was the case in 2005/2006. Extremely small carryover stocks in 2010/2011 and 2011/2012 caused corn prices to increase to new record levels. Those higher prices severely rationed both feed use and exports, even with the more flexible RFS.

Higher corn prices also affected ethanol producer profit margins. If the demand guarantee of the RFS had been lower in the 2010/2011 and 2011/2012 corn marketing years, the incentives for ethanol production would also have been lower. With lower incentives and smaller margins, ethanol producers would have reduced production, easing the pressure on corn stocks and prices.

Iowa State Model Ethanol Plant Profit Margins and Corn Costs

Key Point:

Tighter corn stocks and higher corn prices since 2009 have reduced ethanol plant profitability. Lower margins have reduced the incentives to increase production. Had the RFS been adjusted in 2010 and 2011 ethanol production would have declined slightly due to a lower demand guarantee.

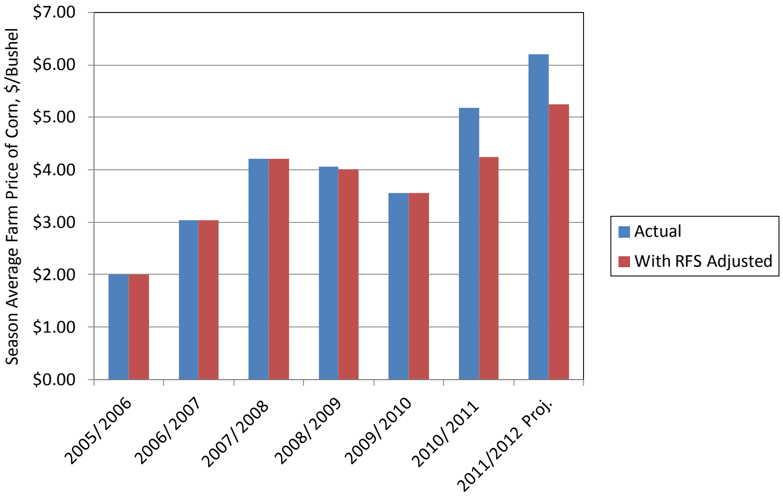


The next chart shows the estimated corn price effect with the RFS adjustment mechanism in effect.

Actual and Estimated Season Average Corn Prices with RFS Adjustment

Key Point:

Automatic RFS adjustments have little or no corn price effect until the extremely tight corn stocks of 2010/2011 and 2011/2012. In those two years the adjustment causes somewhat reduced ethanol production incentives which lead to higher corn stocks and lower corn prices. In both years corn prices are lowered by almost $1.00 per bushel.



Lower corn prices also allow more corn use for feed, and would have lowered food production cost/price pressures. Increased corn availability for livestock and poultry feeding would have enabled more domestic supply of meat and poultry, but consumption would still have fallen from 2007 to 2012.

Not only would corn prices have been lower in 2010/2011 and 2011/2012, price volatility would also have declined. The Babcock and McPhail article cited earlier concluded:

"We examine the marginal effect of ethanol policies such as the RFS mandates and the blending wall on price variability of corn and gasoline. Theoretical and empirical results both suggest that current ethanol policies decrease the price elasticity of demand for both commodities, and therefore increase price variability. An important implication has to do with the policy actions with respect to biofuels and particularly ethanol from corn. Policy actions that result in maintaining or changing the current mandates and/or the blend wall should account for their effect on the price elasticity of demand and price volatility for corn and gasoline markets."

Using a statistical model of gasoline and corn prices the authors ran scenarios with historically low and high crude oil prices, and elimination of the RFS. Corn and gasoline price volatility would be reduced more with low crude oil prices because the incentives to continue ethanol production would be lower in a low energy price environment.

The authors also included elimination of the 10 percent ethanol blend limit (BW, or blend wall, in the table below) in their analysis. That elimination also lowered price volatility, but not by as much as eliminating the RFS in the case of low crude oil prices. "Low" and "High" crude oil prices refer not to a specific price, but the lower and upper ends of the historical range. Gasoline price volatility is also decreased. The results presented in the table below are not surprising. Artificially created, inflexible, demand should increase price volatility.

Price Variability of Corn and Gasoline Under Different Crude Oil Price Scenarios

Scenario	Corn CV	Gasoline CV
High crude oil prices		
RFS, BW, and tax credits	0.2654	0.2365
Elimination of BW	0.2008	0.2180
Elimination of RFS	0.2441	0.2295
Low crude oil prices		
RFS, BW, and tax credits	0.3043	0.2703
Elimination of BW	0.2952	0.2661
Elimination of RFS	0.2497	0.2518

The "CV" is the coefficient of variation. It is the standard deviation of the corn or gasoline price divided by the average of the respective price. As such, it is a measure of the volatility of the prices relative to their averages.

The annual RFS adjustment mechanism contained in the Goodlatte bill would, in agreement with this model, also reduce the incentives to produce ethanol when corn prices are high due to corn production shortages. While corn prices would still increase with poor weather, corn price volatility would be lowered if the ethanol demand guarantee was lowered for a year. When crude oil prices are at the low end of their historic range the effect would be more than when they are at the high end.

In the current situation the 2012 corn crop under severe drought stress across much of the Corn Belt, and ending stocks are critically low. An RFS formula-based adjustment mechanism is more important now than ever.

Summary: RFS Flexibility Needed for Corn-Based Ethanol

The current, inflexible, corn-based ethanol RFS coupled with the inability of farmers to produce enough corn to satisfy all potential users has led to sharp increases in corn costs and price volatility for all users. The RFS should be reformed to allow for automatic adjustments to the RFS to reduce incentives for ethanol production in years when corn stocks are forecast to reach critically low levels.

Even with a lower and more flexible RFS, market conditions may justify no change, or higher, ethanol production. In this case a lower RFS would have little or no effect on ethanol producers or production. However, in the event of poor ethanol production margins, a lower RFS would be an added incentive for ethanol producers to reduce production, making more corn available for other users, and potentially higher stocks. Price and cost pressures would be lowered for all corn users, including ethanol producers.

An automatic adjustment to the corn-based ethanol RFS offers potential benefits for all corn users, with no significant downside for ethanol production or profitability. In fact, the long term viability of corn-based ethanol production would be improved by a more flexible RFS that encourages lower corn demand in years when corn crop shortfalls occur.

RFS Adjustments for Cellulosic Ethanol

An ambitious RFS schedule and generous tax credits for cellulosic ethanol have completely failed to produce any meaningful amount of fuel. The first commercial scale plant (Poet/DSM) is under construction, It is scheduled to come online in 2013. However, it will cost about $250 million to build, and have only 20 million gallons-per-year initial capacity, but only if it operates as designed.

The 2013 cellulosic ethanol RFS calls for 1.0 billion gallons of cellulosic ethanol. The 2013 cellulosic RFS, and all years beyond 2013, is grossly unrealistic.

The 2007 cellulosic RFS was recently examined in great detail by the National Research Council[16]. A broad-based, multi-disciplinary, group of experts concluded that meeting the current cellulosic RFS schedule is highly unlikely. Extraordinary technical barriers to successful commercialization of cellulosic ethanol were described in detail. In addition, the report found significant issues with increased greenhouse gas emission goals, cost-efficient feedstock production, increased competition for food crop land, increased federal subsidy costs, increased water use, and potential air quality degradation.

In light of these recent findings, the EPA should reexamine the 2007 RFS schedule for cellulosic ethanol. Any cellulosic ethanol RFS should reflect the realities of technical barriers, fuel costs, food production, and environmental impact.

In addition to the technical issues with increased cellulosic ethanol production, there is also a major price and competitiveness problem. Corn-based ethanol has already saturated the E10 market. Unless cellulosic ethanol is fully price competitive with gasoline, it will be very difficult to move beyond the current E10 volume ceiling. Simply put, while there is a blending mandate, motorists will not voluntarily buy higher blend levels unless the cost per mile is at least as good as E10. Mandating purchase of a product for which there is no purchase incentive will prove to be very difficult.

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[16] National Research Council. Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy. Washington DC. 2011.

Appendix: Gasoline Price Models

Model 1, Monthly Gasoline Prices, Crude Oil Prices, Ethanol Production and Other Related Factors:

January, 2000 to February, 2012 monthly average New York harbor conventional gasoline regular spot price FOB (Cents per Gallon) is a function of:

Explanatory Variable	Estimated Coefficient	T Statistic
Intercept	-60.273	-1.60
Crude oil composite acquisition cost by refiners ($/barrel)	2.582	46.03
Production of fuel ethanol (000 barrels)	0.000589	1.65
Percent utilization of refinery operable capacity	1.499	4.23
Month end crude oil stocks (excluding strategic petroleum reserve) (000 barrels)	0.0000818	3.25
Motor gasoline ending stocks (000 Barrels)	-0.000726	-4.96
Net gasoline exports (000 Barrels)	-0.000351	-1.53
Katrina effect, Sept-Oct 2005 = 1, otherwise 0	30.585	4.27
MTBE withdrawal effect, Apr-Aug 2006 = 1, otherwise 0	23.138	5.27
2007 refinery outages, Mar-Jul 2007 = 1, otherwise 0	26.967	6.05
If month is January = 1, otherwise 0	14.391	3.61
If month is February = 1, otherwise 0	16.699	4.08
If month is March = 1, otherwise 0	9.371	2.51
If month is April = 1, otherwise 0	4.886	1.31
If month is May = 1, otherwise 0	3.443	0.88
If month is June = 1, otherwise 0	-2.770	-0.69
If month is July = 1, otherwise 0	-7.739	-1.85
If month is August = 1, otherwise 0	-9.117	-1.97
If month is September = 1, otherwise 0	-1.928	-0.48
If month is October = 1, otherwise 0	-7.511	-1.81
If month is November = 1, otherwise 0	-5.835	-1.54
If month is December = 0 (base price for seasonal variation)	NA	NA

n = 146, Degrees of Freedom = 124, R^2 = 0.988

A “T Statistic” of ±1.98 is required to be statistically significant from zero at the 95 percent level.

Discussion: Except for ethanol production all of the variables are statistically significant and have the expected direction of influence. Ethanol production and net gasoline exports were not statistically significant.

Model 2, Monthly 3:2:1 Crack Spread, Crude Oil Prices, Ethanol Production and Other Related Factors:

January 2000 to February 2012 monthly average New York gasoline and heating oil prices and the crude oil composite acquisition cost by refiners were used to compute the 3:2:1 crack spread ($/barrel). The crack spread is modeled as a function of:

Explanatory Variable	**Estimated Coefficient**	**T Statistic**
Intercept	-20.246	-1.633
Crude oil composite acquisition cost by refiners ($/barrel)	0.152	8.237
Production of fuel ethanol (000 barrels)	0.000156	1.328
Percent utilization of refinery operable capacity	0.540	4.625
Month end crude oil stocks (excluding strategic petroleum reserve) (000 barrels)	0.0000249	3.011
Motor gasoline ending stocks (000 Barrels)	-0.000249	-5.164
Net gasoline exports (000 Barrels)	-0.000170	-2.248
Katrina effect, Sept-Oct 2005 = 1, otherwise 0	10.808	4.581
MTBE withdrawal effect, Apr-Aug 2006 = 1, otherwise 0	6.764	4.685
2007 refinery outages, Mar-Jul 2007 = 1, otherwise 0	7.997	5.451
If month is January = 1, otherwise 0	4.774	3.638
If month is February = 1, otherwise 0	5.246	3.896
If month is March = 1, otherwise 0	2.169	1.762
If month is April = 1, otherwise 0	0.098	0.080
If month is May = 1, otherwise 0	-0.863	-0.674
If month is June = 1, otherwise 0	-2.774	-2.098
If month is July = 1, otherwise 0	-4.713	-3.432
If month is August = 1, otherwise 0	-5.093	-3.343
If month is September = 1, otherwise 0	-2.199	-1.647
If month is October = 1, otherwise 0	-3.266	-2.395
If month is November = 1, otherwise 0	-2.172	-1.742
If month is December = 0 (base price for seasonal variation)	NA	NA

n = 146, Degrees of Freedom = 124, R^2 = 0.740

A “T Statistic” of ±1.98 is required to be statistically significant from zero at the 95 percent level.

Discussion: Except for ethanol production all of the variables have the expected direction of influence. Ethanol production was not statistically significant. Net gasoline exports had a negative, and weakly significant, effect on the 3:2:1 crack spread.

The magnitude of the ethanol production and net gasoline export effects are is almost the same, but with opposite sign. As was shown earlier, since 2007 increased ethanol production (gasoline energy equivalent) has been very near to the increase in gasoline net exports. To any extent that these two effects are real, they tend to cancel each other out during that period of time.

Model 3, Monthly Gasoline Crude Oil Price Ratio, Ethanol Production and Other Related Factors:

January 2000 to February 2012 monthly average New York gasoline price and the crude oil composite acquisition cost by refiners ratio were used to compute a price ratio of gasoline to crude oil. That ratio is modeled as a function of:

Explanatory Variable	**Estimated Coefficient**	**T Statistic**
Intercept	0.803	2.676
Crude oil composite acquisition cost by refiners ($/barrel)	-0.00142	-3.177
Production of fuel ethanol (000 barrels)	0.00000201	0.706
Percent utilization of refinery operable capacity	0.0133	4.723
Month end crude oil stocks (excluding strategic petroleum reserve) (000 barrels)	0.000000428	2.134
Motor gasoline ending stocks (000 Barrels)	-0.00000556	-4.775
Net gasoline exports (000 Barrels)	-0.000000627	-0.342
Katrina effect, Sept-Oct 2005 = 1, otherwise 0	0.214	3.751
MTBE withdrawal effect, Apr-Aug 2006 = 1, otherwise 0	0.100	2.866
2007 refinery outages, Mar-Jul 2007 = 1, otherwise 0	0.138	3.886
If month is January = 1, otherwise 0	0.1262	3.971
If month is February = 1, otherwise 0	0.1347	4.131
If month is March = 1, otherwise 0	0.0970	3.254
If month is April = 1, otherwise 0	0.0711	2.391
If month is May = 1, otherwise 0	0.0591	1.905
If month is June = 1, otherwise 0	-0.0049	-0.152
If month is July = 1, otherwise 0	-0.0395	-1.187
If month is August = 1, otherwise 0	-0.0544	-1.474
If month is September = 1, otherwise 0	-0.0034	-0.106
If month is October = 1, otherwise 0	-0.0432	-1.309
If month is November = 1, otherwise 0	-0.0296	-0.980
If month is December = 0 (base price for seasonal variation)	NA	NA

n = 146, Degrees of Freedom = 124, R^2 = 0.675

A “T Statistic” of ±1.98 is required to be statistically significant from zero at the 95 percent level.

Discussion: Except for ethanol production all of the variables have the expected direction of influence. Ethanol production was not statistically significant. Net gasoline exports had a negative, but statistically insignificant, effect on the price ratio.

Interestingly, as crude oil prices increase, the ratio of gasoline to crude oil price declines. This is likely due to the dilution of fixed refining costs as crude oil prices rise.

Model 4, Monthly Gasoline Crude Oil Price Spread versus Crude Oil, Ethanol Production and Other Related Factors:

January 2000 to February 2012 monthly average New York gasoline price and the crude oil composite acquisition cost by refiners were used to compute a cents per gallon price spread of gasoline to crude oil. That spread is modeled as a function of:

Explanatory Variable	**Estimated Coefficient**	**T Statistic**
Intercept	-60.273	-1.599
Crude oil composite acquisition cost by refiners ($/barrel)	0.201	3.576
Production of fuel ethanol (000 barrels)	0.000589	1.647
Percent utilization of refinery operable capacity	1.499	4.228
Month end crude oil stocks (excluding strategic petroleum reserve) (000 barrels)	0.0000818	3.252
Motor gasoline ending stocks (000 Barrels)	-0.000726	-4.960
Net gasoline exports (000 Barrels)	-0.000351	-1.525
Katrina effect, Sept-Oct 2005 = 1, otherwise 0	30.585	4.265
MTBE withdrawal effect, Apr-Aug 2006 = 1, otherwise 0	23.138	5.274
2007 refinery outages, Mar-Jul 2007 = 1, otherwise 0	26.967	6.048
If month is January = 1, otherwise 0	14.391	3.608
If month is February = 1, otherwise 0	16.699	4.080
If month is March = 1, otherwise 0	9.371	2.505
If month is April = 1, otherwise 0	4.886	1.310
If month is May = 1, otherwise 0	3.443	0.884
If month is June = 1, otherwise 0	-2.770	-0.689
If month is July = 1, otherwise 0	-7.739	-1.855
If month is August = 1, otherwise 0	-9.117	-1.969
If month is September = 1, otherwise 0	-1.928	-0.475
If month is October = 1, otherwise 0	-7.511	-1.813
If month is November = 1, otherwise 0	-5.835	-1.540
If month is December = 0 (base price for seasonal variation)	NA	NA

n = 146, Degrees of Freedom = 124, R^2 = 0.675

A “T Statistic” of ±1.98 is required to be statistically significant from zero at the 95 percent level.

Discussion: Except for ethanol production all of the variables have the expected direction of influence. Ethanol production was not statistically significant. Net gasoline exports had a negative, but statistically insignificant, effect on the margin.

Interestingly, as crude oil prices increase, the gross margin between the gasoline and crude oil prices increases. This is likely due to increasing refining costs as crude oil prices rise.

Potential Impacts of a Partial Waiver of the Ethanol Blending Rules

Preface

Four years ago, as the temperature of rhetoric in the food-versus-fuel debate rose with the prices of corn and oil, Farm Foundation asked three economists from Purdue University to take an objective look at the complex forces that were driving food prices. While oil prices are not at 2008 levels this summer, drought and high temperatures are pushing corn and soybean prices to record levels, and the food vs. fuel debate is once again heated.

Now as then Farm Foundation and Purdue University are not about fueling these fires. Our shared mission is to be a catalyst for sound public policy by providing objective information to foster deeper understanding of the complex issues before our food and agriculture system today. As a result of this shared commitment, Purdue University economists Wallace Tyner, Farzad Taheripour and Chris Hurt have written this paper to examine the effects of what is perhaps the most commonly discussed policy response to this summer's drought—a waiver of the ethanol blending rules mandated in the Energy Independence and Security Act of 2007.

Building on years of work, including a series of three Farm Foundation publications "What's Driving Food Prices", the authors provide a clear description of the complex economics of corn and ethanol markets and a rigorous assessment of the implications and, just as importantly, the uncertainties of changes in U.S. renewable fuels policy.

Perhaps the key to understanding the policy choices facing us is to recognize, as the authors so aptly point out, that at this point the economic damage of this year's drought has been done and policy decisions are now about how the cost will be shared among corn farmers, livestock farmers, taxpayers and consumers, both at home and around the world. The policy choices in front of us are not pleasant or easy. Our hope is that this paper can help provide policy makers and all of the stakeholders in our food and agricultural system with the knowledge to make the choices informed ones.

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August 16, 2012

Potential Impacts of a Partial Waiver of the Ethanol Blending Rules

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The drought has raised concerns about available corn supplies, corn prices and the consequences to end users. As indicated in previous work [1], the United States entered this season with low stocks, and the drought will drop those stocks further. Corn price has gone up about 60% since June 15, and the near futures price is currently about \$8/bushel (bu.). The price of corn affects many items consumers purchase:

- Livestock products such as meat, dairy, and eggs;
- Soft drinks and food products containing corn sweeteners;
- Gasoline containing 10% or more ethanol made from corn;
- Other food items that contain corn starch, corn flour, or corn directly.

The lack of corn availability is a critical concern to all end users, including livestock feeders, export customers, the ethanol industry, and ultimately domestic and foreign consumers. There will not be enough corn for everyone to continue consuming at historic rates. Some end users will have to cut back—perhaps sharply. Who will that be?

The Renewable Fuel Standard (RFS) mandates the use of renewable fuel, which translates mainly to ethanol made from corn. However, livestock producers have requested a partial waiver of that mandate reasoning that if less corn moves to ethanol, there may be more, at lower prices, for their industry. Also, Arkansas Gov. Mike Beebe has petitioned for a waiver, and EPA is required to respond to that request.

The focus of this paper is how the drought may impact the corn and ethanol markets, and how an EPA ethanol waiver might affect those markets. The paper describes how the outcomes will depend on a host of factors such as oil prices, corn prices, final corn production, the flexibility of oil refiners and blenders, and the potential use of Renewable Fuel Identification Numbers (RINs).

The drought also will affect the soybean crop and reduce the availability of high protein feed products, but that dimension or biodiesel will not be addressed in this paper. This paper also will not address whether or not there should be a Renewable Fuel Standard, nor will it cover impacts of other policy options beyond a waiver. There are many policy possibilities, which may be explored in future work. This paper is limited to the question of impacts of a possible waiver.

Since mid-June, the price of corn ethanol has increased about 60¢ per gallon (27%), and it may continue to increase. Since gasoline is 10% ethanol, that implies a 6¢/gallon increase in the gasoline pump price due to the drought if all that price increase were passed through to the retail level. However, corn ethanol is still less expensive than gasoline on a volume (per gallon) basis. Ethanol also is exported, but it is not clear what impact the higher ethanol price will have on ethanol exports. To the extent exports are reduced, that would reduce demand for corn for ethanol and lead to some reduction in the corn price.

This paper describes a) how the RFS works; b) provides a qualitative assessment of some of the drivers that ultimately will determine the impacts of a partial waiver of the RFS for 2013; and c) provides some quantitative estimates of possible waiver impacts over a range of different assumptions.

The drought is the reason for the economic losses, but the EPA and other policy decisions could affect, to some extent, who bears the costs of the drought.

Qualitative assessment

How high corn price affects the ethanol market down the road depends on several factors. Today, ethanol is priced below the benchmark gasoline product, Reformulated Gasoline Blendstock for Oxygenate Blending (RBOB). Generally, when ethanol is cheaper than RBOB, blenders still have an incentive to blend 10% ethanol with gasoline. However, there are many different specifications of gasoline blended with ethanol. Conventional Gasoline Blendstock for Oxygenate Blending (CBOB) is used in every state and generally is less expensive than RBOB. California has its own gasoline specifications. There are many regional markets with different vapor pressure and other specifications. However, in any situation, ethanol has value as an oxygenate and octane enhancer.

If the corn price continues to increase, and ethanol price moving with it surpasses gasoline by a significant margin, blenders may not have an economic incentive to blend ethanol. In fact, there has been an 8% fall in ethanol production over the past seven weeks as the higher corn price puts pressure on ethanol margins. This shows that markets can and do adjust, with less corn being used for ethanol. Adjustment might have been greater in the absence of the mandate.

The United States' statutory RFS requires blenders to use 13.2 billion gallons (BG) of ethanol in 2012 and 13.8 BG in 2013.[1] With about four months left, the remaining 2012 obligation is about 5.6 BG. Blenders receive a credit, called a RIN, for each gallon of renewable fuel blended. It is via RINs that EPA keeps track of compliance with the RFS. If more gallons than required by the RFS are blended in any given year, blenders are allowed to carry-forward unused RINs for possible use in the next year. In fact, by using prior year RINs each year, blenders can roll forward RINs indefinitely. Paulson and Meyer [2] have estimated the stock of RINs currently available to be 2.6 BG. That means, if they chose, blenders could use as little as 3 BG of ethanol for the remainder of 2012 to meet their obligation. To the extent that carry-forward blending credits were used in 2012, more ethanol plant closings and less ethanol production could be seen.

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[1] Actually there is no requirement for corn ethanol, just renewable fuel. However, in practice, the conventional biofuel part of the RFS consists today of ethanol from corn or sorghum, mainly corn.

Some technical constraints in ethanol blending could keep ethanol demand from falling quickly. If ethanol demand falls, it would be a slow reduction rather than an abrupt change. Some of the carry-forward RINs might be used in 2012 with the remainder rolled forward to 2013. However, for a number of reasons, most blenders will probably continue blending ethanol at the same 10% rate in 2012 unless the ethanol price surpasses gasoline by a big margin, which seems unlikely in 2012.

In addition, there currently are no financial incentives for blenders to use RINs to meet RFS obligations if the ethanol price is below RBOB. In recent weeks, ethanol prices have been 25¢ to 40¢ below RBOB, but not necessarily below blending products like CBOB. For ethanol to reach RBOB, a) the corn price has to rise significantly, forcing up the ethanol price; b) the gasoline price must fall significantly; or c) some combination of the two. RINs will not be used until the refiners have the economic incentive to do so.

The real question is what happens in 2013, when the ethanol blending obligation increases to 13.8 BG. That increased ethanol demand clearly puts pressure on corn usage and prices, with limited supply due to drought. EPA received a request from several livestock sector groups to initiate a review to reduce the corn ethanol mandate for 2012 and 2013. Normally, EPA issues its decisions on the level of the RFS in November of the year before the RFS is applied. If EPA were to maintain that calendar, the agency would have until October to gather information on the extent of "economic harm" done by the originally stipulated RFS level and to decide whether to issue a partial waiver to reduce the 2013 mandate. We do not think EPA will issue a waiver for 2012.

The impact of a partial waiver for 2013 would depend on: 1) the price of crude oil and thus gasoline; 2) the magnitude of the drought induced corn production loss and the resulting corn price; 3) the extent to which blenders have an economic incentive to reduce ethanol blending; and 4) some technical issues, discussed below, related to conversion from 10% or more ethanol to lower ethanol blends.

Technical and oil market issues

It is useful to understand some of the technical and market constraints related to ethanol blending.

- Much of the regular gasoline that is produced today is 84 octane, and must be brought up to 87 octane for retail sale. It is brought up to 87 octane by blending 10% ethanol, which has 115 octane [3]. According to refinery and industry sources, it may take three to six months for refineries to adjust to producing 87 octane instead of 84 octane. This time lag would only begin once it is economically attractive to make the change. Whether it was economically attractive to continue using ethanol would depend to a significant degree on how the price of ethanol compared with the price of other octane and oxygen sources. Even if technically and economically feasible to make the change, it is not clear if refineries would make the change if they perceived the waiver to be a one-time event only for 2013.

- Another issue is the vapor pressure of the fuel. Gasoline blends must meet EPA upper limits on vapor pressure to reduce evaporative emissions. The limits are higher (less constraining) in winter months than in summer months. Ethanol, with a vapor pressure of 18 psi, increases the vapor pressure of the blended fuel. But 10% ethanol blends have a higher (1 pound psi) summer threshold, which might make ethanol blending more attractive. High-octane light hydrocarbons might be available to replace ethanol in winter months for a relatively short period. However, the prices of these ethanol alternatives have increased over the past month. The prices, availability and environmental impacts of these products relative to ethanol will be an important determinant in their use to replace ethanol.

- The actions and reactions of refiners and blenders may vary widely. The decision of a company that owns both refineries and ethanol plants could be quite different from a company that has no stake in the ethanol business.

- Existence of take-or-pay contracts also could limit reduction in ethanol demand. A take-or-pay contract requires the buyer to either take the physical product or pay a pre-determined penalty. These contracts would encourage ethanol plants and blenders to continue to produce and consume ethanol. While these contracts are used in the industry, the extent of their use is unknown.

- The following quote from Oil Price Information Service [4] perhaps summarizes the current situation:

  > *"For most of 2012, and indeed much longer than that, creating finished gasoline by blending in ethanol up to 10% of the final product saved suppliers as much as 5-15 cents/gal. Now many markets have price structures such that blenders are losing money when mixing in ethanol."*

  This same article mentions that the prices of alternative octane enhancers also shot up in July.

Possible combinations that could play out in 2013

- If the season average corn price is around $8 or higher, which seems likely, and crude oil remains at $100 or lower, then reducing the RFS could reduce the demand for ethanol--and consequently the demand for corn--if it is economically feasible for refiners and blenders. However, the market response to a waiver is very hard to predict. If the waiver resulted in less demand for ethanol, that would, in turn, lead to less demand for corn and a lower corn price. More ethanol plants may close or operate at less than full capacity, at least temporarily. However, it is not clear how quickly the fuel industry could adjust to not using ethanol or if it would be economically feasible. In other words, for technical and economic reasons, the waiver could have little or no near-term impact, but it is hard to predict how refineries and blenders would respond.

- If corn price remains around $8, crude oil is less than $100 and blenders did not use their RINs in 2012, they could use them in 2013 if economically warranted. That would effectively waive part of the RFS for 2013. Also, blenders could opt to borrow some 2014 credits to meet 2013 obligations. At this point, that option seems unlikely, as it would lead to very high obligations in 2014. Any waiver from EPA would be in addition to the blending flexibility created by the surplus RINs. The effective blending mandate under this condition would be much lower and could result in lower ethanol demand, lower corn use, lower corn price, and more ethanol plant closings or operating at less than capacity. Again, this might not happen for economic and technical reasons.
- If corn price remains in the $8 range and the price of crude oil increases to the area of $120, waiving part of the RFS would have little impact because ethanol likely would be demanded by the market regardless of the level of the RFS. In addition, with a higher crude price, refiners would have less incentive to convert operations to a lower ethanol blend.

These different possibilities are summarized in Table 1.

Table 1. Possible Waiver Impacts Under Different Technical and Market Assumptions

Market and Technical Conditions	**Likely Waiver Impact on Ethanol Demand**
High corn price Moderate crude oil (<$100) Limited refining and blending flexibility	Little impact of a waiver
High corn price Moderate crude oil (<$100) Refining and blending flexibility	Possible waiver impact
High corn price Moderate crude oil (<$100) Refining and blending flexibility RIN credits available for use in 2013	Possible significant waiver impact
High corn price High crude oil price (>$120) Limited refining and blending flexibility	Little impact of waiver
High corn price High crude oil price (>$120) Refining and blending flexibility	Likely small impact of waiver, but possibility of larger impact

Another possibility would be for EPA to totally waive the “other advanced” mandate, which is 0.75 BG for 2013. Sugarcane ethanol is included in that category. If that mandate were waived, all the sugarcane-based ethanol would move into the conventional category with lower RIN prices. It would then be counted toward meeting the implied mandate, which could reduce corn ethanol production. This would only represent about 275 million bushels of corn. But the sum of the other advanced mandate plus carry-forward RINs could potentially be about 1.2 billion bushels of corn. That represents about 24% of the effective corn mandate, which is roughly the size of the projected corn crop shortfall. With the higher corn ethanol price, more sugarcane ethanol would be imported, which also effectively lowers the demand for corn ethanol.

Quantitative assessment

A range of possible impacts depends on the price of oil, the price of corn, the magnitude of the drought, the economics of switching away from ethanol, and technical flexibility of refiners and blenders. First, assuming limited flexibility on the part of refiners and blenders in the near term, the impact of a waiver would be very small or nil. If refiners and blenders cannot or choose not to change their current practice of using 10% ethanol blends, then a waiver does not matter. Technical and market constraints would override the waiver.

However, refiners and blenders may have some degree of flexibility in production. This is certainly true the longer the time horizon, so the question is to what extent it is true in the confines of one year. There is not a complete answer to that question, but many of the factors that will determine it are described above.

The next question: What would be the impact of a partial waiver under the assumption that refiners and blenders do have some flexibility in reducing ethanol use and substituting other octane and oxygen additives for ethanol to meet final product specifications? For this paper, estimates were done using a partial equilibrium model developed and used for previous ethanol policy work [5-9]. The model was updated, tuned according to recent observations, and modified for this work on drought impacts. The analysis was done for several levels of partial waiver or use of available RINs in 2013. As indicated above, it is unlikely any waiver will be issued for 2012.

The model for this analysis includes expectations before the drought with a full 13.8 BG RFS for 2013. Then it assumes the drought with three alternative ethanol blending levels: 11.8 BG, 10.4 BG, and 7.75 BG. For this analysis, it does not matter whether the reduced blending levels result because of the use of RINs or a partial waiver. However, the 11.8 BG level could be seen as no waiver and the use of 2 BG of RINs. (Use of some RINs in 2012 and surplus 2013 RINs carried forward to 2014 could limit the 2013 usage to around 2 BG.) The case of 10.4 BG represents 75% of the 13.8 BG RFS and could result through any combination of waiver, use of prior RINs, or use of sugarcane ethanol. The drought may reduce corn production 25% from pre-drought expectations, so EPA might consider a case that could reduce corn ethanol use through some combination of RINs and waiver by that same fraction. Finally, the case of 7.75 BG represents a waiver of 3.45 BG (25% of RFS) plus use of all the estimated available 2.6 BG of RINs, estimated to be the maximum possible ethanol reduction level if economic and technical hurdles could be overcome.

These simulations were run for three possible degrees of drought severity: stronger, median, and weaker. The target corn production levels for these three cases are 10.5, 11.0, and 11.5 billion bushels. Corn production varies a little bit among the ethanol demand cases, as more corn is harvested with the higher corn price than with lower corn price. In other words, there is some very limited supply response even after the drop is in the ground as farmers make harvest and use decisions. The 11 billion bushel case was the median from a recent Reuters survey of analysts [10]. It is also the level in a recent F.C. Stone report [11].

USDA's August 10, 2012, WASDE projection [12] is 10.8 billion bushels, with a yield of 123.4 bushels/acre, which is between the stronger and median drought cases. The results for all three cases are summarized in Table 2.

Table 2. Waiver Impact Simulation Results under Varying Blending Levels and Degrees of Drought Severity

Description	**Expectation Before Drought**	**Drought with 13.8 BG Ethanol**	**Drought with 11.8 BG Ethanol**	**Drought with 10.4 BG Ethanol**	**Drought with 7.75 BG Ethanol**
Stronger Drought:					
Corn production (Bil. bu.)	14.65	10.50	10.45	10.42	10.35
Corn used for ethanol	5.11	5.11	4.37	3.85	2.87
Domestic food and feed use	6.72	3.96	4.59	5.03	5.58
Exports	1.82	1.43	1.49	1.53	1.63
Corn price ($/bu.)	5.26	8.57	7.89	7.45	6.58
Median Drought:					
Corn production (Bil. bu.)	14.65	11.00	10.95	10.92	10.85
Corn used for ethanol	5.11	5.11	5.11	3.85	2.87
Domestic food and feed use	6.72	4.39	5.02	5.45	6.25
Exports	1.82	1.49	1.56	1.62	1.73
Corn price ($/bu.)	5.26	7.81	7.14	6.67	5.80
Weaker Drought:					
Corn production (Bil. bu.)	14.65	11.50	11.45	11.42	11.35
Corn used for ethanol	5.11	5.11	5.11	3.85	2.87
Domestic food and feed use	6.72	4.81	5.42	5.84	6.62
Exports	1.82	1.58	1.66	1.72	1.86
Corn price ($/bu.)	5.26	7.02	6.36	5.89	5.02

Note: The corn yields for these three cases are 120, 126, and 132 bu/ac.

Domestic corn use for feed and food varies with the level of ethanol production and drought severity. For example, in the median case, corn used for food and feed would be about 4.4 billion bushels with a full RFS. If ethanol production drops to 10.4 BG, corn use for food and feed would be about 5.5 billion bushels. Corn exports for the case of median drought are about 1.5 billion bushels with a full RFS and around 1.6

billion bushels with 10.4 BG of ethanol. These results are not directly comparable with August 2012 WASDE values because of differences in assumptions on ethanol, feed, export uses and stock changes.

With the full RFS and no prior year RINs credits, the corn price ranges between $7.02 and $8.57 depending on the severity of the drought. It is not clear to what extent the corn market has already priced in not only the median level of drought, but also some use of carry-forward RINs.

Reducing blending to 11.8 BG reduces corn price between $0.66 and $0.68 per bushel depending on the severity of the drought. In other words, with no EPA action, the carry-forward RINs could result in the corn price falling about $0.67/bu. At least part of that decline may already be priced in to the corn market. Assuming the 11.8 BG level is the realistic base for considering waiver impacts, given that the prior blending credits can be used, the movement to 10.4 BG reduces corn price an additional $0.44 to $0.47 per bushel. Going to 7.75 BG from 11.8 BG reduces price by $1.31 to $1.34 per bushel in total.

The bottom line: if refineries and blenders have flexibility to reduce ethanol usage in the short term, use of prior blending RINs credits and/or a waiver could reduce corn price around $1.30/bu for a large waiver or $0.47/bu for a modest waiver. This analysis does not do a full evaluation of feed costs for the livestock industry; such an analysis would also need to evaluate the impacts of lowering the mandate on other feed ingredients, such as distillers grains, soybean meal, forages and other grains or feedstuffs that may be used in rations.

Comparison with other reports

To date, two other studies have been released related to this topic. Bruce Babcock [13] used a model developed at Iowa State University to estimate the impact of carry-forward RINs plus an additional waiver. He assumed an average yield of 138 bu/ac. Our paper assumes yields 18, 12 and 6 bu/ac lower for the three cases. Babcock's numerical results appear to be driven largely by the yield assumption and the assumption of the nature of ethanol demand. His ethanol demand structure has flexibility for the first level of ethanol reduction, due to either carry-forward RINs or waiver, but little or no flexibility beyond that. He simulates three cases: 1) a full RFS mandate assumed to be 13.6 BG; 2) use of 2.4 BG of RINs (flexible mandate); and 3) a full waiver. His analysis gets a difference in corn price between the full mandate and the flexible mandate cases of $0.91/bu. for the 2.4 BG use of RINs—similar to this paper's analysis of $0.67/bu for a 2 BG RIN usage.

Going from the flexible mandate case to no mandate yields another $0.28/bu. price reduction in Babcock's analyses. This result is driven by the assumed shape of the demand curve for ethanol.

Starting from the full mandate case, what this paper calls refining and blending flexibility is assumed, but after dropping to about 10 BG there is no further flexibility. Thus, for the first reduction in ethanol demand from use of carry-forward RINs, refining and blending flexibility are assumed. The first part of the waiver case from 11.2 to about 10 BG has a little flexibility, but after that, it is equivalent to this paper's no flexibility case, which means no ethanol use response. In fact, based on the demand curve that is presented in the Babcock paper, there would be no difference between a 2 BG waiver and a full waiver. After about 10 BG, there is no response of ethanol demand to the price ratio of ethanol and gasoline. Babcock recognizes this is a critical assumption and states, "If this demand curve overstates the value of ethanol to blenders, then the effects of removing the mandate would be larger." There are many other results reported in the Babcock paper, but these are the key values to compare with the results of this paper.

The results from use of carry-forward RINs are comparable in the two papers, but waiver impacts are different. Babcock essentially assumes a no flexibility case and gets little impact from a waiver, as does this paper. This paper's empirical results assume there is some degree of refining and blending flexibility over a fairly large range, so a larger corn price response results. However, it is important to repeat that in this paper, the range of corn price impacts from a partial waiver is zero to $1.30/bu. Babcock's value of $0.28/bu. falls within that range.

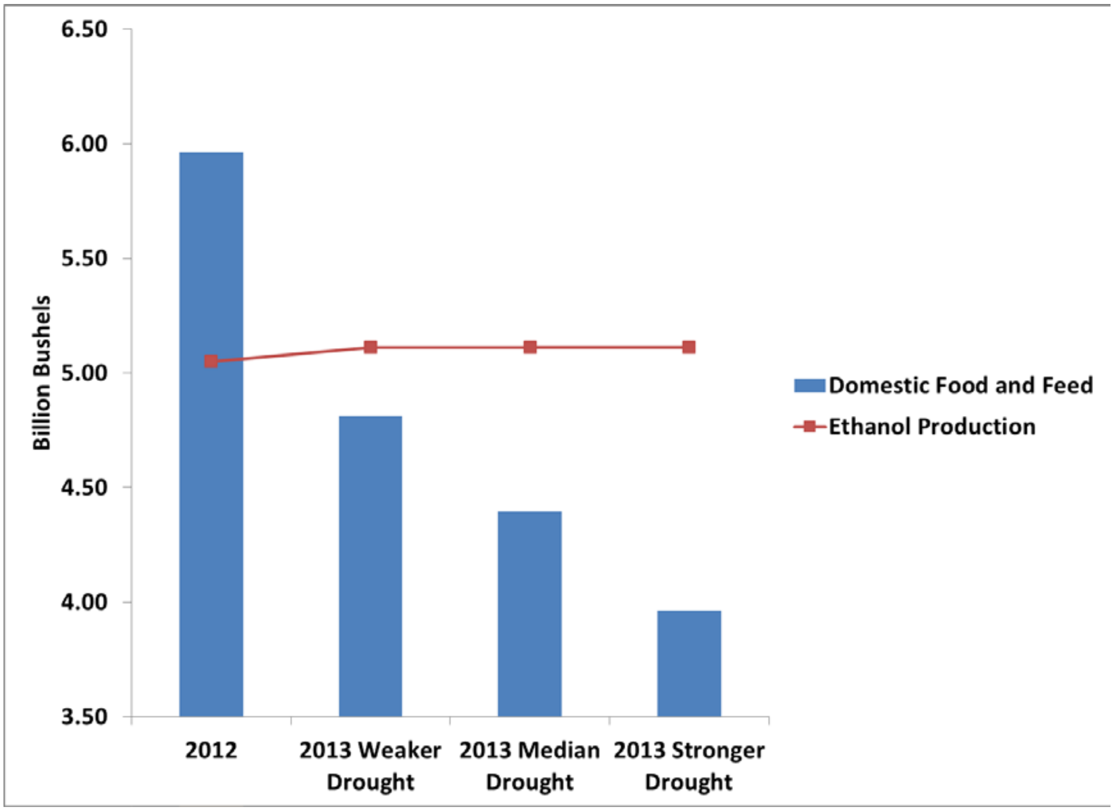
The second paper was done by Scott Irwin and Darrell Good from the University of Illinois [14]. They have a demand for ethanol assumption similar to Babcock. They do not do empirical estimates. They simply argue that the use of carry-forward RINs would be enough to reach the perfectly elastic portion of the demand curve, so a waiver would have no impact on corn price. Their assumption is equivalent to that of this paper's no flexibility case, which projects zero impact. However, the degree of refiner and blender flexibility if a waiver were issued is unknown. Unlike the Irwin/Good paper, this paper argues there is limited flexibility to adjust to lower corn use for ethanol in the short-run, i.e. 2012, but there could be some reduction in corn use below the blend wall over the entire September 2012 through August 2013 marketing year.

Summary

In making its waiver decision, EPA will have to weigh the economic harm of higher corn prices to livestock producers and to food and fuel consumers, against the interests of crop producers and ethanol producers. Livestock producers face substantially higher feed costs, much of which they cannot pass on to consumers in the short run. If there is limited flexibility to reduce corn use for ethanol, livestock producers must do more of the adjustment, i.e. reduce herd size or find other feed options, as illustrated in Figure 1. The line depicts the steady ethanol use of corn under different drought assumptions, and the bars show domestic food and feed use assuming the mandated amounts of corn ethanol are produced.

However, there likely would be some adjustment, such as the drop in ethanol production that is already occurring. The August 10, 2012 WASDE report indicates a 500 million bushel drop in corn use in ethanol, compared with USDA's pre-drought forecast. That amounts to 1.38 BG of ethanol. So clearly Figure 1 represents an extreme case with absolutely no adjustment in ethanol demand for corn in the base. In addition, some downward adjustments in corn use can come from foreign buyers, and there may be some opportunity to draw down stocks somewhat.

Figure 1. Illustration of Domestic Food and Feed Use in 2013 with No Flexibility in Ethanol Corn Demand



Ultimately, consumers will face higher prices for all livestock products and food items that use corn and higher fuel costs. Many ethanol producers entered the business because of the government guarantee of a market. A waiver might reduce that market and thus harm those producers. Ethanol producers already face tighter margins with the higher corn prices.

Corn producers who have a corn crop would be harmed by any action that lowers corn prices. However, federally-subsidized crop insurance will provide a substantial cushion for the sector if the individual producers have adequate coverage.

EPA will have to determine what impact a waiver actually would have given the way the market functions. The most likely technical outcome is that refiners and blenders could and probably would reduce ethanol use to some extent, but how much is uncertain for 2013. If conditions are such that issuing a waiver would have little impact, the decision becomes more symbolic than one with real impact.

If refiners and blenders do not have or choose not to use short-term blending flexibility, a partial waiver would not reduce the amount of corn used for ethanol. To the extent they do have flexibility, a small waiver could reduce corn price around $0.47/bu, and a large waiver could reduce it as much as $1.30/bu over the case of RINs alone being used. The carry-forward RINs alone provide about $0.67 corn price reduction, so the range of impact of a RFS waiver on corn price is zero to $1.30/bu given the assumptions used for this analysis.

In summary, the drought will ultimately impact consumers of food and fuel and the businesses that produce that food and fuel. The magnitude and direction of the impacts depend to some extent on the decision by the EPA to reduce the RFS depending on conditions highlighted in this paper. USDA is estimating that 2013 food prices will rise 3% to 4% [15]. Prices of some food items will be affected for subsequent years as well. For fuel, the short-term impact of the drought could be limited to some increase in pump prices due to higher ethanol prices caused by higher corn prices. If EPA issued a large partial waiver, and if the refining and blending sectors had flexibility, ethanol use could fall, and gasoline prices might fall a bit, as well. But estimating that change is beyond the scope of this paper. Longer term impacts depend on what happens not only to corn price, but to crude oil price and government policy.

It is important to understand that economic harm in the tens of billions of dollars has already been done by the drought. The corn price is substantially higher than would have transpired in a normal year. In considering a waiver, EPA cannot change the loss, but can only redistribute it among the affected parties—ethanol producers, livestock producers, corn growers, and ultimately domestic and foreign consumers. To the extent that the refining and blending industry has flexibility, issuing a waiver helps livestock producers and livestock product consumers, and it hurts ethanol producers and crop growers. To the extent that little short-run flexibility exists among refiners and blenders, the waiver does little to change the status quo. It is therefore critical that EPA does a thorough assessment of the extent of flexibility in refining and blending operations before reaching a waiver decision.

What should be clear is that high uncertainty remains on the possible impact of an EPA partial waiver of the RFS. A partial waiver certainly is not a “stroke of the pen” solution as implied by a recent *New York Times* editorial [16]. This paper has described what will ultimately be the major determinants of the impacts. The longer term implications of a waiver go beyond the scope of this paper.

Acknowledgements

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References

1. Abbott, P., C. Hurt, and W.E. Tyner, *What's Driving Food Prices in 2011?*, in *Issue Report* 2011, Farm Foundation.
2. Paulson, N. and S. Meyer, *An Update on RIN Stocks and Implications for Meeting the RFS2 Mandates with Corn Ethanol*, in *FarmDocDaily* August 1, 2012, University of Illinois.
3. Platts, *Methodology and Specifications Guide - Petroleum Products & Gas Liquids: US, Caribbean and Latin America,* June 2012.
4. Oil Price Information Service, *July Brings Blenders to Knees.* Independent Refined Products Prices and Comprehensive Analysis for All US Markets, July 23, 2012. **33**(30).
5. Tyner, W.E. and F. Taheripour, *Renewable Energy Policy Alternatives for the Future.* American Journal of Agricultural Economics, 2007. **89** (5): p. 1303-1310.
6. Tyner, W.E. and F. Taheripour, *Policy Options for Integrated Energy and Agricultural Markets.* Review of Agricultural Economics, 2008. **30** (3): p. 387-396.
7. Tyner, W.E., F. Taheripour, and D. Perkis, *Comparison of Fixed Versus Variable Biofuels Incentives.* Energy Policy, 2010. **38**: p. 5530-5540.
8. Tyner, W.E., *The Integration of Energy and Agricultural Markets.* Agricultural Economics, 2010. **41**(6).
9. Tyner, W.E., *Policy Alternatives for the Future Biofuels Industry.* Journal of Agricultural and Food Industrial Organization,, 2007. **5** (2): p. article 2.
10. Nelson, S. *POLL - US Crop shrinks further: bottom may be near*. Thompson Reuters, July 31, 2012.
11. F.C. Stone. *August 2012 FC Stone Survey*. August 3, 2012.
12. U.S. Department of Agriculture, *World Agricultural Supply and Demand Estimates, August 10, 2012*: Washington, D. C.
13. Babcock, B.A., *Preliminary Assessment of the Drought's Impacts on Crop Prices and Biofuel Production*, in *CARD Policy Brief 12-PB-7* 2012, Center for Agricultural and Rural Development, Iowa State University.
14. Irwin, S. and D. Good, *Ethanol-Does the RFS Matter?*, in *FarmDocDaily* August 2, 2012, University of Illinois.
15. U.S. Department of Agriculture Economic Research Service. *CPI Food Price Index*. August 6, 1012; Available from: http://www.ers.usda.gov/data-products/food-price-outlook.aspx
16. Carter, C.A. and H.I. Miller, *Corn for Food, Not Fuel*, in *New York Times* July 30, 2012: New York.

Ethanol's Lost Promise

An Assessment of the Economic Consequences of the Renewable Fuels Mandate

September 14, 2012

I. Executive Summary

Under U.S. law, U.S. petroleum refiners and other so-called obligated parties must blend ever larger volumes of renewable fuels into the U.S. gasoline and diesel fuel supply. The program is known as the Renewable Fuel Standard (RFS).[1] Corn ethanol is not mandated under the RFS. However, 98% of "conventional biofuels" produced in the U.S. and blended into gasoline are derived from corn, thus creating a de facto mandate for corn ethanol. The RFS mandate for conventional biofuels is set to rise from 13.2 billion gallons in 2012 to 15 billion gallons in 2015. With the additional mandate for advanced and cellulosic biofuels, the total blending requirement rises to 36 billion gallons by 2022. The U.S. Environmental Protection Agency (EPA) administers the RFS program and is the only U.S. agency with the authority to waive or delay implementation of volumetric mandates for renewable fuel blending into the gasoline and diesel pools.

In response to concerns over reductions in corn production from the widespread drought, five state governors have petitioned the EPA to either reduce or waive the RFS mandates and nearly 200 members of Congress (from both the Senate and House) have publicly announced their support for a waiver. The EPA announced on August 20th, 2012 that it will accept comments for 30 days on the governors' waiver request. The EPA is expected to act on the requests before November 13, 2012, but the agency's likely response, if any, is unknown.

Drought throughout much of the U.S. farm belt is expected to severely reduce the 2012 corn crop. The U.S. Department of Agriculture (USDA) in June 2012 predicted a record 14.79 billion bushels of corn for the current harvest, but their forecast was revised down to 10.73 billion bushels in September 2012. The new forecast places the corn harvest at the lowest level since 2006 and 13% below 2011 output. Poor expectations on corn harvests are now setting all time price records with corn rising above $8 per bushel. High corn prices have made ethanol production unprofitable for producers with higher cost

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[1] The federal program promotes several categories of renewable fuels, not just ethanol, under the so-called Renewable Fuel Standard (RFS). The Energy Independence and Security Act of 2007 ("EISA") proposed four renewable fuel mandates, instead of the single mandate as was the case under earlier legislation. Under EISA 2007, the Renewable Fuel Standard (RFS) program was expanded as follows:

* RFS program includes diesel, in addition to gasoline;

* The volume of renewable fuel required to be blended into U.S. transportation fuels will increase from 9 billion gallons in 2008 to 36 billion gallons by 2022.

structures, and several ethanol plants have been idled or are operating at reduced capacity. Ethanol production has declined from 920,000 bbl/d (barrels per day) in June 2012 to 829,000 bbl/d during the final week of August. The Energy Information Administration (EIA) forecasted in its September *Short Term Energy Outlook* that production will average 830,000 bbl/d in the second half of 2012 and 870,000 bbl/d during 2013. An 870,000 bbl/d production rate would consume 4.9 billion bushels of corn over one year. The U.S. is a net exporter of ethanol, but imports have declined by 80% since the beginning of the year to 20,000 bbl/d.

Ethanol is currently blended into the gasoline pool at 9.7% concentration and blending volumes have plateaued 2010.[2] But volumetric requirements under the RFS will soon take ethanol past the 10% "blendwall." EPRINC has calculated that by 2014 the blendwall is likely to be breached. At that time, the gasoline pool will be completely saturated by ethanol at virtually 10% concentration, carryover RINs (renewable identification numbers) will be exhausted, and cost and distribution constraints mean that higher ethanol blends such as E15 and E85 will provide little relief for obligated parties to meet RVOs (renewable volumetric obligation). However, given the potential that U.S. gasoline consumption may continue to decline and that more carryover RINs could be used in the current period to overcome further declines in ethanol production, there is a distinct risk that the blendwall will be breached in 2013.

Obligated parties such as refiners have several means for meeting RFS mandates in 2012 should ethanol production become severely curtailed or blending become uneconomic. There are an estimated 2.4 billion carryover RINs which can be applied towards 2012 RVOs.[3] Ethanol inventories were at 18.7 million barrels (785.4 million gallons) as of the final week of August and some of these inventories could be drawn upon by obligated parties to help meet volumetric blending requirements. Obligated parties face a dilemma if they choose to meet current volumetric obligations through greater use of RINs and existing inventories. This is because ethanol blending is much more costly for obligated parties once the blendwall is reached, and using inventories and RINs now, particularly in a short supply environment, would preclude using them later when they are much more valuable. Any waiver that does not push off

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[2] EIA data, EPRINC calculations

[3] Many obligated parties hold RINs, in effect, a blending credit from previous periods in which they blended at levels above the RFS requirement. These credits can also be purchased on the open market. RINs can be applied to future blending requirements, but the volume of RINs are limited and expire at the end of the calendar year following generation. The 2.4 billion RIN figure is a widely used and uncertain estimate.

the blendwall, perhaps by as much as 2-3 years, will not substantially reduce current blending demand. Unless the blendwall is pushed off by several years, obligated parties will continue to face a strong economic incentive to continue blending ethanol at up to 10% concentration and acquire RINs in the current period to apply to future obligations.

Ethanol producers have called for no revisions in the mandate for blending of conventional biofuels into the transportation fuel supply. The ethanol producers have provided econometric studies and other research that concludes that the mandate has provided large benefits to the U.S. such as enhanced energy security, lower gasoline prices, and the production of a large volume of a DDGS (dried distillers grain with solubles), a by-product for feeding livestock. With regard to ethanol's effect on gasoline prices, ethanol producers have relied on an RFA (Renewable Fuels Association) sponsored and oft quoted study by the Center for Agriculture and Rural Development that claims the RFS mandate has reduced U.S. gasoline prices by over $1/gallon.[4]

EPRINC's assessment of the economic and energy security implications of the ethanol mandate concludes that the benefits of the mandate are exaggerated and are now imposing substantial costs on the production of transportation fuels and food. These costs are likely to grow as the percentage of ethanol in the gasoline pool exceeds 10%. The following findings summarize the main conclusions of the EPRINC assessment.

EPRINC's findings are as follows:

- A near term waiver of blending requirements (6 months to 1 year) would have little effect on corn demand for the production of ethanol. Obligated parties would still have to plan for RVO compliance once the waiver ends. Blending would still have to occur at high levels now, as obligated parties would want to acquire RINs to prepare for the high (and future) cost of crossing the blendwall. Refiners will also need time to adjust their gasoline yields in response to lower ethanol production. A longer term waiver (2-3 years) at some level at or below the blendwall would allow for a proper assessment of the nation's crop situation, provide end-users with a stable planning environment, and permit refining operations to adjust fuel output. Such a

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[4] Xiaodong Du and Dermot J. Hayes, *The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to 2012. May 2012, Working Paper 12-WP 528. See* http://www.card.iastate.edu/publications/dbs/pdffiles/12wp528.pdf

waiver would likely reduce corn prices[5], providing economic benefits in the form of feed and food prices, and would reduce the risk of a price spike in gasoline as obligated parties begin blending ethanol at levels above 10% of the gasoline pool.

- There are no low-cost solutions for marketing renewable fuels into the transportation fuel supply in the near-term at levels above 10% of the gasoline pool. So called higher ethanol blend options, such as E85 (70-85% ethanol blends for flex fuel vehicles) have failed to achieve market success due to their high cost, poorer mileage performance relative to gasoline, and lack of availability. EPA has recently approved E15 for model year 2001 and newer light duty vehicles. E15, however, faces a large number of infrastructure, liability, and cost issues, all of which will limit widespread adoption. Auto manufacturers have not provided warranties for non-flex fuel vehicles using so-called E15 blends.

- The energy security and cost savings benefits from ethanol have been exaggerated. Ethanol did not reduce gasoline prices by more than $1/ gal in 2011 as was concluded in the oft quoted study from the Center for Agricultural and Rural Development at Iowa State University (CARD). Extensive independent econometric research and EPRINC cost-based models conclude that ethanol had little or no effect on the price of gasoline.

- Even if ethanol blending were determined strictly by cost and market conditions, total blending would be unlikely to fall below 400,000 bbl/d from current blending volumes of around 800,000 bbl/d. Ethanol blending at the lower level would continue because ethanol remains a valuable blending component to meet octane requirements and other fuel specifications required by EPA. Higher blending levels would occur depending upon cost and market conditions.

- Fuel adjustments to reductions in ethanol blending are both low cost and technically achievable given time. A reduction in ethanol blending could be made up through relatively small yield adjustments at U.S. refining plants. For example, if U.S. ethanol blending declined to 400,000

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[5] The Farm Foundation and Purdue University, *Potential Impacts of a Partial Waiver of the Ethanol Blending Rules,* August 16, 2012, http://www.farmfoundation.org/news/articlefiles/1841-Purdue%20paper%20final.pdf

bbl/d, U.S. crude oil refiners could make up the volume through yield adjustments of less than 2%, well within technical and historical performance levels of the past decade.

- By-product production of feed from ethanol production, DDGS, has not substantially lowered the cost of raising livestock in the United States. The ethanol industry purchases approximately 40% of the U.S. corn crop and is the largest purchaser of corn in the United States. Even when DDGS volumes are returned to the livestock feed supply chain, 30% of U.S. corn production is consumed for fuel production. DDGS prices are directly correlated to corn prices; despite the rapid growth of DDGS production resulting from the boom in corn for ethanol, DDGS supply growth has come at the expense of existing feeds such as corn and soy. Twenty percent of the two most widely planted crops in the U.S., corn and soy, went to biofuels production during the 2011/2012 crop year.

- The RFS' volumetric mandates have created inelastic demand for ethanol. Many supporters of the blending mandate have claimed that the program has substantial flexibility since it permits obligated parties to use RINs in a subsequent year or even carry a deficit into the next year. However, the use of carryover RINs, or even carrying a deficit, is of limited value. RINs expire after one year after the year in which they are generated and deficits can only be carried over for one year. The supply of carryover RINs will quickly go to zero as obligated parties cross the blendwall. Surplus RINs are needed in the prompt period to offset physical blending below RFS mandated volumes. In 2013 mandated conventional ethanol volumes will surpass 10% of the gasoline pool. Cellulosic and advanced ethanol mandates provide further volumetric requirements. Whatever flexibility is contained in the mandated program disappears when it becomes uneconomic to blend above the RVO on an ongoing basis.

- A multi-year waiver of both the ethanol and biodiesel mandates would free millions of acres of land for food and livestock uses, even after accounting for a decline in DDGS production. As previously stated, a full and long-term waiver of the RFS would not reduce ethanol use to below 400,000 bbl/d. Current biodiesel production, however, would be almost entirely eliminated.

More importantly, a multi-year waiver could free over 18 million acres of existing farm land for the production of crops to meet market needs for food, livestock feed, exports, or fuel.

- Despite the droughts and record prices for corn and other crops, the RFS has ensured that billions of bushels of corn and soy are set to be converted to fuels which offset less than 5% of the nation's petroleum fuel supply. The U.S. refining industry could make up the loss of all biodiesel and 400,000 bbl/d of ethanol production by adjusting gasoline yields within their historical 10 year range while remaining a net exporter of distillate fuel. The additional fuel production from refiners would require both adequate time to make the adjustments and an expectation that government policy would not impose long-term uneconomic blending requirements, i.e., blending at levels above 10% of the gasoline pool. As stated above, EPRINC's assessment is that ethanol blending would continue at or above 400,000 b/d even in an environment free of blending mandates.

II. The Value of Biofuels in the Gasoline Pool

U.S. government officials, including Secretary of Agriculture Tom Vilsack, representatives of the Renewable Fuels Association (RFA), and other supporters of expanded mandates for the use of renewable fuels in the transportation sector have argued that the growth in ethanol blending spurred by the RFS has contributed to large reductions in the price of gasoline. These conclusions were taken from a series of studies from the Center for Agricultural and Rural Development at Iowa State University (CARD). The studies concluded that ethanol use had reduced U.S. gasoline prices by approximately $0.89/gallon in 2010 and $1.09 per gallon in 2011. The results of the study were also circulated widely among members of Congress and were part of an extensive advertising program undertaken by RFA.

The authors of the studies undertook a series of econometric calculations evaluating how the U.S. refining sector and gasoline prices would adjust if growth in the use of ethanol in the transportation fuels sector were constrained. The studies evaluated the consequences of limiting ethanol use across several time periods, but most notable were the consequences of constrained blending between January 2000 and December 2010. The authors state in their most recent report, issued in May:

> *"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 affect 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.[6]"*

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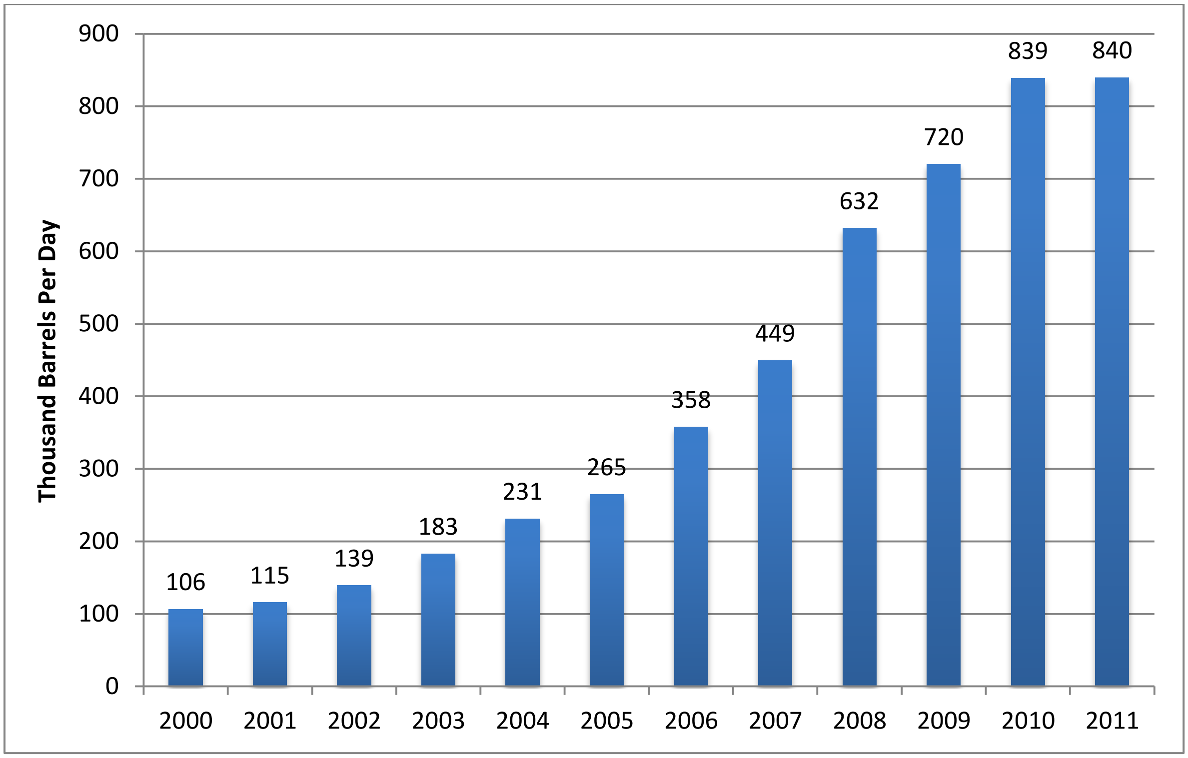
[6] Xiaodong Du and Dermot J. Hayes, *The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to 2012. May 2012, Working Paper 12-WP 528. See* http://www.card.iastate.edu/publications/dbs/pdffiles/12wp528.pdf

Figure 1 below shows trends in ethanol blending in the U.S. gasoline pool between 2000 and 2011. Note that the volumes consumed through 2011 reflect a combination of government mandates and financial incentives, as well as ethanol's market value at low blending levels. The $0.45/gallon ethanol 'blender's credit' and tariff on ethanol imports expired at the end of 2011. The U.S. is also a net exporter of ethanol.

Figure 1. U.S. Ethanol Consumption

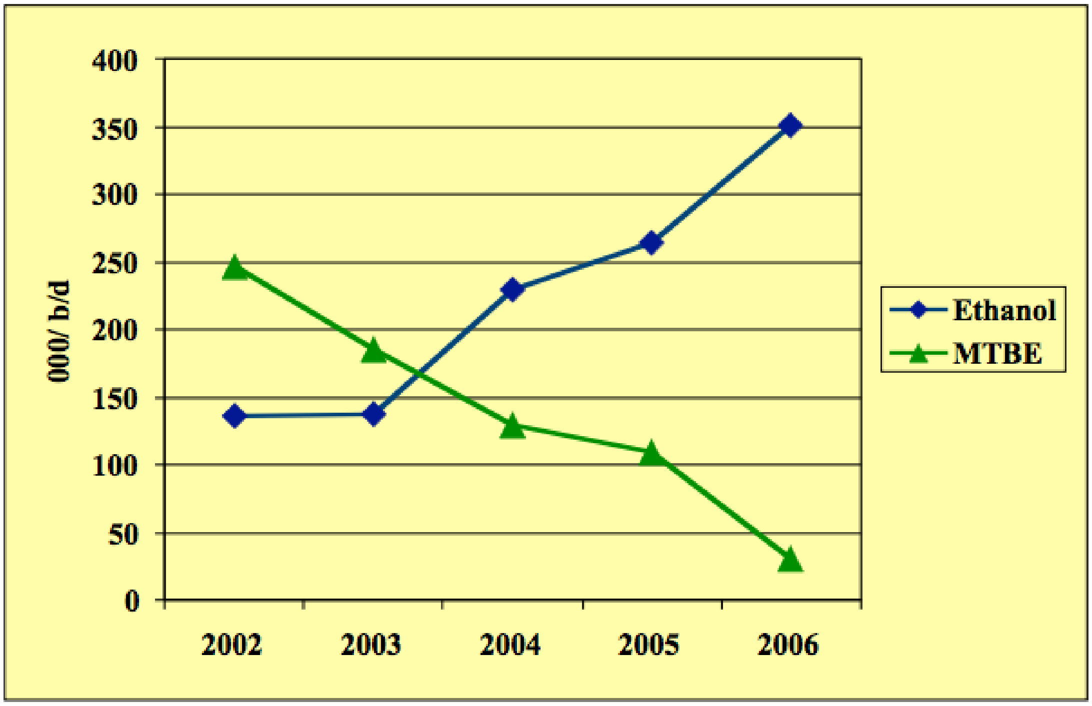


Source: EIA Data

If ethanol blending is constrained to the 2000 level of 1.6 billion gallons as CARD did in their 2011 report, total ethanol blending lost across the entire period averages to approximately 328,000 bbl/d. The averages are higher in the later years. As stated above, the authors concluded that constraining ethanol use to levels used in 2000 would have increased gasoline prices by $0.89/gallon in 2010 and $1.09/gallon in 2011.[7]

Ethanol has considerable value in the refining sector at low volumes because of its value as an oxygenate and its role in meeting octane targets.[8] Given the phase out of the oxygenate MTBE (Methyl Tertiary Butyl Ether) during the past decade due to environmental concerns, ethanol became the natural substitute. Without the RFS mandates ethanol would likely have replaced MTBE on a 1:1 basis and would be blended today at approximately 400,000 bbl/d. Figure 2 below shows change in ethanol and MTBE blending during the MTBE phase-out.

Figure 2. Ethanol and MTBE



Source: EIA Data, chart from and EPRINC report published in the *Oil & Gas Journal*.

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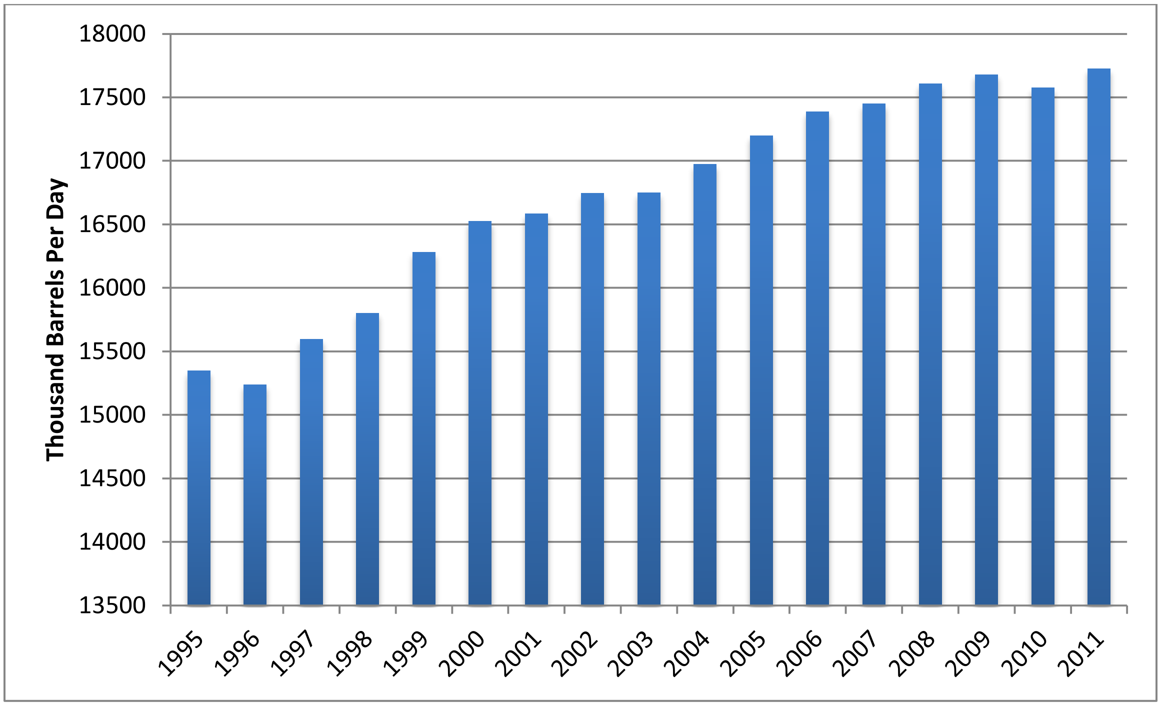
[7] Xiaodong Du and Dermot J. Hayes, *The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to 2012.* Working Paper 12-WP 528, May 2012. See http://www.card.iastate.edu/publications/dbs/pdffiles/12wp528.pdf

[8] Oxygenates are required for the production of gasoline to reduce carbon monoxide that is created during the burning of the fuel. Ethanol replaces the oxygenate MTBE which was phased out during the past decade over environmental concerns.

However, ethanol‘s role at concentrations above 3-5% of the gasoline pool are largely as a substitute for gasoline, but its value is limited by ethanol’s lower BTU content, and ultimately, by limitations of the U.S. auto fleet to absorb ever higher volumes of ethanol. On a volumetric basis, ethanol is often cheaper than gasoline. When adjusted for energy content, ethanol is generally more expensive than the gasoline.

The econometric model tested by Du and Hayes does not adequately reflect operating conditions in the U.S. refining industry. The calculations undertaken by CARD *prohibited any adjustments in refining capacity* and then made a series of calculations on the consequences of limiting annual ethanol use to 1.6 billion gallons annually for the 2000-2010 and then 2000-2011 time periods. However, ethanol production has grown by billions of gallons per year *and* refining capacity grew by 1 mm bbl/d (million barrels per day) from 2000 to 2010 and by 1.2 mm bbl/d from 2000 to 2011. This is enough refining capacity to process over 15 billion gallons of crude annually.

Figure 3. U.S. Operable Refining Capacity



Source: EIA Data

The constraint in ethanol use (in the CARD calculations) and refining capacity leads to a shortage of gasoline and an increase in gasoline imports and prices, measured through a calculation of the "crack spread."[9] The assessment then calculated the expected increases in crack spreads as a proxy for the likely increase in gasoline prices. However, adjusting yields in product slates, increasing or lowering crude runs, and modifying the capital structure of the refinery are all common adjustments that occur in the industry when blending components are unavailable or their relative prices adjust. The CARD results were also inconsistent with extensive research undertaken by EPRINC using cost based modeling.

This loss in ethanol blending represents an average loss in gasoline production of approximately 328,000 bbl/d across the studied time period. However, since the principal substitute for ethanol is gasoline, the volume needed to make up the loss must be reduced to account for energy content, i.e., ethanol has approximately 33% less energy content than gasoline. As a result, the actual loss is closer 200,000 bbl/d of gasoline equivalent. This volume loss could have been easily and inexpensively made up through adjustments in refinery operations through any combination of the following:

1. Short-term adjustments in the yield of the product slate to produce more gasoline and the reduction of other refined products. A major factor in this shift is that the volumetric mandates in the RFS almost entirely target gasoline supplies. Volumetric bio-diesel requirements comprise less than 10% of the total volumetric requirements, the remainder target gasoline supplies. Therefore, the mandates have reduced demand for gasoline, causing refiners to respond by producing more diesel fuel, but not necessarily reducing crude runs.

2. Processing of crude types with higher natural yields in gasoline.

3. Running more crude in refineries with spare distillation capacity, both in the U.S. and abroad, for example, European refiners could easily expand throughput to produce additional volumes of diesel for their home market and at the same time produce additional

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[9] 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. The crack spreads in the CARD study were substantially above the amounts seen in the refining industry over the last 40 years.

volumes of gasoline for the U.S. market. The U.S. has traditionally been a major outlet for excess supplies of European gasoline.

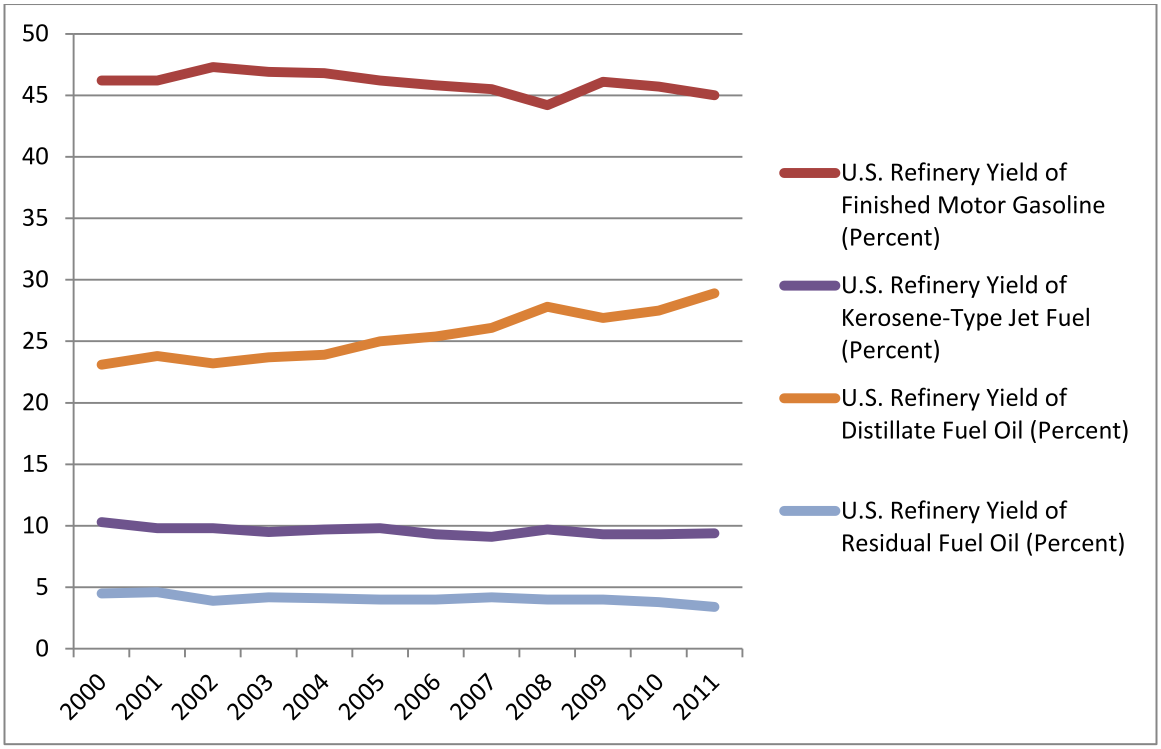
4. Construction of additional capacity at U.S. refiners. This did occur naturally in addition to ethanol growth, but was not included in CARD's model.

5. Import additional gasoline from Europe. European refiners have been awash in excess gasoline since Europe's dieselization initiative. Marginally increasing imports would have had little effect on world prices.

Importance of Adjustments to Refinery Operations

An examination of recent shifts in gasoline shows that refiners could have offset the ethanol volumes lost in 2010 and 2011 without processing an additional barrel of crude oil. Because the RFS mandates are so heavily slanted towards substituting ethanol for gasoline supplies, they have given refiners an economic incentive to shift production away from gasoline towards middle distillates such as diesel. Figure 4 shows the changes in yields over the past decade. The shift can be made through a combination of operational shifts at the refinery, including a change in crude oil feedstock, installing additional processing infrastructure such as a cracker or coker, and adjusting catalysts or blending components. Distillate yields have improved at the expense of stagnating gasoline yields (but because refinery capacity has increased, gasoline production has too) and by the installation of processing equipment to upgrade residual fuel oil to higher value products.

Figure 4. U.S. Refinery Yields

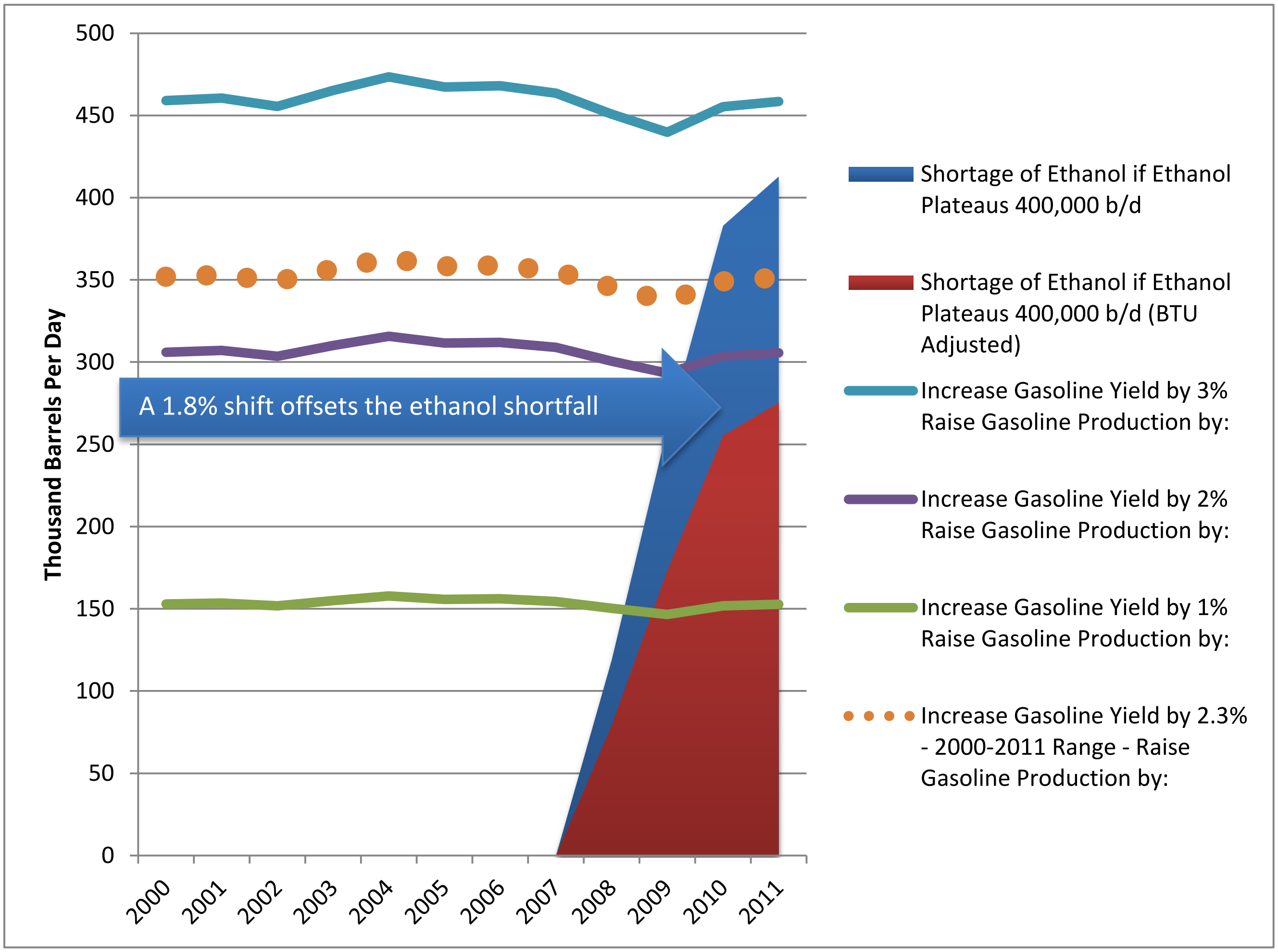


Source: EIA Data

If it is assumed that without the RFS mandates ethanol blending would plateau at 400,000 bbl/d, making it a 1:1 substitute for MTBE, rather than reaching slightly over 800,000 bbl/d in 2010 and 2011, the gasoline pool would have been missing approximately 400,000 bbl/d of ethanol during those two years. Adjusting for ethanol's lower energy content relative to gasoline, the loss is 265,000 bbl/d. U.S. refiners could have overcome this shortage without running a single additional barrel of crude oil by making a remarkably small operational adjustment of their yields – an adjustment well within the 2000 – 2011 gasoline yield range - and the U.S. would still have distillate capacity to support exports in 2012.

Figure 5 below shows how much additional gasoline would be produced if yields were 1, 2 or 3 percentage points higher, given actual crude oil runs through U.S. refineries for the given year. The orange dotted line shows the increase in gasoline production if yields were raised by 2.3 percentage points - this is the range in which gasoline yields moved during 2000 to 2011. Finally, the red and blue lines are the amount of ethanol that would be missing from the market if ethanol blending was capped at 400,000 bbl/d.

Figure 5. Shifting Refinery Yields to Overcome an Ethanol Shortfall



The chart demonstrates that a 400,000 bbl/d ethanol shortfall could have been covered in 2011 had gasoline yields been just 1.8 percentage points higher, from 45% to 46.8%. A 46.8% gasoline yield is equal to or lower than the gasoline yield during 3 of the past 11 years. It is also well under the 2.3 percentage point range in which yields bounced during 2000 – 2011. Even if ethanol is not adjusted for its lower BTU content, the yield shift required to offset the volumetric shortfall is under 3 percentage points.

If the RFS mandates were completely eliminated, ethanol blending might not decline by as much as 400,000 b/d, and in any case, such an adjustment would take several years. But, blending would certainly drop below RFS mandated levels. Refiners have adjusted to the RFS by optimizing operations to account for 10% ethanol gasoline blends. If given the option, some refiners would eliminate ethanol almost immediately while many others would continue to blend at 10% for probably the next one to three years. This also reinforces the importance of a long-term waiver. Future obligations aside, a temporary waiver of months or even a full year does not give refiners enough time to adjust their operations to reduce ethanol blending.

Blending would remain closer to 10% in summer months so that refiners may obtain a '1 lb' RVP (Reid vapor pressure) waiver. Gasoline specifications change during the summer months and a lower RVP of 9 psi (pounds per square inch) is required.[10] By blending 10% ethanol, refiners are granted a waiver of 1 lb. The waiver makes it easier for refiners to meet summer gasoline specifications. E15 will not qualify for a 1 lb waiver.

Figure 5 is not a prediction of what would necessarily occur overnight given the elimination of RFS mandates. However, it illustrates the potential for the refining industry to adjust to more open market conditions and reflects long-term equilibrium demand for ethanol in a mandate free market. The decline in gasoline yields over the past several years were in large part a result of the signal sent by the RFS mandates to refiners which imposed reductions in gasoline output and required ethanol as a replacement. Without the mandate, gasoline yields from U.S. refiners would be higher than they are today.

The ethanol shortfall could be covered without increasing crude oil refinery runs, and therefore without increasing imports. Such a shift might have come at the expense of distillate production and exports. A 1.8 percentage point reduction in distillate yields would have resulted in the loss of 275,000 bbl/d of distillate in both 2010 and 2011. However, this would still have left the U.S. with gross exports of approximately 375,000 bbl/d in 2010 and 575,000 bbl/d in 2011.

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[10] See EPRINC's 2009 report, *A Primer on Gasoline Blending,* http://www.eprinc.org/pdf/primerongasolineblending.pdf

It should be noted that Du and Hayes pointed out some of these limitations in their original 2009 study results, the basis for the highly visible 2010 and 2011 updates. But the following statement from the 2009 study is missing in many of the public statements on the contribution of ethanol use in setting gasoline prices.

> *"These reductions in retail gasoline prices are surprisingly large, especially when one considers that they are calculated at sample mean. The availability of ethanol essentially increased the ''capacity'' of the US refinery 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."*[11]

Gasoline prices rise in the CARD calculations because demand can only be met through higher cost production from the existing installed capacity, either in the U.S. or abroad. Additionally, the CARD model does not account for demand rationing. If gasoline prices were $1.09 higher in 2011, a 30% increase which would have sent prices to nearly $5/gallon, certainly demand would have been somewhat curtailed. It should also be remembered that gasoline is a globally traded commodity. The spot price of gasoline in the Gulf Coast is only a few cents per gallon different from the European spot price in Rotterdam. It is unlikely that the loss of 700,000 bbl/d of ethanol under the CARD model, 460,000 bbl/d of gasoline equivalent after BTU adjustment, would have the effect of raising prices $1.09/gallon globally. The CARD report specifies a price impact only in the U.S. market, but the U.S. market is perhaps the most globally integrated fuels market in the world.

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[11] Du, X., Hayes, D.J., 'The impact of ethanol production on US and regional gasoline markets'. *Energy Policy* (2009), doi:10.1016/j.enpol.2009.04.011

A recent study by joint authors from MIT and UC San Diego highlighted the limitations of the econometric approach undertaken in the CARD study.[12] The MIT/UCSD assessment points out that the estimates of reductions in gasoline prices were inconsistent with the basic economics of the industry. The authors of this study concluded that, at best, they were only able to calculate a $0.13/gallon reduction in gasoline prices. In terms of their econometric model results, these conclusions are insignificant or essentially zero. As the authors of the MIT/UCSD study point out, using the same model as the CARD authors, eliminating ethanol use also would have increased natural gas prices by 65 percent and would have caused an increase in U.S. and European unemployment.[13]

Finally, many proponents of expanded ethanol use in the U.S. gasoline pool point out that such use contributes to U.S. energy security through a reduction in oil imports. However, as stated above, ethanol in the U.S. gasoline pool does not reduce oil consumption barrel for barrel. This is because ethanol has fewer BTUs than conventional gasoline. The expansion of ethanol in the U.S. gasoline pool between 2000-2010 is equivalent to approximately 200,000 bbl/d in crude oil savings. The U.S. Energy Information Administration (EIA) shows no substantial benefits in lower import prices to the U.S. in any scenario in which net demand for crude oil or product imports fall by 200,000 bbl/d, barely more than 1% of U.S. petroleum consumption. Such shifts in net demand from EIA show a reduction in the price of gasoline far less than 5 cents a gallon.

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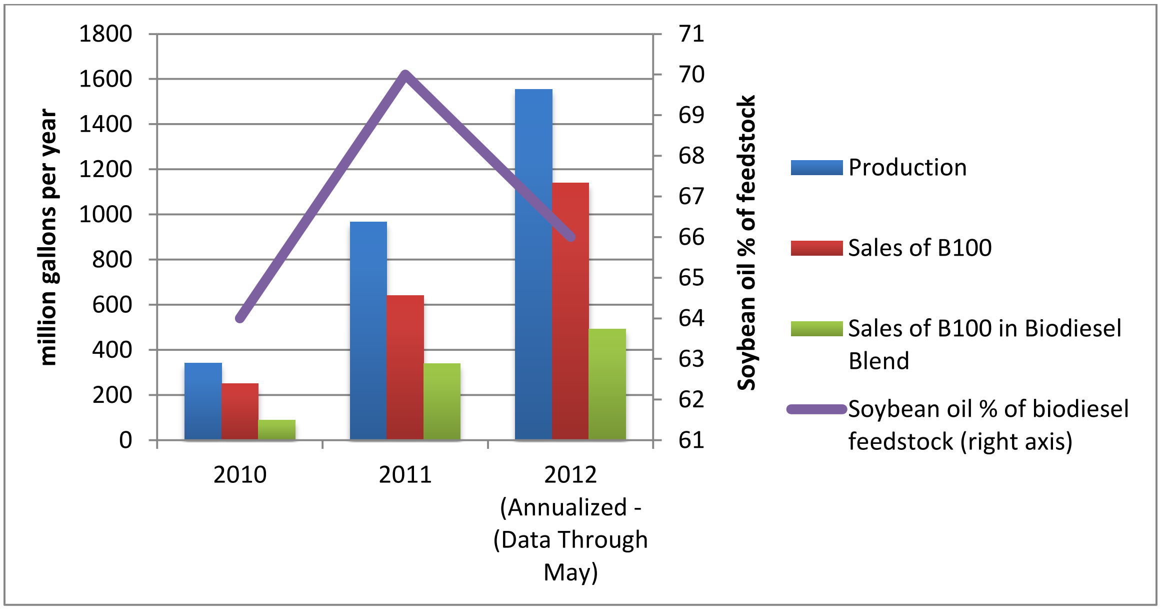
[12] Christopher R. Knittel and Aaron Smith. "Ethanol Production and Gasoline Prices: A Spurious Connection." July 12, 2002. See http://web.mit.edu/knittel/www/papers/knittelsmith_latest.pdf

[13] MIT/UCSD criticisms of the CARD results were very specific, "We show that their results are driven by implausible economic assumptions and spurious statistical correlations. 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." See http://web.mit.edu/knittel/www/papers/knittelsmith_latest.pdf

Biodiesel – Small Contribution

Biodiesel production is currently on pace to reach 1.5 billion gallons in 2012, equivalent to 100,000 bbl/d. 1 billion gallons of biodiesel are required in 2012 by the RFS. The primary feedstock for biodiesel in the U.S. is soybean oil. During the past three years soybean oil has accounted for 64% to 70% of all U.S. biodiesel production. Biodiesel production and soybean oil's share of total feedstock are shown in the chart below. Biodiesel production consumed approximately 10% of the 2011/2012 soybean crop.[14]

Figure 6. Biodiesel Production, Sales and Soybean Oil Share



Source: EIA Data, EPRINC Calculation

In 2012, total production of biodiesel will constitute less than 2.5% of the U.S. distillate fuel supply and less than 1% of total petroleum products supplied. If no biodiesel were produced in 2010 and 2011, and ethanol production dropped to 400,000 bbl/d at the expense of distillate yields, as described earlier, the U.S. would have remained a net exporter of distillate. If all biodiesel production is considered part of the distillate pool, net exports would have declined from 375,000 bbl/d to 353,000 bbl/d in 2010 and from 575,000 bbl/d to 512,000 bbl/d in 2011. These volumes are too small to have any impact on global distillate prices and are contributing to distillate exports rather than reducing petroleum based distillate consumption.

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[14] Iowa State University Biodiesel Balance Sheet, July 23, 2012, http://www.extension.iastate.edu/agdm/crops/outlook/biodieselbalancesheet.pdf

III. Why a Temporary or Partial Waiver Will Not Fix Corn Prices or the Blendwall

Obligated parties are currently facing physical constraints in increasing ethanol blending as called for in the RFS. Ethanol is currently blended at 9.7% concentration in the conventional gasoline pool; the effective limit is 10%, referred to as the blendwall.[15] The physical blendwall was reached in mid-2010. Blending volumes then plateaued at an annual rate of approximately 846,000 bbl/d, equivalent to 13 billion gallons per year. As figure 7 below shows, obligated parties blended above mandated levels up until late 2011 (denoted by the blue arrow). By doing so they generated extra RINs which could be carried over to the following year or sold to other obligated parties. Up to 20% of one's obligation may be carried over and RINs expire at the end of the calendar year following the year in which they were generated.

The RFS mandates continue to grow, yet obligated parties are unable to increase the amount of ethanol they may blend. Obligated parties were, until recently, blending above mandate levels; in 2013 and beyond they will be forced to underblend (denoted by the red arrow), relying on carryover RINs to make up the difference needed to meet RVOs. Conventional ethanol 'mandates' will increase from 13.2 billion gallons in 2012 to 15 billion gallons in 2015. Cellulosic and advanced ethanol rise from a combined 1 billion gallons in 2012 to 20 billion gallons in 2022 in addition to the conventional requirements. Cellulosic and advanced ethanol, which includes Brazilian sugarcane ethanol, may also be substituted for corn based ethanol once their respective mandates are met. This provides some flexibility as sugarcane ethanol has a higher RIN value than corn ethanol, but supply is insufficient to offset a large decline in corn ethanol blending.[16]

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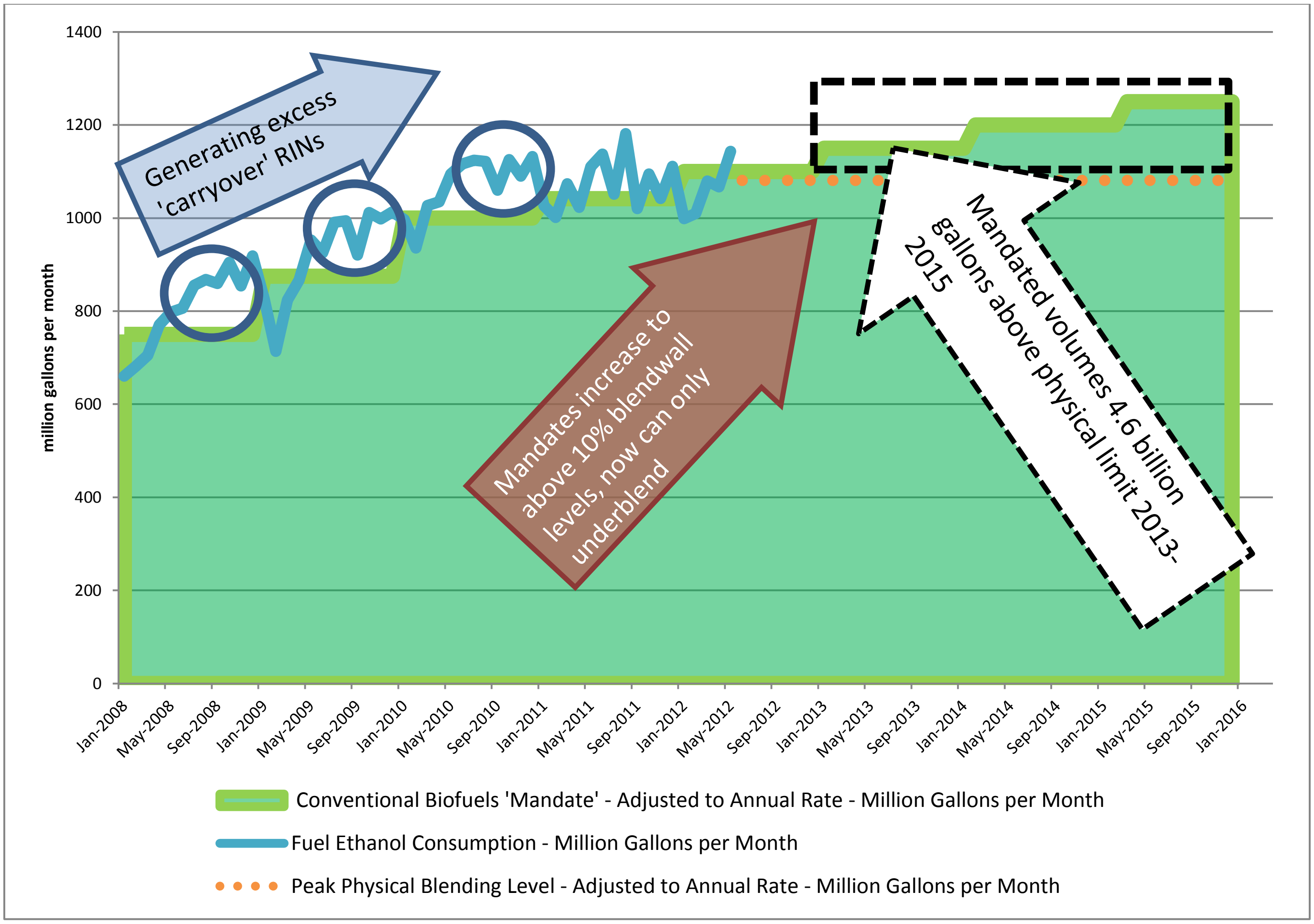
[15] E15 and E85 are not suitable markets for incremental ethanol volumes due their high cost on an energy equivalent basis as well as infrastructure and vehicle fueling constraints.

[16] Cellulosic volumes were partially waived in 2012 as cellulosic ethanol is not yet available in commercial volumes.

Figure 7. The Blendwall and RIN Carryover



In 2013 and beyond, obligated parties will use carryover RINs to offset the RVO deficits created by underblending. As RINs are applied to offset underblending, fewer RINs will be eligible for carryover to the following year. The 2.4 billion carryover RINs believed to be eligible for 2012 obligations are needed to avert a blendwall crisis in 2013 and 2014. Any significant decline in 2012 and 2013 blending, due to reduced ethanol production or other factors such a lower gasoline demand, would only serve to advance the date at which carryover RINs are exhausted.

The black box in figure 7 above highlights years in which obligated parties will face a blending deficit: 2013, 2014, and 2015. Assuming constant gasoline demand (EIA projects a slight decline in 2013) and maximum blending of 13 billion gallons per year, the combined RVO deficit over the 2013-2015 period is 4.28 billion gallons (0.83 billion in 2013, 1.43 billion in 2014, and 2.03 billion in 2015). Therefore, when obligated parties transition to a period of blending below mandated levels in late 2012 or early 2013, the current pool of 2.4 billion carryover RINs will only be sufficient to offset RVO deficits until the end of 2014 at the latest. This would require that remaining RINs are eligible to be carried into each of the following years, which will not necessarily be the case. A blendwall crisis is inevitable by 2015, at the latest, absent a change of current policy.

Although current carryover RINs provide near term flexibility in 2012 and 2013, the rise of RVOs over the 10% physical blending limit renders carryover RINs an ineffective tool for mitigating high crop prices or lowering the cost of producing gasoline. A temporary waiver provides little relief because the availability of carryover RINs have a very limited shelf life (one year) and the potential to overblend (and acquire more RINs) continues to decline as the RVO requirements increase.

Under the RFS, EPA may alter or waive volumetric requirements one year at a time. It is unclear if, and how, EPA will respond to the gubernatorial petition. EPA has a large amount of freedom in its ability to modify RFS requirements at the request of petitioners seeking to lower corn and food prices by reducing the ethanol mandates. But the agency is not required to make any changes, and will only do so if it finds that the mandates are creating severe economic harm.

One possible outcome is that EPA will reduce the 2013 mandate. This would theoretically reduce ethanol blending and production, thereby providing the corn and feed markets with much needed breathing room. However, such a waiver will not have its intended effect as long as future RVOs remain unchanged. Obligated parties are already facing a situation in which they cannot meet their RVOs with physical blending and must turn to a limited and shrinking supply of RINs. If the 2013 volumetric requirement were reduced from 13.8 to 10 billion gallons for example, obligated parties would not reduce blending from the current rate of 13 billion gallons per year to 10 billion gallons. Obligated parties would be pressured to continue to blend at 13 billion gallons, using the partial waiver as an opportunity to accrue carryover RINs which could be used to offset 2013 and 2014 deficits, effectively delaying a blendwall crisis by a year or two. Such a situation means the desired loosening of the corn and grain market is not realized.

If obligated parties were to blend at the reduced rate of 10 billion gallons, they would not generate excess RINs and would face the same shortage of RINs in 2014 or 2015 as they do now. Therefore, any potential waiver which seeks to loosen the corn market in the near term must also consider future volumetric ethanol requirements. As EPA does not have the authority to waive multiple years of the RFS (and perhaps does not have the intention), a legislative change may be required to alleviate pressure in the grain market and avert a blendwall crisis.

IV. Ethanol, Biodiesel, DDGS: Food and Fuel

There has been a long running debate on whether ethanol use in the transportation fuels sector is driving up food prices. Some proponents of ethanol use in the transportation sector argue that the U.S. has enormous capacity to expand production of ethanol's principal feedstock, corn, and can do so with relatively little incremental cost given the availability of land and modern agricultural technology, i.e., many ethanol proponents argue that the supply (cost) curve for expanded corn production does not rise significantly as production increases. Technology, advanced agricultural practices, and the availability of land in the U.S. all suggest that the U.S. can expand agricultural production at relatively low cost, but this view is not universally accepted.[17]

The fundamental question is not whether the U.S. can expand corn production at relatively low cost, or whether using agricultural products in the transportation sector increases food prices, but whether government policy, effectively requiring the use of the nation's two most widely planted crops, prevents traditional market adjustments to changes in supply and demand and imposes substantial costs on the national economy. The current RFS mandates for ethanol use in gasoline requires that ever higher annual volumes of the fuel be allocated to the transportation sector regardless of the price of corn, or the price of competing fuels and technologies.

Prices play a critical role in the marketplace allowing for, and encouraging, adjustments to changes in relative prices and shifts in technology. These interactions play an important role in producing both fuel and food at the lowest possible cost to consumers. The government mandate prohibits such adjustments even in cases when relative prices shift markedly as is now the case.[18] The RFS' volumetric mandates have created inelastic demand for ethanol. As built-in flexibilities such as carryover RINs are unworkable long-term solutions, demand adjustments have and will occur by reducing ethanol and grain exports as well as reducing demand among food related end users.

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[17] Research from the World Bank and other studies show that rising use of food crops for fuel are having a sustained upward price effect on food production costs. See Mitchell, Donald. "A Note on Rising Food Prices". Policy Research Working Paper 4682, Development Prospects Group, The World Bank, July (2008).

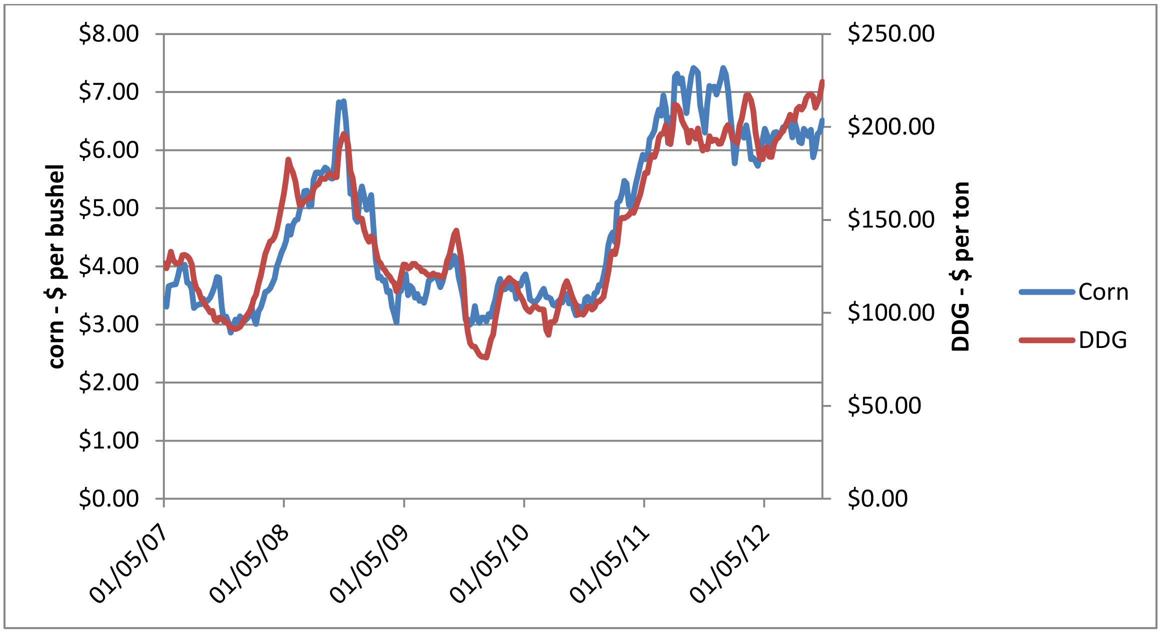
[18] The ethanol mandate is administered by the U.S. EPA. EPA has authority to provide waivers on the mandate but only provides such waivers at this time for so-called advanced bio-fuels such as cellulosic ethanol. Production of cellulosic ethanol has yet to reach levels required under the RFS mandate.

Recent dry weather patterns throughout the agricultural regions of the U.S. are likely to reduce 2012 corn production by approximately 4 billion bushels compared to USDA's (United States Department of Agriculture) June forecast which was made before the onset of the drought. This represents a nearly 30% decline in crop size. Under the renewable fuels mandate, about 5 billion bushels of 2012 corn production will be allocated to ethanol production. However, the lower corn production forecast is likely to see the percentage of ethanol use raise the amount of corn used for ethanol to 5 billion from 4.25 billion bushels if current ethanol production levels are maintained for 12 months. Production has declined by 160,000 bbl/d since the beginning of the year as high corn prices have caused many ethanol producers to idle production.

Soybeans are the second most widely planted crop in country, after corn. As with corn, the year's soybean crop is expected to be significantly smaller than previously expected as a result of the drought. In its September crop outlook, USDA forecasted a harvest of 2.63 billion bushels, down from the 3.05 billion bushels predicted in June. This is expected to be the smallest crop in six years and produce the worst yields in 17 years.

Over the past few years, ethanol producers have in fact purchased about 35-40% of the corn crop. They have also generated millions of tons of DDGS which contribute to the feed supply. Ethanol production from corn generates an animal feed component called DDGS (distillers dried grain with solubles), a protein rich byproduct of the ethanol production process that is used as livestock feed. Therefore, not every calorie of corn they purchase ends up as ethanol, a large portion is returned to the food supply. Note, however, as shown in figure 8 DDGS prices closely track the price of corn.

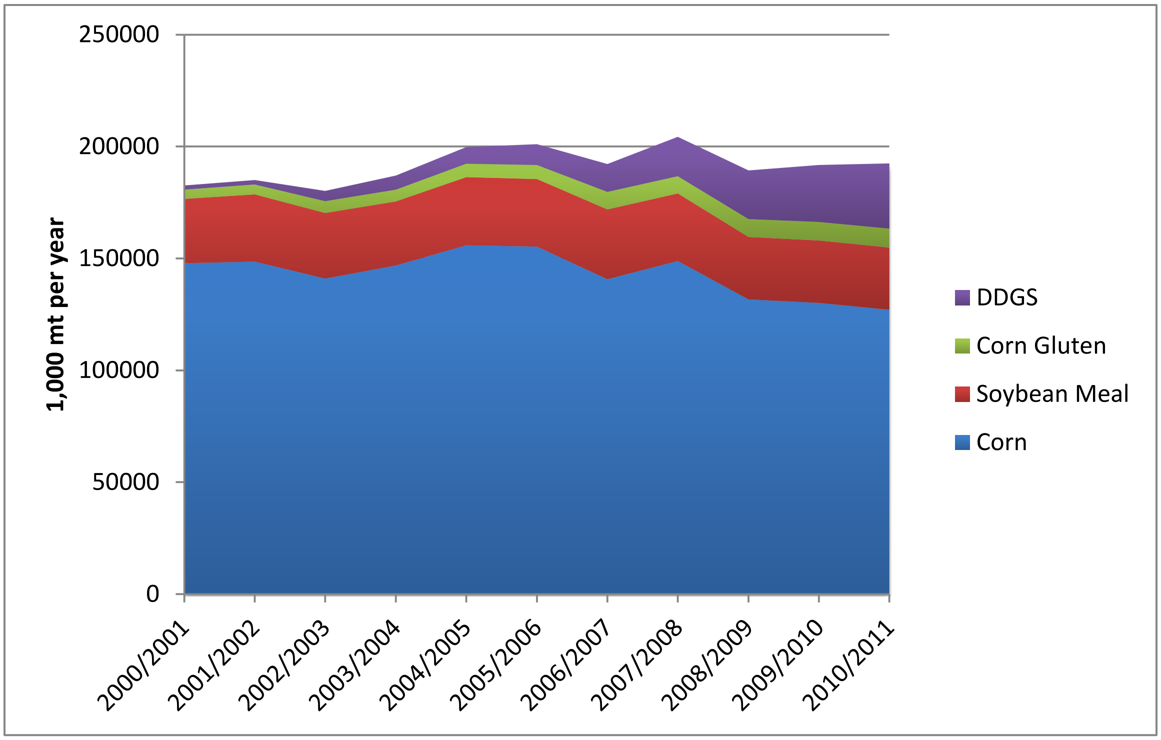
Figure 8. Corn and DDG Prices



Source: USDA Data

Regardless of the reason for corn price increases – a change in planted acres, drought, exports, demand for poultry and livestock feed, demand for high fructose corn syrup and corn flakes, or ethanol demand – rising corn prices raise not only whole corn feed costs but also DDGS costs. Despite huge growth in DDGS production in recent years, DDGS prices remain tied to corn. DDGS growth has largely displaced existing livestock feeds, primarily corn, rather than providing a net contribution; DDGS is the solution to a problem which did not exist before the RFS. Figure 9 below shows the consumption by U.S. livestock of the four most consumed U.S. processed feeds.

Figure 9. Four largest U.S. processed feeds fed, by crop year



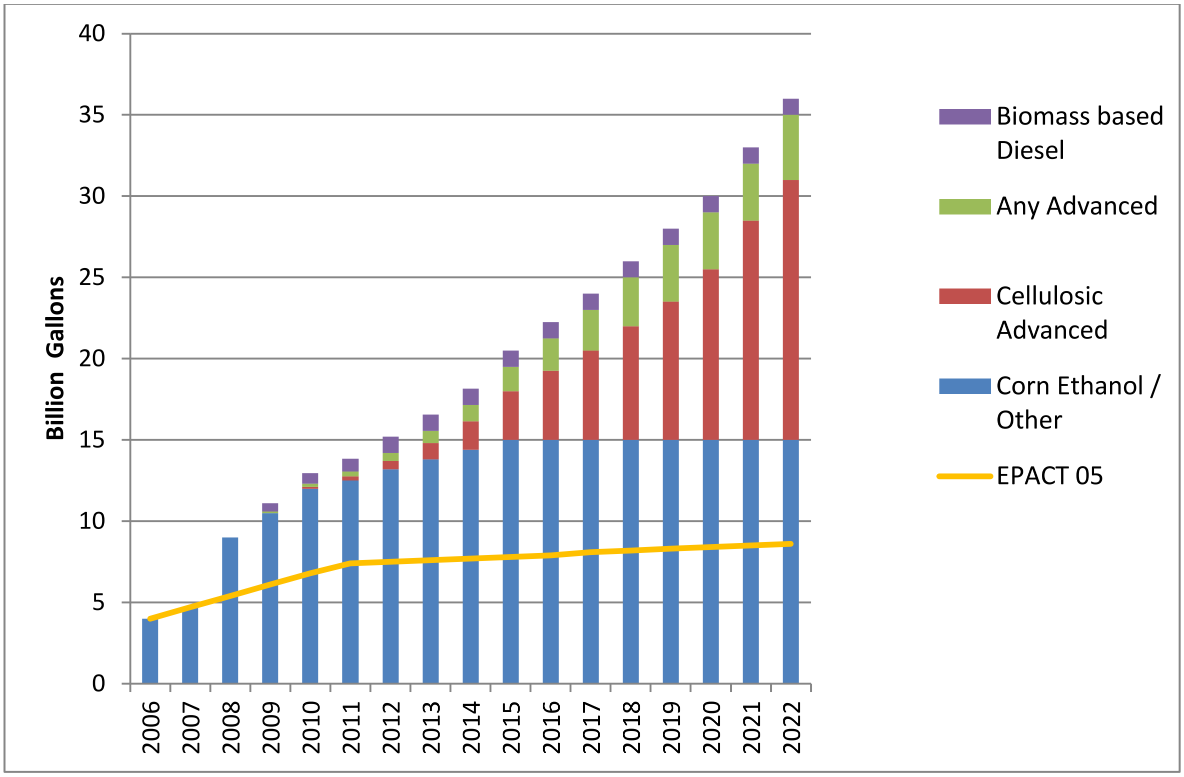
Source: USDA Data, see http://www.ers.usda.gov/media/236568/fds11i01_2_.pdf

When one considers that ethanol producers are the largest purchases of corn, at 40% of the annual corn crop in 2011/2012 compared to 14% in 2005/2006, it is clear that ethanol is a major driving force in setting corn prices and more importantly its mandated use means its use remains relatively inelastic.

The RFS Induced Corn Boom

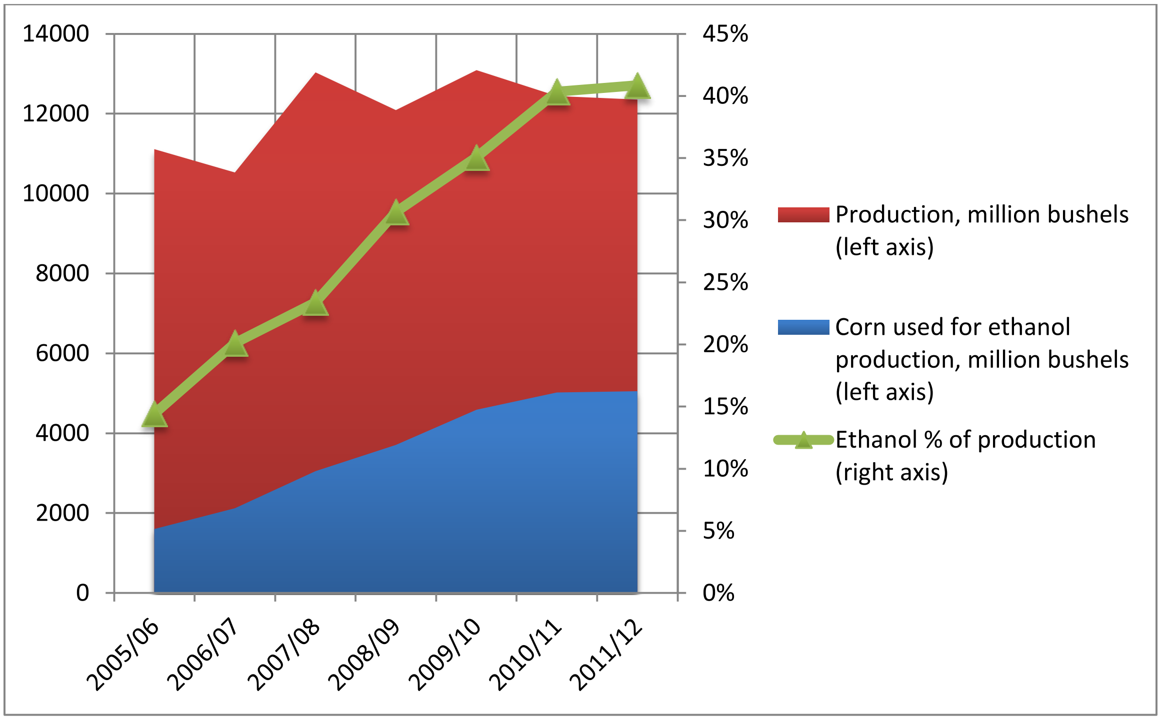
Before the RFS, ethanol was on pace to replace MTBE on a 1:1 basis, which would have put ethanol at 4% of the gasoline pool and require 2 billion bushels of corn annually. But EISA (Energy and Independence Security Act of 2007) went far beyond substituting for MTBE. After EISA was passed in 2007, demand for corn exploded. EISA mandated that 9 billion gallons of 'renewable' ethanol be blended in 2008, growing to 15 billion gallons in 2015. By default, this implied corn ethanol. EISA sent a clear signal to the ethanol and agricultural sectors that there would be immediate and rapid demand growth for corn.

Figure 10. Volumetric Biofuel Mandates Under RFS II



Ethanol demand for corn rose from 14% of the 2005/06 harvest, 1.6 billion of 11.1 billion produced bushels, to 40% of the 2010/2011 harvest, or 5 billion of 12.5 billion bushels. The following chart shows corn production and ethanol corn consumption plotted on the left axis, with ethanol's share of total produced bushels on the right axis.

Figure 11. Corn for Ethanol



Source: USDA Data, EPRINC Calculations

Corn growers responded to the mandates by planting more corn – but not enough. Planted corn acres increased 12.4% from the 2005/2006 crop year to the 2011/2012 crop year. In 2005/2006 81.78 million acres were planted compared to 91.92 million acres in 2011/2012. Yields improved from 2005/2006 through 2009/2010, rising from 147.9 bushels per acre (b/a) to 164.7 b/a, contributing to additional supply growth. But for the past two years yields have declined. The 2011/12 crop yielded just 147.2 b/a and the current 2012/2013 crop is expected to come in at 122.8 b/s, according to USDA's September outlook.

The 12.4% increase in planted corn acres has not been enough to offset the growth in corn demand for ethanol. This is exacerbated by the recent reversal in yield growth. Ethanol demand for corn in terms of acres planted has grown 26.3 million acres during the past seven years, from 11.4 million acres in 2005/2006 to 37.7 million acres in 2011/2012. After accounting for growth of 10 million planted acres during this period, demand for ethanol still consumes 16 million acres from existing pre-RFS levels. The net result from this overwhelming demand growth is a 210% increase in the price of corn since 2005/2006 and a reduction in corn use by other industries. FarmEcon, LLC pointed out in a July 2012 report that "following the late 2007 increase in the RFS, food price inflation relative to all other goods and services [including energy] accelerated sharply to twice its 2005-2007 rate."[19] Table 1 below shows the data described above broken down into individual years.

Table 1. Corn Acreage, Yields, Use and Prices

Crop Year	Alcohol for fuel ethanol	Planted acreage (Million acres)	Production (Million bushels)	Yield per harvested acre (Bushels per acre)	Weighted-average farm price (dollars per bushel)
2005/06	1,603.32	81.78	11,112.19	147.90	2.00
2006/07	2,119.49	78.33	10,531.12	149.10	3.04
2007/08	3,049.21	93.53	13,037.88	150.70	4.20
2008/09	3,708.89	85.98	12,091.65	153.90	4.06
2009/10	4,591.16	86.38	13,091.86	164.70	3.55
2010/11	5,021.21	88.19	12,446.87	152.80	5.18
2011/12	5,050.00	91.92	12,358.41	147.20	6.20
05/06 vs 11/12	***214.97%***	***12.40%***	***11.21%***	***-0.47%***	***210.00%***

Source: USDA Data, EPRINC calculations.

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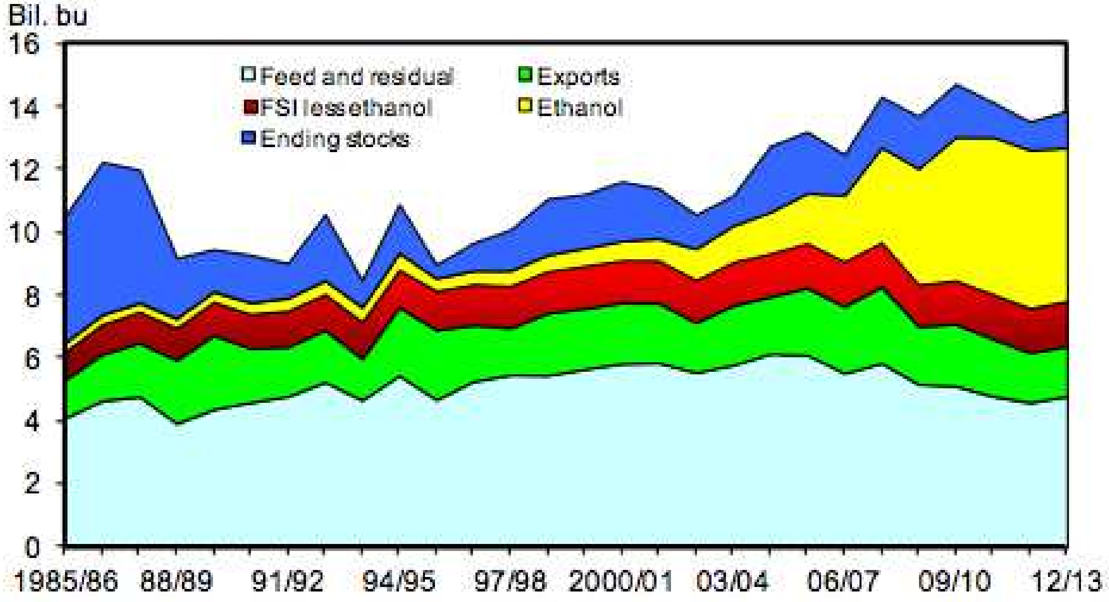
[19] *The RFS, Fuel and Food Prices, and the Need for Statutory Flexibility*, FarmEcon LLC, July 16, 2012

The USDA chart below shows corn consumption by end user. Consumption growth following the passing of EISA has come at the expense of non-ethanol sectors.

Figure 12. Corn Consumption by Sector



Source: USDA, World Agricultural Outlook Board, *WASDE.*

<u>DDGS as a Corn and Soy Substitute</u>

Ethanol refiners use the starch in corn to create fuel alcohol, commonly referred to as ethanol. The ethanol production process generates a protein rich byproduct called DDGS. DDGS is used a feed component for cattle, swine, and poultry feed rations. Approximately 17 pounds of DDGS are generated per bushel of corn processed at an ethanol plant. A typical ethanol plant generates 2.7 gallons of ethanol per bushel of corn. DDGS is primarily a substitute for corn feed but can also substitute for soy meal in certain cases. It may only be fed to livestock in limited quantities and therefore cannot fully replace corn and soy meal, rather it compliments them.[20]

The boom in ethanol production has led to corresponding growth in the DDGS market. DDGS production has grown from 25.92 million short tons (mm st) in 2007/2008 to a projected 42.33 mm st

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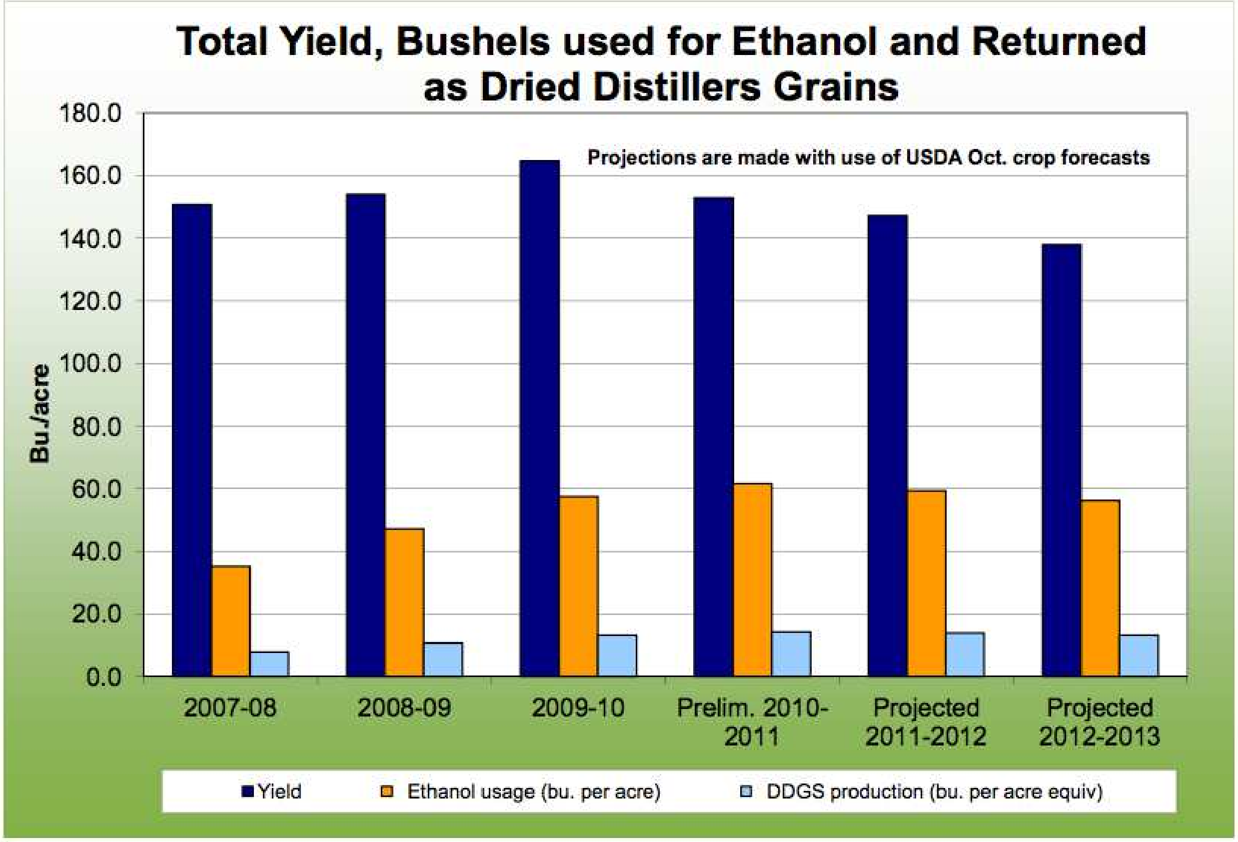
[20] See USDA, http://www.ers.usda.gov/media/236568/fds11i01_2_.pdf

for the 2011-2012 crop year. According to Iowa State University's DDGS Balance Sheet, in 2011/2012 DDGS substituted for 7.9 million acres of corn (1,159 million bushels of corn equivalent) and 6.09 million acres of soybean production. So although ethanol producers purchased 34 million acres worth of corn last year when yields were 147 bushels per acre, 14 million acres of soy and corn equivalent in the form of DDGS were returned to the feed supply. Sales of DDGS also provide cost recovery for ethanol producers and are an important part of producers' revenue streams.

The chart below comes from the DDGS Balance Sheet. The amount of DDGS produced is directly proportional to the amount of corn consumed by ethanol plants, although quality may vary slightly. The Balance Sheet's calculations for corn and soy bushels offset by DDGS take into account DDGS' higher energy content by weight relative to corn.

Figure 13. Corn Yields, Ethanol Use and DDGS Returned.



Source: Iowa State University DDGS Balance Sheet, July 23, 2012.

Soy is the second most consumed biofuel feedstock. For the 2011/2012 crop year, Iowa State University estimates that 10.2% of all harvested soy acres, or 7.4 million acres of 73.6 acres, were used for biodiesel production.[21] This is another figment of the RFS. The RFS calls for 1 billion gallons of biodiesel in 2012 – despite the fact the US is on track to export 12 billion gallons of distillate in 2012. Biodiesel is often too costly for obligated parties or in short supply. This has led to high biodiesel RIN prices, often over $1/gallon, which have created their own economic signals: several companies have recently faced Federal charges for producing tens of millions of dollars of fraudulent biodiesel RINs.

U.S. biofuel production from corn and soy consumed 41.5 million acres of a combined 161 million harvested corn and soy acres during the 2011/2012 crop year. Corn and Soybeans are the two most widely planted and consumed crops in the United States. DDGS 'offset' a combined 14 million acres of biofuel land use according to Iowa State's DDGS Balance Sheet. This leaves net biofuel land use at 27.5 million acres, representing 17.1% of total harvested corn and soy acreage. This data is reflected in the table below. Acreage for corn ethanol includes ethanol that is eventually exported.

Table 2. Corn and Soy Acreage, Biofuel Use, DDGS Offset for 2011/2012 Crop

	Harvested Acres (million)	Acres for Fuel 2011/2012 Crop Year	Acres Offset by DDGS from Corn Ethanol	Net Acres Use for Fuel	Net % of Harvested Corn and Soy Acres Used for Fuel
Corn	84	33.8	7.9	25.9	30.83%
Soy	77	7.7	6.09	1.61	2.09%
Total	***161***	***41.5***	***13.99***	***27.51***	***17.09%***

Source: Iowa State University Data, EPRINC Calculation.

Note that 7.7 million acres of soy went to biofuel production and 6.09 million acres were offset by DDGS from corn ethanol production. One way to consider this is that recent growth in corn ethanol production has generated enough DDGS to offset a majority of the soybean production used for biodiesel.

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[21] http://www.extension.iastate.edu/agdm/crops/outlook/biodieselbalancesheet.pdf

Recall that U.S. ethanol consumption could be reduced to 400,000 bbl/d, all biodiesel supplies could be removed from the market, and with a small adjustment in yields, U.S. refiners could make up this shortfall of biofuels without processing any additional crude oil and would remain a net exporter of distillate fuels. If the RFS were waived for both conventional ethanol and biodiesel, allowing such a situation to occur, the decline in biofuel land use would be dramatic. Table 3 shows net biofuel land use for 400,000 bbl/d of ethanol and no biodiesel. It is likely that some ethanol would be exported, as it is today, and therefore, ethanol production would be slightly higher. There may also be some discretionary blending above the 400,000 b/d level if it is economically attractive. This 400,000 bbl/d assumes only production for domestic consumption replacing MTBE. Because biodiesel offers no unique qualities at low concentrations, as ethanol provides as an oxygenate, and given the high price of biodiesel fuels and biodiesel RINs, it is likely that biodiesel in its current soy-derived form would vanish from the marketplace.

Table 3. Biofuel Land Use: 400,000 bbl/d ethanol, no soy biodiesel

	Gross Acres for Fuel (millions)	Acres Offset by DDGS (million)	Net Acres for Fuel (million)
Corn	15.43	3.61	11.82
Soy	0.00	2.78	-2.78
Total	***15.43***	***6.39***	***9.04***

Source: Iowa State University data, EPRINC calculations

Table 4 shows the net change between tables 2 and 3 and the resulting land use savings.

Table 4. Net land use change between tables 2 and 3.

Current Net Acreage for Fuel (after DDGS 'offset'), million acres	27.51
Net Acreage for Fuel in waived RFS scenario - 400,000 bbl/d ethanol (excludes exports), no soy-based biodiesel	*9.04*
Biofuel Land Use Reduction	***18.47***
Biofuel Land Use Reduction, % change	***67.13%***
% of 2011/2012 corn and soy harvested acreage not needed for biofuels	11.47%
DDGS Shortfall, Million Acres of Corn and Soy Equivalent	-7.60
Net Biofuel Land Use Reduction after DDGS Shortfall	***10.86***
Net Biofuel Land Use Reduction after DDGS Shortfall, %	***39.49%***

Source: Iowa State University data, EPRINC calculations

The result is that biofuel land use declines by 18.47 million acres, nearly 70%. But because corn processed at ethanol plants is reduced, the supply of DDGS declines by 7.6 million acres of corn and soy equivalent and would have to be recovered by planting an equivalent amount of feed crop. Although this shortfall would have to be made up by planting 7.6 million acres of corn and/or soybeans, the use of this 7.6 million acres would no longer be driven by ethanol-centric policy concerns. After accounting for the 7.6 million acre DDGS claw back, almost 11 million acres of land, 40% of current biofuel land use (net of DDGS offset), would remain to be allocated to market driven uses. Eleven million acres is equivalent to an area 1.6 times the size of the state of Maryland.

An important insight to come out of this scenario is the impact of reducing both the conventional ethanol and biodiesel mandate together. If only the conventional ethanol mandate is waived, a significant amount of DDGS that has served to offset soybean for biodiesel use would be lost. With the biodiesel mandate still in place and the ethanol mandate waived, the full 7.7 millions acres of soybean remain consumed by the biodiesel sector as opposed to 1.61 when the DDGS offset from corn ethanol is considered. This increases the 7.6 million acre DDGS shortfall in table 4 by 6.09 million acres to 13.69 million acres. The shortfall will in large part be offset with increased corn consumption by ethanol plants and grain end-users, dampening the impact of waiving the corn ethanol mandate. When both are waived together, the loss of DDGS supplies from decreased corn ethanol production is matched by a decline in soybean consumption for biodiesel, partially offsetting one another.

A reduction in ethanol and soy biodiesel production would reduce the supply of DDGS. The benefits to livestock producers are twofold. Reduced ethanol demand for corn will lower corn prices. Due to the correlation between corn and DDGS prices, DDGS will follow lower. Livestock producers will have additional flexibility in feeding their animals as more corn and soy become available, and at a lower cost. The DDGS boom was driven by the RFS, not by a problem with corn and soy supplies. Livestock producers will have the option to return to less DDGS intensive feed mixes if they wish.

Conclusion

The principle benefit of an RFS waiver is to open up flexibility in both the food and fuel markets. For example, it is reasonable to believe that U.S. ethanol production would be 100,000 to 200,000 bbl/d higher than the 400,000 bbl/d to which we have limited this scenario. Corn prices could drop significantly as the grain's largest purchaser, the ethanol industry, scales back consumption. A decline in corn prices would lead to more competitive ethanol prices and increased discretionary blending and exports. This would also serve to offset to the DDGS shortfall. Refiners would be free to adjust their operations in order to maximize efficiency rather than adjusting to the RFS. The livestock industry would have more freedom in choosing feed components. Not only is DDGS limited in its applications for livestock, its market share (and price) has grown proportionally with the increase in corn ethanol production at the expense of existing feed options. The livestock industry would certainly like the RFS to be adjusted in order to provide more feed choices.[22]

Despite the droughts and record prices for corn and other crops, the RFS has ensured that billions of bushels of corn and soy are set to be converted to fuels which offset less than 5% of the nation's petroleum fuel supply. These fuels can be replaced by a slight change in refinery yields and would not jeopardize the Unites States' position as a net distillate fuel exporter. The droughts are unlikely to threaten the blending mandate in 2012. Carryover RINs, which were anticipated to be used in 2013 and 2014 to offset physical blending limitations, can be applied in 2012 to meet RVOs. The loss of these RINs

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[22] The Cattle Network, http://www.cattlenetwork.com/cattle-news/Livestock-poultry-coalition-petitions-for-RFS-waiver-164288416.html

will accelerate the arrival of the blendwall. Meanwhile, cattle slaughter rates are rising because DDGS and other feed costs have risen dramatically in recent months. The food and fuel industries will adjust, but the question is at what cost?

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Can biofuels policy work for food security?

An analytical paper for discussion

Chris Durham, Grant Davies, Tanya Bhattacharyya

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Contents

Preamble

In April 2012, the UK published its Bioenergy Strategy, setting out the Government's commitment to bioenergy alongside the need to ensure it is produced sustainably:

> "Bioenergy is expected to play a key role in our ability to meet the 2020 renewables target as well as longer term carbon reduction targets to 2030 and 2050. But we recognise that bioenergy is not automatically low carbon, renewable or sustainable: alongside its many positives, bioenergy carries risks.
>
> "The UK bioenergy strategy, published jointly by DECC, Defra, DfT sets a framework of principles to guide UK bioenergy policy in a way that secures its benefits, while managing these risks.
>
> "The strategy's overarching principle is that bioenergy must be produced sustainably and that there is a role for UK Government to steer sustainable development of bioenergy in the UK and as far as possible internationally."
>
> http://www.decc.gov.uk/en/content/cms/meeting_energy/bioenergy/strategy/strategy.aspx

The Bioenergy Strategy commits the UK Government to further work to investigate the merits of temporarily flexing or otherwise relaxing biofuels mandates at times of agricultural price pressures (page 72). The current paper presents work by Defra analysts to explore some of the potential implications of this idea. It does not represent a change in Government policy.

The authors are all staff at the UK Department for Environment, Food and Rural Affairs (Defra). Chris Durham is an Economic Advisor on Commodities Markets and Global Food Security. Tanya Bhattacharyya is an Assistant Economist. Grant Davies is an Economic Advisor on Partial Equilibrium Modelling.

The authors are grateful for advice received from colleagues at HM Treasury, the Department for Transport, the Department for Energy and Climate Change, the Department for Business, Innovation and Skills and the Organisation for Economic Cooperation and Development. All errors are our own.

Executive Summary

Grains and oilseeds produced for use in biofuels could be allowed to flow into animal feed or human food markets during temporary spikes in the price of agricultural commodities. Currently this is strongly discouraged from happening by legal requirements to blend biofuels with conventional transport fuel (often called biofuels mandates or blending obligations), but temporarily relaxing these requirements could allow agricultural markets to work more efficiently and reduce the size of a price spike.

A system of flexible mandates would in effect create a 'virtual grain store'. Biofuels mandates have led to increased agricultural production relative to a state of the world where there are no biofuels mandates - this extra supply could follow market forces onto food or animal feed markets during a price spike, if the mandates allowed it.

Research carried out by the UK Department for Environment, Food and Rural Affairs (Defra) shows that up to 15% of a hypothetical spike in the price of "coarse grains" could be avoided if the European Union removed its biofuels mandate at the same time as prices started to spike (coarse grains include maize, barley, oats etc.). The work also finds that similar action in the US could avoid over 40% of a hypothetical spike in coarse grain prices.

Introducing flexibility into biofuels mandates is only one potential way to reduce price spikes in grain markets. Better information on supply and demand and encouraging undistorted international trade, as well as a number of other initiatives are also currently being pursued by the G20 and others in order to reduce volatility in agricultural commodities markets. This proposal should be seen as part of a broader effort to consider all policy options; it is important to investigate further so this option can be considered alongside its alternatives.

In the European Union (EU), biofuels production is encouraged in a number of ways. The Renewable Energy Directive obliges a 10% share of renewable energy in the transport fuel mix by 2020, subject to the "sustainability" of production and commercial viability of second-generation biofuels. It is left to individual EU Member States to decide how best to achieve this target, and across the trading bloc reduced taxes, production subsidies and capital grants may be used. The EU also imposes various tariffs and quotas on imports of biofuels. These targets are for renewable energy in any form, but current technology and infrastructure mean that biofuels produced from grain and other foodstuffs are the most cost-effective way to meet them.

US biofuel policy consists of quantitative mandates for biofuel consumption (the Renewable Fuel Standard) requiring that by 2022, 36bn gallons of renewable fuel be consumed annually and of this 15bn gallons come from maize-ethanol (this translates into a need for about 143 million tonnes of maize in 2022 – equivalent to 45% of the 2010/11 maize harvest in the USA). Since the US is the only major maize-ethanol producer, this acts as an effective US production mandate. Until January 2012, there was also a subsidy to ethanol blenders (the ethanol blenders' tax credit) and import duties payable on biofuels.

Removing the EU blending obligation (but retaining import tariffs and tax support) in the same year as a hypothetical spike in the global price of wheat, could reduce the magnitude of the spike by anything from 10% to 35%. Similarly, a hypothetical spike in the price of coarse grains could be mitigated by up to 15% by removing the blending obligation. These two price spikes are simulated by introducing a 25% reduction in the area of wheat or coarse grain harvested in the EU in either 2011 or 2018, which leads to price rises of up to €200 per tonne for wheat and €100 per tonne for coarse grain.

Reducing the US blending obligation to one half of its current value in the same year as a spike in the global price of coarse grain, could reduce the magnitude of the spike by around 40%. The model we used to calculate these figures would not allow for both US and EU mandates to be completely removed at the same time: the adjustment required in international commodities markets proved too large for the model to solve. This hints at the significant benefits of coordinated policy, but the important impacts of unilateral action by either the EU or US also demonstrate that it may not be necessary to wait for coordination.

These results are based on the AGLINK-COSIMO partial equilibrium model of the next 10 years of the global agricultural economy, developed and maintained jointly by the OECD and FAO. Results are generated from highly stylised scenarios in which agricultural prices spike, but oil markets are unaffected. In this model, the benefits of flexing biofuels mandates are therefore achieved at zero cost to oil or bioenergy markets. It will be useful to develop this initial analysis to explore alternative scenarios including feedback effects in the oil market, and to investigate what impacts there could be on bioenergy markets.

As with any modelling exercise, this approach has its limitations and there are reasons to believe the results presented here could over- or under-estimate the true potential of the idea. The model ignores the impact of panic buying and export restrictions, which often come in response to a price spike – if this policy avoided panic behaviour or export restrictions, its benefits would be significantly greater than suggested here. However, it also ignores how biofuels refiners might respond differently to a temporary rather than permanent change in the blending mandate. Further analysis of this idea should therefore not rely exclusively on high-level modelling.

Both the trigger and the mechanism used to introduce flexibility into mandates are crucial, and deserve more attention because these will dictate the impacts of the proposal on bioenergy and other markets. The trigger must be independent of political control to ensure this does not become a tool for market management and increase uncertainty in agricultural and bioenergy markets. The mechanism by which flexibility is introduced could potentially be designed to avoid a reduction in the overall ambition of bioenergy targets. Specific proposals for triggers and mechanisms need to be investigated and their costs and benefits assessed.

This work reveals the very significant potential associated with a mechanism that allows market forces to direct grain between biofuels, animal feed and food markets during a temporary supply shortage and price spike. It has not examined the implications of this idea for bioenergy markets and stops short of examining a particular mechanism, instead calling for commitments to more work to develop specific proposals and to appraise their individual merits.

The urgency of considering this proposal now arises from a review by the European Commission of EU renewable energy targets due in 2014, when a decision whether to introduce such flexibility into biofuels mandates could, in principle, be taken.

Introduction

Throughout 2011, volatility in agricultural markets was hotly discussed in international policy circles: The UK published its Foresight Project on *The Future of Food and Farming*, the G20 committed to a 5-point Action Plan including action on volatility in agricultural markets and the UN's Committee on Food Security used its annual meeting in October to discuss volatility. For the second time in 5 years, agricultural commodities prices experienced a significant spike.

Many scientific papers point to the potential for volatility to increase in the future. Increased climate variability that impacts on agricultural yields is expected to result from climate change, and higher average incomes are likely to make demand for grains less responsive to prices, causing prices to rise further in response to shocks with important consequences for those on lower incomes.

Previous research conducted by UK Government Officials (HMG 2010) has argued that to date, biofuels are unlikely to have been a major driver of price spikes. The 2007/08 agricultural price spike was the result of a number of factors, including low international stock levels (itself a function of poor harvests in certain key countries and growing consumption), initial concerns about the 2008 harvest, rapid increases in energy costs, a significant weakening of the US Dollar and export restrictions imposed by some 30 countries. However, this paper contends that more flexible biofuels policies which allow grain to follow market forces during an agricultural price spike, could augment availability for food and animal feed and help to reduce the magnitude of similar grain price spikes in the future.

There are a number of potential ways to address volatility in agricultural markets, including:

- improving provision of information, as proposed by the G20 and institutionalised in the Agricultural Markets Information System (AMIS)
- improving the efficiency of the agricultural sector
- trade liberalisation
- stocks policies
- more flexible biofuel mandates

This paper is designed to open up an important debate: should biofuels policies in the EU or the US be adjusted to help reduce price volatility in global food and animal feed markets? It explores reasons why we might want to use biofuels policy to reduce volatility in global agricultural markets, and presents new research by Defra analysts that demonstrates the potential of this idea.

The paper has been prepared by Defra officials to inform and promote discussion. It does not represent a change in UK Government policy towards biofuels.

This paper demonstrates that removing support for biofuels during a grain price spike could reduce the magnitude of the spike. If implemented in the EU, this proposal could reduce the magnitude of a spike in the price of wheat by anything from 10% to 35%. Similarly, a spike in the price of coarse grain could be mitigated by up to 15%.

If a similar approach was followed in the US, modelling (presented in Annex A) shows that the magnitude of a spike in the price of coarse grain could be reduced by 40% if half the mandate was made flexible (the figure grows to over 55% reduction in the size of the spike if 75% of the mandate is temporarily waived).

The role that biofuels play in causing price spikes and general volatility in agricultural markets is the subject of much debate in academic and policy circles, and is not revisited here. However our findings suggest that, whether or not biofuels contribute to price spikes and volatility, introducing flexibility into biofuels mandates could potentially contribute to a solution.

Although there are challenges associated with implementing this proposal, the magnitude of its effects suggests it is worth further consideration. A first step would be to design more specific implementation options and assess each of these on their own merits.

The paper has eight sections. Section 2 provides background on biofuels policy and how it may increase volatility in agricultural markets; section 3 develops this into a reason for government action and section 4 runs through existing policy initiatives to address volatility. Section 5 presents the results of Defra's new research and section 6 discusses the practicalities of implementing flexibility in biofuels mandates. Section 7 concludes the paper and section 8 proposes a series of "next steps" for the UK Government if it chooses to develop the idea further. Annex A presents the results of modelling flexibility in US biofuels markets, and Annex B describes the parameters we changed in the model to carry out our research.

What do biofuels policies do to agricultural markets?

This section explores what biofuels policies in the EU and US do to markets, in order to frame the subsequent discussion.

Governments may have a range of objectives when encouraging the use of biofuels. But changes in oil, grain and other prices mean that the optimal amount of biofuel production for the purposes of these objectives is constantly changing. An "economically efficient" biofuels policy would allow grains and other resources to be switched between biofuel production and other uses as dictated by the relevant market prices. With fixed blending obligations and mandates, this adjustment is prohibited so such policies could in theory represent a significant market distortion – in the face of any price spikes, fixed biofuel mandates effectively force all of the adjustment in demand onto the food and animal feed sectors.

Al Riffai et al. (2010) provide a good overview of the major biofuels policies affecting EU markets, including EU, US and Brazilian policies. In the EU itself there are several initiatives to promote use of biofuels: the Renewable Energy Directive and the Fuel Quality Directive set obligations for blending biofuels with conventional transport fuels; the Energy Tax Directive allows Member states to use tax incentives[1]; production subsidies and capital grants are also used as alternative incentives, in particular by the UK. Together these policies lead to significantly more biofuels production than a free market would given the current constraints around information, certainty of investment and climate change impacts. In 2014 the European Commission will be reviewing its targets for renewable energy.

US biofuel policy consists of quantitative mandates for biofuel consumption (the Renewable Fuel Standard) requiring that by 2022, 36bn gallons of renewable fuel be consumed annually and of this 15bn gallons come from maize-ethanol. Since the US is the only major maize-ethanol producer, this acts as an effective US production mandate. Until January 2012, there was also a subsidy to ethanol blenders (the ethanol blenders' tax credit) and import duties payable on biofuels (Yacobucci 2012).

Collectively these policies will raise the price of agricultural commodities and will contribute to making prices more volatile, although at current levels of biofuel production the size of these effects is hotly debated and perhaps small (for examples of this debate see OECD 2006, 2008; HMG 2010; Babcock 2011; Laborde 2011; Wright 2011).

In theory: as increasing demand incentivises agriculture to produce more, the marginal (and average) cost of production rises relative to the counter-factual and so does price because either poorer quality land has to be used or more intensive (and expensive) farming methods must be employed. These price increases will incentivise efficiency gains in the long run, bringing prices down again somewhat, but not below the price level we would have seen without demand from biofuels. Stimulating demand for specific crops (biofuels feedstocks) also encourages land away from alternative crops/uses. Equally, by imposing an obligation on blending biofuels with petrol or diesel, this "extra demand" for grains and oilseeds is largely constant[2], irrespective of availability and price of

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[1] The UK chooses not to use this particular lever.

[2] To be precise, the overall demand for biofuels is constant, and if sufficient and cheaper alternatives to grain were available, blenders today could switch to biofuels produced using alternatives to grains and oilseeds.

feedstocks[3]. Consequently, when grains are scarce the consequences of reduced supply (i.e. reduced consumption) falls on other markets, and in particular the food and animal feed markets, rather than being shared between these and the biofuels market.

However, there is also a significant body of literature on the need to reduce the use of fossil fuels in transport and to find alternatives that do not contribute to climate change. The challenge for Governments is to find policy levers that contribute to their carbon reduction objectives without imposing avoidable costs elsewhere.

In *Price Volatility in Food and Agricultural Markets: Policy Responses*, 10 international organisations suggest introducing flexibility as "a second-best alternative" to removing mandates altogether (FAO et al. 2011).

The United Nations Conference on Trade and Development (UNCTAD, undated web page) has called "For the United States and the European Union and for other countries relying on mandated blending volumes or percentages to introduce flexibility in those targets so as to restore the natural balance played by markets."

Why does this matter?

It is not simply enough to assert that biofuels policies could be redesigned to reduce the magnitude of price spikes: there remains the important question of why this matters.

The terms "price volatility" and "price spikes" are often used interchangeably because they share many of the same impacts, but the difference can be important. "Price volatility" tends to be used to describe multiple variations in price over a period of time, so a single spike that is preceded and followed by stable prices does not indicate a volatile market. This has led commentators like Gilbert and Morgan (2011) to conclude it is too early to say whether, post-2007, we have entered a new phase of higher price volatility. Price spikes, on the other hand, involve rapidly rising and then falling prices, so have a specific direction. Evidence collected by the UK's Government Office for Science suggests that factors such as climate change could lead to more price spikes in future as the frequency and severity of extreme events increase (Foresight, 2010).

Price volatility and price spikes matter when they affect incomes, either of producers or consumers. Volatility can also affect investment decisions, reducing "risk-adjusted" returns on investment and potentially leading to less investment in agriculture. "Net consumers" (those who produce food, but consume more) in developing countries may be more affected than others by price spikes because they spend a larger share of income on food and may have fewer alternatives to switch between as prices rise. For these net-consumer

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However, the modelling we undertake here accounts for this degree of substitution and still finds a significant benefit to the proposal.

[3] Some EU member states have a mechanism whereby blenders can buy-out of their obligation to use biofuels if the costs are high relative to the oil price, but in practice the threshold for taking advantage of this buy-out option has never been reached.

households, diverting resources from staples into producing higher value cash crops is more difficult/unattractive where food markets are volatile.

It is plausible that the global market responds in an "economically efficient" manner to higher volatility by increasing privately held stocks of grain. Gilbert (2011) writes, "there is no generally valid theoretical argument that, at the world level, private storage will be inadequate". In effect, players in the global market can be expected to efficiently correct for higher volatility by making use of futures markets and/or increasing privately held stocks.

Indeed, the "optimum" amount of volatility in agricultural markets will not involve perfectly stable prices, because such a situation could only be achieved at extremely high cost and would lead to a miss-allocation of resources between these artificially stable agricultural markets, and other more volatile markets. But this does not imply that we should ignore the potential impact of biofuels mandates on volatility. Biofuel mandates are an instrument of public policy. The question is whether they should be designed in ways that reduce or increase agricultural market volatility.

This has led some commentators to share UNCTAD's view that "the relationship between biofuels and food price spikes should be interpreted more as a policy failure than as an intrinsic and unavoidable consequence of the production of biofuels." (UNCTAD, undated webpage).

A menu of solutions for addressing volatility

Regardless of whether biofuels are responsible for price spikes or volatility, there is a general need to reduce volatility for the benefit of those at risk of food insecurity, to promote investment and "pro-poor" growth. There is at least a case for the costs of this action being borne by states with stretching biofuels mandates, since these states commonly have significant international development objectives.

But of course biofuels mandate flexibility is not the only potential solution to volatility in agricultural markets. There is a history of unsuccessful attempts to reduce volatility in commodities markets. In the past, the following have been tried:

- International Commodities Agreements (ICAs) were used in the past to try to manage price volatility, but proved much more effective at raising prices than stabilising them (Gilbert 2011, Gilbert and Morgan 2010).
- Publicly held global stocks might reduce volatility, although there is evidence that these simply crowd-out private stocks and prove very expensive (Miranda and Helmberger 1988; Gilbert and Morgan 2010; Gilbert 2011).

In more recent years, the following have been suggested:

- Better market information may reduce volatility. In May 2011 the G20 highlighted that some volatility in agricultural markets could be avoided simply by providing better information, and this led to the creation of the Agricultural Markets Information System (AMIS) (G20 2011).

- Nationally or regionally held stocks may be an alternative for areas without private stocks or access to global markets (Gilbert 2011).
- To mitigate the effects of volatility at a national level, Governments could buy "call options" in futures markets (Morgan 2001, Gilbert and Morgan 2010). These tools are also available to businesses and individuals.
- Wright (2011) has proposed a mechanism for diverting grain from "non-essential" to "essential" uses in times of crisis. The UK Department for International Development (DfID) have commissioned a study to explore this idea further.

A more complete list of policy options would also include improving the productivity and responsiveness of the agricultural sector, and removing trade distortions in agricultural markets.

Finally, to this suite of policy options it is important to add the relatively new possibility of flexible biofuels mandates. Similar to improving free trade and productivity, but unlike the proposals relating to public and private stocks, flexing existing biofuels mandates need not further increase agricultural commodities prices at the same time as reducing volatility. To date, evidence on the costs and benefits of introducing flexibility into biofuels mandates is much less developed than for some other options. But the modelling reported in the rest of this paper suggests that the possible magnitude of the impact of biofuel mandate flexibility on international price volatility is very significant and should be taken seriously by the international community.

Estimating the potential impact of flexible mandates

This section outlines the method, results and conclusions of a modelling exercise undertaken by Defra analysts.

At a minimum, a flexible biofuels mandate needs two characteristics:

- Bring grain onto the food market if and only if there is an emerging price spike.
- Re-introduce the mandate only when food/feed grain is once again in sufficiently large supply.

Without making further assumptions about the delivery mechanism, Defra analysts have taken a first look at the impact of relaxing EU biofuels support during a few different grain price spikes. Defra has also examined the impacts of flexibility in the US mandate in a separate exercise, reported in the annex to this paper.

Due to modelling limitations, our work only examines the impact of removing support during an agricultural price spike – we continue to explore how best to reintroduce support in our model at the end of the spike.

Introduction to the modelling exercise

Four price spikes were investigated one at a time using the AGLINK-COSIMO 2010 model (OECD/FAO 2010). For each spike we ran the model twice – first to see what happens if EU biofuels support is maintained, then if support is removed entirely in the same year as the spike. Nothing else in the model was changed from the OECD/FAO assumptions (Annex B reports more precisely which parameters were changed). The four spikes we examined are:

1. **Wheat shock 2011**: 25% reduction in the area of wheat harvested in the EU in 2011
2. **Wheat shock 2018**: 25% reduction in the area of wheat harvested in the EU in 2018
3. **Coarse grain shock 2011**: 25% reduction in the area of coarse grains harvested in the EU in 2011[4]
4. **Coarse grain shock 2018**: 25% reduction in the area of coarse grain harvested in the EU in 2018

These different price spikes can be thought of as the result of unusually poor weather in Europe, leading to a reduction in global availability of grain. The shocks should not be interpreted as the result of biofuels policy.

This approach does not allow us to test whether biofuels mandate flexibility could help to avoid panic behaviour, either by consumers in the form of panic buying or producing states in the form of export restrictions. Currently there are no agricultural models that claim to be able to simulate such behaviour.

Detailed method for modelling exercise

This section outlines the method in more detail and discusses its main strengths and weaknesses. Readers interested in how we changed the structure of the AGLINK-COSIMO model can refer to Annex B.

AGLINK-COSIMO is a "partial equilibrium model" of the global agricultural economy, which is designed to answer questions about how changes in policy might affect agricultural markets over the next 10 years. It is therefore forward-looking, and can provide results broken down by region, by agricultural product and by usage.

To do this, AGLINK-COSIMO examines the complex interactions between different products grown in different regions and used for various purposes all over the world. For instance, our shocks to the wheat area in the EU translate into a price spike for coarse grain as well as wheat, because higher wheat prices make coarse grain-derived animal feed and bioethanol more attractive, so demand for coarse grain increases and price

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[4] Maize is used as shorthand to mean all coarse grains, which actually includes barley etc. Maize makes up a large proportion of coarse grains at the global level so this is a reasonable simplification.

follows. Changes in EU production lead to global changes in price because production in the EU affects how much is available elsewhere in the world through imports and exports. Demand for wheat for use as human food, for animal feed and for biofuels changes by different amounts even though they all face the same price spike[5], depending on the alternatives that are available for each use. By-products from biofuels production re-enter the market as animal feed.

Twenty-four different combinations of shocks and flexible biofuels support were examined as part of this investigation, but the most significant results were seen when all support for biofuels was removed so this is what we report. Results from other model runs are discussed briefly in section 6.4 below, and show that removing the blending obligation alone is roughly equivalent to removing all support.

We focussed attention on shocks occurring in the wheat and coarse grain markets because these are by far the largest grain markets, so our shocks have impacts on the largest number of consumers. It would equally have been valid and possible to examine shocks in oilseed markets, which are likely to respond even more to relaxing EU support for biofuels because biofuels are a more significant source of demand in these markets[6].

The four shocks lead to between 70% and 150% rise in the annual price of wheat or coarse grain. For comparison, between March 2007 and March 2008, wheat prices rose almost 125%; between June 2007 and June 2008, maize prices rose 75%. This shows that whilst a weather shock that knocks out 25% of EU production is not very realistic, the resulting price spikes are of a similar magnitude to observed spikes in the recent past.

To remove all support for biofuels in the model:

- Taxes were set at the same level as diesel for biodiesel or petrol for bioethanol;
- Blending obligations were removed, leaving blending to the market;
- Import tariffs on biofuels were eliminated for imports from all nations.

Following the end of each price spike, the model did not re-introduce EU support for biofuels. This was simply to help the model solve, and we discuss its implications for the results in section 6.5.

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[5] AGLINK-COSIMO effectively models a single global price for wheat (although durum wheat is modelled separately for the EU market). This implies the same wheat could be used for human food, animal feed or biofuels production. Whilst that may not always be the case (perhaps because of quality standards for human consumption), the tight link between the prices of different types of wheat indicates that there is enough substitutability at the margin. For a graphical example of how prices of hard (bread) wheat and soft (animal feed) wheat move together, see Section 3 of Defra's monthly Farming and Food Brief http://www.defra.gov.uk/statistics/category/food-farm/monthly-brief

[6] In 2010, EU production of biofuels accounted for 39% of EU demand for oilseeds, compared to 3% of demand for each of coarse grains and wheat. Data from AGLINK-COSIMO database.

All other assumptions in AGLINK-COSIMO were left unchanged from the OECD-FAO *Agricultural Outlook 2010*, including assumptions about the oil price, population growth, incomes, total transport fuel growth and third country support for biofuels.

We discussed this approach to modelling biofuels mandate flexibility with colleagues from OECD who designed the biofuels module of AGLINK-COSIMO, and agreed this was the correct way to proceed.

The prices of wheat, coarse grain, oilseeds, bioethanol and biodiesel were recorded for each of the model runs.

Results of modelling exercise

This section presents results of the modelling exercise, showing how removing biofuels support in the EU can mitigate the 4 different price spikes. Results for each spike are presented in turn.

Results for a Wheat price spike in 2011, and in 2018

The shocks to wheat production result in the price of both wheat and coarse grain rising; other grain prices were left broadly unaffected[7]. Wheat and coarse grain prices are therefore both reported in Table 1.

Table 1: Results for wheat shocks in 2011 and 2018[8] - units are all Euros per tonne

Grain	EU biofuels support?	2010	2011 (shock)	2012	2017	2018 (shock)	2019
Wheat	Yes	€141	€264	€126	€147	€374	€141
	No	€141	€242	€125	€147	€295	€141
Coarse Grain	Yes	€70	€79	€66	€73	€103	€69
	No	€70	€78	€66	€73	€93	€69

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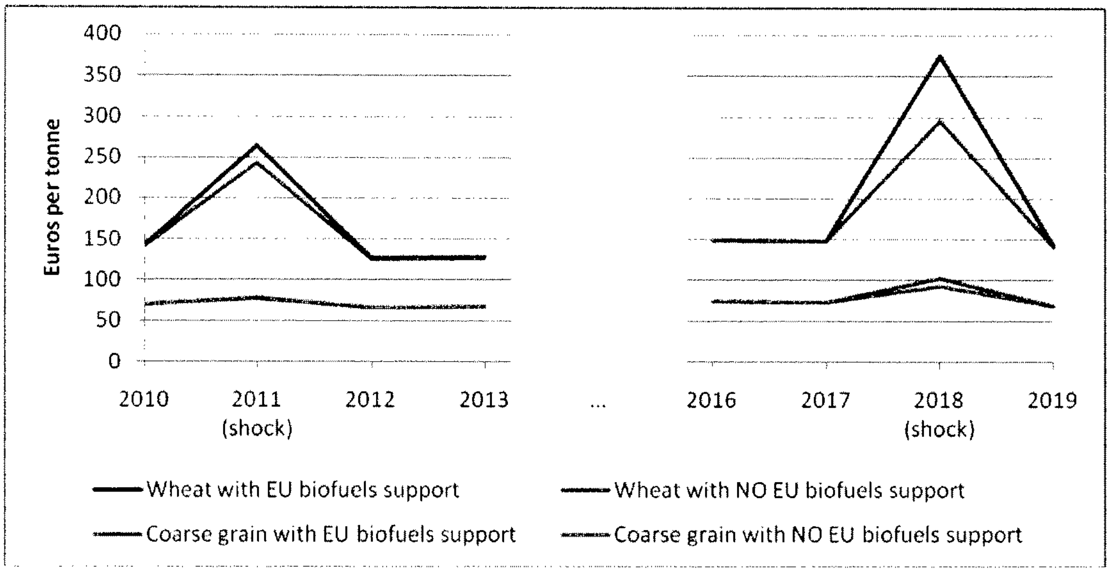
[7] Oil seed prices did rise, but only by around 4%. This is discussed in section 6.3.3

[8] Note that these shocks occur in separate model runs, i.e. the shock in 2018 is run on a model where there is no shock in 2011. The results are presented in one table purely for convenience.

Figure 1: Chart showing effect on world price of removing EU biofuels support during two wheat price spikes



The results show that the price spikes are partially mitigated by the removal of biofuels support. When there is a shock in the wheat market and both wheat and coarse grain prices rise, removing biofuels support can avoid 10-35% of this prices rise (10% for coarse grain in 2018 and 35% for wheat in 2018). These percentage changes are calculated relative to prices in the baseline version of AGLINK-COSIMO 2010, before we introduced production shocks or changes to EU biofuels support.

A few further observations:

- The mitigating impact of flexible biofuels support is greater in 2018 than 2011 because of the higher proportions of grains and oilseeds used for biofuels rather than for food or feed.[9]
- The price level following the end of the spike is lower than it was before the spike
- A temporary shock to wheat production has a fairly small impact on the price of coarse grain, in comparison to the effect on wheat price.

Results for a coarse grain price spike in 2011, and in 2018

When coarse grain production was shocked in 2011 and 2018, again we found that both coarse grain and wheat prices rose so these are reported in Table 2.

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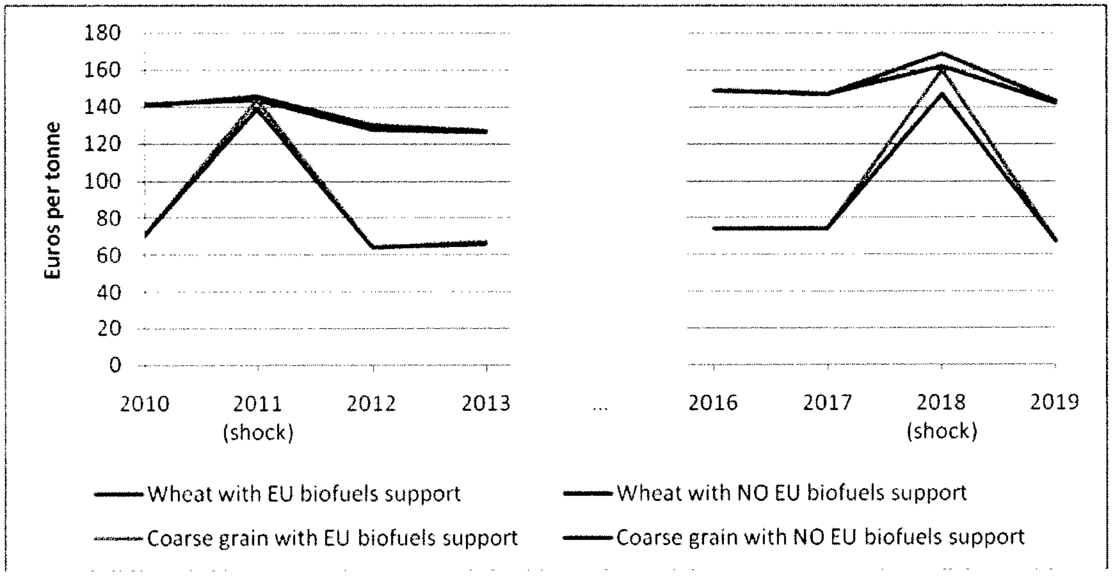
[9] The proportion of global production used in biofuels production is projected to increase by 14% for vegetable oil and 92% for wheat between 2011 and 2018. Maize is expected to see only a 3% increase.

Table 2: Results for maize shocks in 2011 and 2018 – units are all Euros per tonne

Grain	EU biofuels support?	2010	2011 (shock)	2012	2017	2018 (shock)	2019
Wheat	Yes	€141	€146	€130	€147	€169	€143
	No	€141	€144	€127	€147	€162	€142
Coarse Grain	Yes	€70	€144	€64	€74	€160	€67
	No	€70	€139	€64	€74	€147	€67

Figure 2: Chart showing effect on world price of removing EU biofuels support during two coarse grain price spikes



When there is a shock in the coarse grain market and both coarse grain and wheat prices rise, removing biofuels support in the EU can once again avoid 7-35% of this price rise (7% for coarse grain in 2011 and 35% for wheat in 2018).

Additionally:

- The mitigating impact of biofuels flexibility is again stronger in 2018 than in 2011
- The price level after the end of the spike is lower than it was before the spike
- A shock to coarse grain production has a fairly small impact on the price of wheat, in comparison to the effect on coarse grain price.

Impact of flexible mandates on other markets in the modelling exercise

AGLINK-COSIMO is designed to examine agricultural markets across the globe, and may be less suited to looking at precise quantities and prices for refined products like biodiesel and bioethanol in great detail[10], but for completeness these results are presented here.

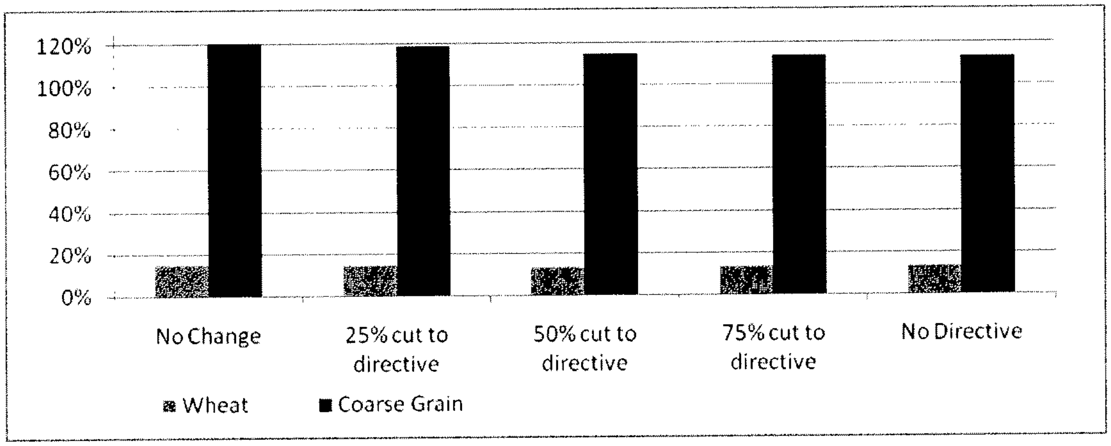
The four shocks we introduced to the model affected only feedstocks used to refine bioethanol, but there were also indirect impacts of these shocks on the price of oilseeds, which are used to make biodiesel.

- With EU biofuels support removed during a spike and (unlike the policy proposal) never reintroduced in our model, ethanol production in the EU falls by 30% 2 years after the 2011 price spikes, or by 60% 2 years after the 2018 price spikes. If support were reintroduced following the end of the spike it is unclear how ethanol production would respond, although it is likely to be lower during the period when mandates are relaxed.
- The price of oilseeds rises by 4% in response to each coarse grain shock, but by only 2-3% if EU biofuels support is removed.
- In spite of the modest rises in oilseed prices, there is no impact on vegetable oil prices and biodiesel production is unaffected.

Alternative forms of flexibility in the modelling exercise

In addition to exploring the complete removal of EU biofuels support, we also investigated partial reductions in support. For both the wheat and coarse grain shocks in 2011, we examined the impact of reducing all support by 25%, 50% and 75% as well as the impact of retaining the preferential tax rate but reducing the import tariffs and blending obligation by 25%, 50% and 75%. Finally, we investigated the effect of removing the obligation alone, and then import tariffs alone.

Figure 3: Price rises that result from a 25% reduction in the area of coarse grain harvested in the EU in 2011, for various changes to EU support for biofuels production



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[10] Whilst the biofuels module of AGLINK-COSIMO may be less developed than other parts of the model, it still represents the best available description of the links between global agricultural and bioenergy markets, and is more than adequate for this purpose.

Results of these alternative forms of flexibility were unsurprising: The more support that was removed, the greater the mitigating impact on grain prices. Removing the blending obligation alone was equivalent to removing all support. We also modelled removing import tariffs alone during a coarse grain shock in 2011, and found it lowered grain prices by around 3%[11].

Discussion of modelling exercise

The modelling exercise clearly demonstrates that there is potential for flexible biofuels mandates to mitigate a price spike, but given the limitations of the model it does not provide a complete picture of all the costs and benefits of such a proposal. The model fails to capture the potential for a robust system of flexible mandates to avoid panic behaviour, nor does it fully consider the costs to biofuels producers. Such considerations would require a fuller cost-benefit analysis of the sort described in the final section of this paper on page 20.

Focussing on the results, these can be explained fairly simply and appear to support the theoretical justification for exploring flexible mandates:

- Removing EU support for biofuels makes the entire demand side of the grain market responsive to price (as opposed to just the food and feed components of demand), so demand from biofuels producers contracts a little along with demand in the rest of the food/feed market. This "burden-sharing" avoids the need for such high prices in the food/feed markets.
- As biofuels production in the EU is set to more than double over the next 10 years (OECD 2010), it is unsurprising that reducing support in 2018 has a bigger impact than in 2011. However, this does not necessarily mean that the biofuels market will remain as reliant on (and responsive to) EU support as it is today.
- Following the end of the price spike, EU biofuels support is not reinstated in order to help the model solve, so grain prices appear lower than before the spike and bioethanol production declines after a few years. It seems unlikely that either of these effects would occur if EU biofuels support were reinstated, although there could be a long-term impact on ethanol production if EU support were flexed frequently. This is clearly an area that requires further investigation.

The fact that biofuels support is not reinstated following the end of the spike has been identified as a weakness in our approach, but we can state with confidence that it has not affected the headline results on the potential of this policy idea. AGLINK-COSIMO models biofuels supply as a function of prices in the current year and historic refining capacity – it does not include expectations of future demand (see Annex B for the detail). This means that it would provide the same results on the mitigating potential of removing biofuels support during a price spike, whether or not support were reinstated at a later date.

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[11] This suggests that removing the blending obligation and import tariffs together results in some overlap, since the sum of the two isolated effects is larger than the effect of removing them simultaneously.

However, there are other reasons to believe these results are an over-estimate of the impact that mandate flexibility might have in reality, as well as reasons to believe they are an under-estimate.

The model we have used is designed to look at the medium-run implications of changes to global agriculture, and may exaggerate the ability of the economy to respond over the course of a single year. By exaggerating the response of farmers to a price spike, it will tend to underestimate the size of this spike and therefore the potential of short-run policies to mitigate such a spike. In technical terms, the model uses medium-run elasticities that tend to be larger than short-run elasticities.

This modelling exercise ignores "panic behaviour" and may therefore be an underestimate of the effectiveness of flexible mandates/flexible support in general. If, for instance, it is known that a certain price will trigger the release of large amounts of grain onto the food/feed markets, this could be enough on its own to avoid panic buying or even to avoid the imposition of export bans. In such a situation, the mechanism prevents further "unnecessary" price rises altogether.

We have attempted to explore what would happen if both EU and US biofuels support were removed at the same time during a global price spike, but the policy changes proved too large for our model to solve. On the one hand this underscores how fragile modelling of this sort can be, but it hints at the very substantial impact that coordinated policy might have. To provide a more global perspective on the potential of this idea, we modelled flexibility in US mandates separately, and report results in Annex A.

Our modelling also ignores how biofuels refineries and blenders might respond to a temporary rather than permanent change in EU support (this criticism would be valid whether or not we reinstated support in the model following the price spike, as explained above). A handful of EU Member States are currently failing to meet their blending obligation (Al-Riffai et al. 2010), so biofuels blenders might use a temporary relaxation to build inventories in order to meet the obligation when it is reinstated in the future. Such "smoothing" behaviour could reduce the effectiveness of this policy.

The model assumes that grain used for biofuels is of the same quality as grain used for animal feed, and so can be brought onto the animal feed market if required. If a very large proportion of biofuels feedstocks were unsuitable for animal feed (perhaps because the grain was cultivated on contaminated land) then the effects of flexing mandates could be smaller than modelled. There is no evidence that this is currently the case on a sufficient scale to be of concern.

Furthermore, if biofuels become increasingly commercially viable, production may grow to exceed the blending obligation and start responding to price signals. In such a situation, relaxing the blending obligation will have little or no short-term impact on demand for grains from biofuels and this policy will cease to be an effective way to mitigate grain price spikes (Laborde 2011). However, in such a situation, the biofuels market naturally becomes responsive to changes in feedstock prices so the need for flexible policy is also removed.

Brazil provides a good illustration of this point: in Brazil there is a blending obligation but it is currently exceeded by ethanol production from sugar cane, so at the current ratio of oil price to sugar price[12] removing the Brazilian obligation would not affect today's prices of sugar and maize[13]. It is therefore possible that the effectiveness of flexible biofuels mandates as a tool to mitigate volatility in agricultural markets (whether the result of biofuels or not) has a natural time limit of a few decades at most.

To the authors' knowledge, there have not been similar attempts by others to model the impact of flexible biofuels mandates in the EU. However, the results in Annex A, which explores the same policy idea for the US, can be compared to recent work by Bruce Babcock (2011). Babcock found that removing subsidies for ethanol production in 2011 would have led to a 17% reduction in maize prices. He also confirmed that "the model results show that if market conditions are tight because of poor maize yields, then the mandate will have a larger-than-average impact on market prices because it forces all the adjustment to tight supplies onto the livestock sector."

Practicalities of implementation

There are challenges that this proposal will need to overcome if it is to be pursued, and most arise from considering how it would work in practice. The report for the G20 *Price Volatility in Food and Agricultural Markets* (FAO et al. 2011) contains an annex which explores some of these challenges, and is largely paraphrased here:

- The rule that triggers flexibility requires careful design, although it could be relatively simple to operate. One simple option is for a rule based on market prices: at a pre-defined (real) price of grains, mandates could be relaxed by some amount, and if the price reaches a second threshold they could be relaxed more. Alternatively, Laborde (2011) suggests the decision rule might need to take account of existing stocks, for which data is notoriously unreliable. Babcock (2011) suggests that feedstock supplies are the key metric, including both stocks and production. To provide the predictability needed to avoid panic behaviour, a publicly known rule would be required (FAO et al 2011).
- The precise nature of the flexibility is also important. This paper has discussed temporary reductions in the ambition of mandates, but Babcock (2011) suggests an alternative: in relation to the US he describes introducing flexibility by "increasing the limits by which fuel blenders can bank or borrow blending credits when meeting their blending obligation". This refers to the idea that over-production in one year can count towards meeting the obligation in another, and may be attractive because

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[12] Commercial viability of biofuels depends critically on the costs of inputs like sugar, grain and oilseeds and on the price biofuels can be sold for. Recently, whilst sugar prices have been rising, the oil price has been so high that refining sugar cane for bioethanol makes commercial sense.

[13] However, the mandate could still affect investment and production in the longer term if there is a risk that biofuels will not always remain commercially viable.

it retains the overall level of ambition of the mandates whilst providing biofuels blenders with more discretion over their cost base.

- The trigger needs to be independent of political pressure to ensure it is used when necessary and not at other times. If this is not the case, policy uncertainty could translate into increased rather than decreased market volatility.
- International policy coordination is likely to be required for the proposal to be at its most effective. The intention to bring more grain onto the food markets could be undermined if other countries respond to the removal of EU mandates by increasing their consumption of biofuels. FAO et al. (2011) suggests the Committee on Global Food Security might be a good forum to facilitate such coordination.
- This is a highly politicised area of the economy, not least because for the most part both the biofuels and agricultural industries benefit from a significant amount of Government support. FAO et al. (2011) discusses this further.

The scale of each of these challenges needs further assessment.

Conclusion

There are a number of challenges that can be foreseen in implementing the idea of flexible mandates, but our modelling work demonstrates the very significant benefits that could be gained if these challenges can be overcome.

The paper demonstrates that removing support for biofuels during a price spike could reduce the magnitude of the spike. If implemented in the EU, this proposal could reduce the magnitude of a spike in the price of wheat by anything from 10% to 35%. Similarly, a spike in the price of coarse grain could be mitigated by up to 15%.

Perhaps the most notable challenges relate to international policy coordination: introducing flexibility into biofuels mandates cannot be done alone by the UK.

We have assumed that mandates will continue to drive production of biofuels in the EU, but it is possible this will not be the case – consistently high oil prices could lead production to exceed its mandate. If and when biofuels become widely and consistently commercially viable the need for mandates, flexible or otherwise, will not arise.

Based on the evidence and discussion in this paper we suggest that the proposal is worth exploring further. In particular, two early tasks will be to explore specific triggers and implementation mechanisms, and to assess how quickly it could be implemented in either the EU or the US. A key date for the EU will be the European Commission's review of bioenergy targets in 2014.

What's next?

This paper has been written to inform and stimulate debate, but it also makes a case for work to develop a more detailed policy proposal. Here we suggest what some of that work might involve.

Significant refinement of policy, including wide engagement

As indicated in the conclusion, it will be important to understand if and when biofuels production is likely to become generally commercially viable. This needs to be set against the likely policy effort and time required to draft, adopt and implement revisions to the EU Renewable Energy Directive in order to allow flexible mandates to become a reality. If it looks like there are only a few years between implementing the changes and mandates becoming irrelevant, it may be worth going no further.

Section 7 identified a number of other challenges associated with introducing flexibility into biofuels mandates and these require attention to assess which are avoidable, and which if any are insurmountable. Section 6.5 also identified a number of reasons to be wary of the modelling results, so more detailed economic analysis would be helpful.

Early and constructive engagement with the UK biofuels industry, the European Commission, other EU member states and experts in agricultural commodities markets will be essential to developing a credible and acceptable policy option. This is likely to highlight both more challenges and potential solutions, and will be an important test of the rationale for action put forward in this paper.

The discussion around practicalities of implementation suggests that the costs associated with this proposal are highly dependent on the how the proposal is implemented. A poorly designed trigger could introduce unnecessary uncertainty into the biofuels market, with implications for investment and long run growth of the market in the same way that volatility in agricultural markets can also affect investment. A poorly designed method for introducing flexibility could make it harder for national governments to meet renewable energy objectives. Simple alternatives that avoid these problems are suggested in this paper, but need to be developed further.

For example, it would be worth exploring a trigger based purely on market prices because these represent an easily accessible aggregation of all available market information. Perhaps at given thresholds in an index of grain prices, mandates could be relaxed by 50%, 75% and 100% and reintroduced when the index falls.

It might also be worth exploring different "mechanisms" for introducing flexibility, perhaps developing Babcock's idea of allowing blenders to "bank" contributions to their obligation when grain is cheap, and "borrow" when grain prices spike.

A fuller cost-benefit analysis of specific options

Throughout this paper we have argued that there are costs and benefits, winners and losers from this proposal. Examining the impacts of the proposal on agricultural prices is not enough to make a complete case for introducing flexibility into biofuels mandates: these benefits need to be weighed against costs to biofuels refineries.

A fuller cost-benefit analysis according to guidance set out in HM Treasury's Green Book (HMT 2003) involves attempting to put money values on all impacts of the proposal. Benefits may arise in agricultural markets from lower prices paid by grain consumers, whilst costs may arise from lower profits to biofuels refiners.

Bibliography

Al-Riffai P, Dimaranan B & Laborde D 2010. *Global Trade and Environmental Impact Study of the EU Biofuels Mandate.* Available at: http://trade.ec.europa.eu/doclib/docs/2010/march/tradoc_145954.pdf

Babcock B 2011. *The Impact of US Biofuels Policies of Agricultural Price Levels and Volatility.* ICTSD, Geneva. Available at: http://ictsd.org/downloads/2011/12/the-impact-of-us-biofuel-policies-on-agricultural-price-levels-and-volatility.pdf

CFS 2011. *Committee on World Food Security thirty-seventh session final report.* FAO, Rome. Available at: http://www.fao.org/fileadmin/templates/cfs/Docs1011/CFS37/documents/CFS_37_Final_Report_FINAL.pdf

FAO, IFAD, IMF, OECD, UNCTAD, WFP, World Bank, WTO, IFPRI, UN HLTF 2011. *Price Volatility in Food and Agricultural Markets: Policy responses.* Available at: http://www.oecd.org/dataoecd/40/34/48152638.pdf

Foresight 2011. *The Future of Food and Farming.* The Government Office for Science, London. Available at: http://webarchive.nationalarchives.gov.uk/+/http://bis.gov.uk/foresight/our-work/projects/current-projects/global-food-and-farming-futures

G20 2011. *Ministerial Declaration: Action Plan on Food Price Volatility and Agriculture.* Available at: http://agriculture.gouv.fr/IMG/pdf/2011-06-23_-_Action_Plan_-_VFinale.pdf

Gilbert C 2011. *International Agreements for Commodity Price Stabilisation. An Assessment.* OECD, Paris. Available at: http://www.oecd-ilibrary.org/agriculture-and-food/international-agreements-for-commodity-price-stabilisation_5kg0ps7ds0jl-en

Gilbert C & Morgan C 2010. *Food Price Volatility.* The Royal Society, London. Available at: http://www.bis.gov.uk/assets/bispartners/foresight/docs/food-and-farming/drivers/dr18-food-price-volatility.pdf

HMG 2010. *Agricultural price spikes 2007/08: Causes and policy implications.* Defra, London. Available at: http://archive.defra.gov.uk/foodfarm/food/security/price.htm

HMT 2003. *The Green Book.* TSO, London. Available at: http://www.hm-treasury.gov.uk/d/green_book_complete.pdf

Laborde D 2011. *Domestic Policies in a Globalised World: What you Do is What I Get. Consequences of biofuel mandates for global price stability.* Available at: http://www.foodsecurityportal.org/sites/default/files/A_brief_overview_of_Foodsecurity_and_Biofuels_1.pdf

Miranda M & Helmberger P 1988. "The effects of commodity price stabilisation programs". *American Economic Review*, **78**, 46-58.

Morgan C 2001. "Commodity futures markets: a review and prospects. *Progress in Development Studies,* **1,** 139-150.

ODI 2011. *Cereals outlook for 2011/12 – maize in the red zone.* June update.

OECD-FAO 2006. *OECD-FAO Agricultural Outlook 2006-2015.* OECD, Paris.

OECD 2008. *Biofuels Support Policies – An Economic Assessment,* OECD, Paris.

OECD-FAO 2010. *OECD-FAO Agricultural Outlook 2010-2019.* OECD, Paris.

OECD-FAO 2011. *OECD-FAO Agricultural Outlook 2011-2020.* OECD, Paris.

Oxfam 2011. *Growing a better future.* Oxfam, Oxford. Available at: http://policy-practice.oxfam.org.uk/publications/growing-a-better-future-food-justice-in-a-resource-constrained-world-132373

UNCTAD, undated webpage. UNCTAD's position on biofuels policies and the global food crisis. Available at: http://www.unctad.org/templates/Page.asp?intItemID=4526&lang=1

Wright B 2011. "Chapter 23: Addressing the biofuels problem: food security options for agricultural feedstocks". Published in Prakesh A 2011. *Safeguarding food security in volatile global markets.* FAO, Rome. Available at: http://www.fao.org/docrep/013/i2107e/i2107e23.pdf

Yacobucci B 2012. *Biofuels Incentives: A Summary of Federal Programs.* Congressional Research Service. Available at: http://www.fas.org/sgp/crs/misc/R40110.pdf

Annex A: Modelling the impact of flexibility in US biofuels mandates

Author's note: This annex was written as a stand-alone paper exploring the potential impacts of flexible biofuel mandates in the US. We were keen to explore the implications of introducing flexibility to both EU and US mandates simultaneously but our agricultural models could not solve with such substantial global policy changes, so the US was modelled independently.

Grant Davies

Defra, June 2012

Introduction

1. Cross-Whitehall analytical work in relation to the 2007/8 price spike in agricultural markets concluded that a "fuller appraisal of the different types of biofuels policies and their impact on agricultural markets is required, in particular the impact of inflexible quantitative targets for biofuel consumption[14]".

2. However, it is important to note that available evidence does **not** suggest that biofuel demand has been a major driver in agricultural price spikes during 2007/8 and more recently in 2010/11.

3. Nevertheless, given the size of the US biofuel policy in particular, ensuring grain for biofuels is not unavailable to food markets in times of relative shortage could play a role in reducing the magnitude of price spikes in grain markets.

Overview of US Biofuel Policy

4. The US biofuel policy consists of quantitative mandates for biofuel consumption (the Renewable Fuel Standard) requiring that by 2022, 36bn[15] gallons of renewable fuel be consumed annually and of this 15bn gallons come from maize-ethanol. Since the US is the only major maize-ethanol producer, this acts as an effective US production mandate. There is also a subsidy to ethanol blenders, the ethanol blenders' tax credit.

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[14] HMG (2010). The 2007/8 Agricultural Price Spikes: Causes and Policy Implications.

[15] For reference, the US consumes around 140bn gallons of gasoline annually at present.

5. The Administrator of the Environmental Protection Agency (EPA) can waive the Renewable Fuel Standard mandates under certain circumstances; in particular, if "implementation of the requirements would severely harm the economy or environment of a state, a region, or the United States, or if EPA determines that there is inadequate domestic supply of [grain for] renewable fuel."[16] The request for a waiver can be made by US States, refiners and blenders. The EPA Administrator can also initiate the waiver without receiving a request. There are also provisions for "regular reviews of the impact of the mandates."[17]

Economic Modelling

6. The OECD-FAO Aglink-Cosimo model was used to illustrate the potential for mandate waivers to mitigate price spikes as it allows us to run simplistic scenarios around the US biofuel mandate during price spikes. Results of these models should be interpreted with caution.

7. Firstly, a price spike in grain markets was simulated by reducing the US maize area harvested by 40% in 2011 – maize is the most important coarse grain globally – whilst maintaining the US biofuel mandate and ethanol blenders' subsidy. Secondly, various scenarios were simulated which waivered an increasing share of the US biofuel mandate but maintained the ethanol blenders' subsidy.

8. Consequently these illustrative scenarios show that a temporary reduction in the level of the mandate (a waiver) mitigates the hypothetical price spike significantly. This is because grain which was originally produced for ethanol manufacture moves into the food and feed market, increasing grain availability and dampening price increases.

9. Scenario outputs are given in Figure A1 below.

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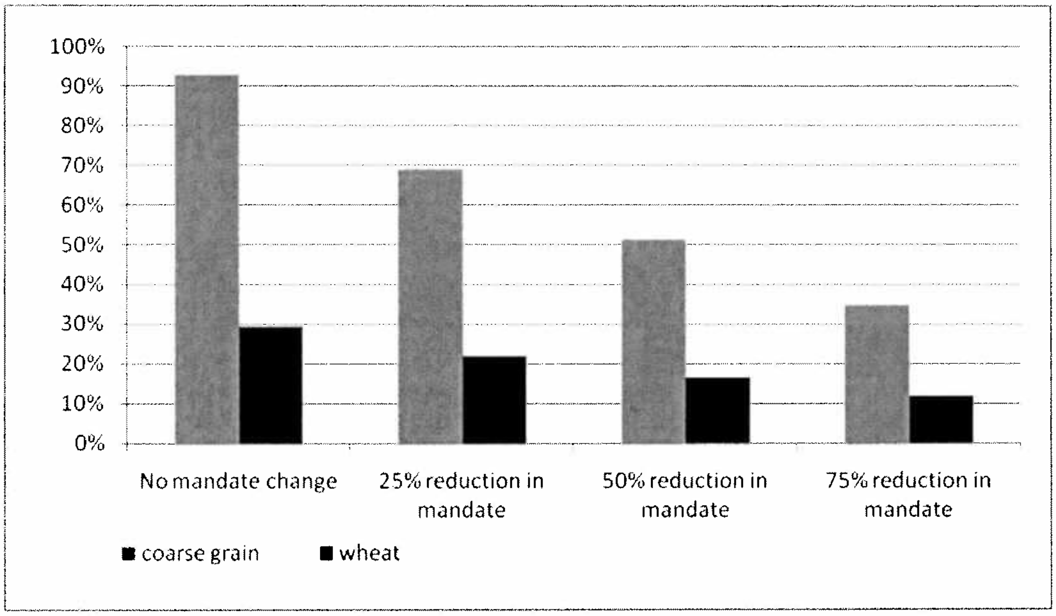
[16] Energy Independence and Security Act of 2007, or EISA (Public Law 110-140)

[17] Energy Independence and Security Act of 2007, or EISA (Public Law 110-140)

Figure A1: Increase in world grain prices following 40% reduction in global maize area, under different biofuel mandate waivers



10. In the scenario where the mandate is unchanged, the world coarse grain price is projected to rise by just over 90% in response to the reduction in maize area and production. On the other hand, if maize area is reduced but the mandate is waived by 75% then the price rise is projected to be 35%. Given that wheat and maize are substitutes for animal feed, wheat prices are also projected to rise in response to the reduction in global maize production. When the mandate is unchanged, wheat prices are projected to rise by around 30% in response to the fall in maize area. Alternatively, when the mandate is reduced by 75% wheat prices are projected to rise by 12% in response to the fall in maize area.

11. When the mandate is reduced, price increases are correspondingly mitigated and the larger the waiver, the greater the price mitigation, as more grain is free to move from ethanol to food and feed use. Furthermore, the effect of waiving the mandate is projected to be quite large. For example, *halving the mandate* reduces the projected price rise by over 40 percentage points; in other words, the impact on world coarse grain prices is also *roughly halved.*

12. These scenarios emphasise the importance of the **design** rather than the existence of biofuel policies. Waiving the mandate during temporary supply shortages in any given year and/or encouraging biofuel production through more flexible means such as incentives and subsidies (in place of mandates) could play an important role in mitigating the magnitude of price spikes in grain markets.

Annex B: Simulating the change in biofuels policy in AGLINK-COSIMO 2010

This annex describes the detail of which parameters were changed in AGLINK-COSIMO to arrive at the results presented in the body of the paper and in Annex A. It is included to help experts who might wish to repeat the exercise, or comment on the approach we have taken.

AGLINK-COSIMO is a recursive-dynamic, partial-equilibrium, supply and demand model of world agriculture, developed and maintained jointly by the OECD and FAO. It covers annual supply, demand and prices for the principal agricultural commodities produced, consumed and traded in each of the countries represented in the model. The model contains advanced biofuel modules for both the US and the EU.

Simulating a grain price shock in AGLINK-COSIMO

Grain prices in the model balance the European market for individual grains. For example, the European wheat price solves the following market balancing equation:

$$0 = \textit{E27 wheat production}_t + \textit{E27 wheat stocks}_{t-1} + \textit{E27 wheat imports}_t - \textit{E27 wheat consumption}_t - \textit{E27 wheat stocks}_t - \textit{E27 wheat exports}_t$$

Grain production in any given region or country in AGLINK-COSIMO is expressed as the product of area harvested and yield per hectare. For example, with respect to wheat:

$$\textit{wheat production}_t = \textit{wheat area harvested}_t * \textit{wheat yield}_t$$

Area harvested itself depends on (lagged) gross revenues for the crop in question and for competing crops. Yields, when endogenous, are simple functions of prices and/or time trend variables which serve as proxies for technological change.

In order to simulate a supply shock to the EU grain market in a given year we therefore exogenised the relevant grain area equation and reduced the area by 25% as compared to the baseline value in that year alone. Such a shock significantly reduces grain production in one year.

Removing/waiving biofuel support policies in AGLINK-COSIMO

European Union

Biofuel support policies in the E27 are represented as blending obligations, tax incentives and tariffs on imported bioethanol and biodiesel. All are exogenous.

In order to remove blending obligations the following variables were set to zero in the model:

> ***E27_ET_QCS..OBL = 0*** *(ethanol blending obligation abolished)*
>
> ***E27_BD_QCS..OBL = 0*** *(biodiesel blending obligation abolished)*

In order to remove the tax incentives on biofuel consumption, taxes on ethanol and biodiesel were set equal to their fossil-fuel equivalents.

> ***E27_ET_TAX=E27_GAS_TAX*** *(equivalent taxes on ethanol and gasoline)*
>
> ***E27_BD_TAX=E27_DIE_TAX*** *(equivalent taxes on biodiesel and diesel)*

In order to remove tariffs on bioethanol and biodiesel, the following variables were set to zero in the model:

> ***E27_ET_TAS = 0*** *(ethanol import tariff set to zero)*
>
> ***E27_BD_TAV = 0*** *(biodiesel import tariff set to zero)*

United States

Biofuel policy in the US is set out in the RFS legislation. In the model, US biofuel policy is represented as quantitative mandates on ethanol production, tax credits to ethanol blenders (increasing the margin on ethanol production) and tariffs on imported ethanol.

In the modelling exercise detailed in Annex A, only the quantitative mandates on ethanol production are altered. Both the tariff on imported ethanol and the tax credit to ethanol blenders are maintained[18].

US corn-ethanol output is calculated as a product of the corn-ethanol capacity in place and the utilisation rate of that capacity. US corn-ethanol capacities are modelled as a function of the quantitative mandate set by the RFS and also the economic returns to corn-ethanol production.

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[18] It is noteworthy that both have now lapsed in US legislation.

US corn-ethanol capacity $_t$ ***= f (corn-ethanol capacity*** $_{t-1}$ ***, RFS mandate*** $_t$ ***, margin on ethanol production from corn*** $_{t-1,2,3,4}$ ***)***

The US mandate for ethanol production (the "*RFS mandate* $_t$" term in the previous equation) is exogenous in the model and can be split into the amount of corn-ethanol supported by the RFS in any given year and the maximum amount of corn-ethanol permitted by the RFS. To get the results presented in Annex A, we ran scenarios in which the mandate was reduced by 25%, 50% and 75%. Accordingly, the following variables were reduced by 25%, 50% and 75% respectively:

USA_RFS_CG *(amount of corn-ethanol supported by the RFS)*

USA_RFS_CG..MAX *(maximum amount of corn-ethanol permitted under the RFS)*

Ethanol Production and Gasoline Prices: A Spurious Correlation

Christopher R. Knittel and Aaron Smith*

July 12, 2012

Abstract

Ethanol made from corn comprises 10% of US 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 estimates have been cited in numerous speeches by Secretary of Agriculture Thomas Vilsack. These estimates are based on a series of papers by Xiaodong Du and Dermot Hayes. We show that these results are driven 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 US and Europe. We even show that ethanol production "increases" the ages of our children.

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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 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 estimates have been cited numerous times by Secretary of Agriculture Thomas Vilsack (see the opening quote of this paper for one example). These estimates are based on a series of papers by University of Wisconsin and Iowa State University economists Xiaodong Du and Dermot Hayes[2], who use monthly regional data to estimate the relationship between ethanol production and the profit margin for oil refiners.

Given the obvious 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 and statistical theory

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

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

Figure 1: Renewable Fuel Association ad campaign, 2010

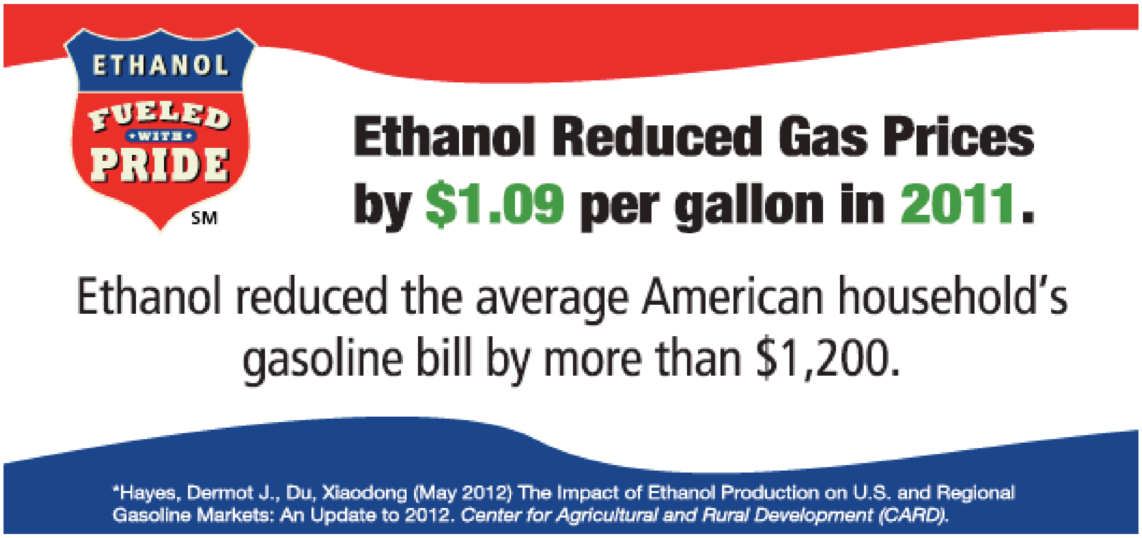
Note: http://domesticfuel.com/2011/07/26/rfa-ads-tout-ethanol-reducing-gas-prices/.

suggest effects that are near zero and statistically insignificant.

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 US ethanol production: the US price of natural gas and unemployment rates in the US 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 US, 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 quickly 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

Figure 2: Renewable Fuel Association ad campaign, 2011



ETHANOL
FUELED
WITH
PRIDE
SM

Ethanol Reduced Gas Prices by $1.09 per gallon in 2011.

Ethanol reduced the average American household's gasoline bill by more than $1,200.

*Hayes, Dermot J., Du, Xiaodong (May 2012) The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to 2012. *Center for Agricultural and Rural Development (CARD).*

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

Figure 3: Renewable Fuel Association Metro Bus Billboard

Note: http://www.abengoa.es/htmlsites/boletines/en/octubre2011/produccion.html.

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 The Basic Economics

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 could have 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. A barrel of oil contains 42 gallons, so every dollar per barrel increase in oil prices raises wholesale gasoline prices by about 2.4 cents. Thus, when oil is \$100 per barrel, roughly \$2.40 of the price of gasoline will be the cost of crude. 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 US. To put this into perspective, the US consumes roughly 20 percent of world oil. Roughly half of the US oil consumption goes toward gasoline and ethanol comprises roughly 10 percent of our gasoline-blend fuel. Thus, on a volumetric basis, US 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, US 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)).

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.[3] Du and Hayes focus on the refining margin. They estimate

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[3] Ethanol is an ingredient in gasoline, so the retail price of gasoline also depends on the price of this ingredient. If the energy-equivalent price of ethanol is less than that of wholesale gasoline, then using more ethanol lowers the price of gasoline and vice versa. Apart from the summer of 2006, when a supply crunch caused ethanol prices to spike, the relative prices of ethanol and wholesale gasoline have been similar enough that the marginal effect of using more of one ingredient than the other has not been more than a few cents per gallon, after accounting for differences in tax treatment and energy content (DeGorter and Just (2009)). Like Du and Hayes, we do not study this channel any further.

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. 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 liquified 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:

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

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, based on energy costs and NGPL use, 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 5 plots the crack spread for each Petroleum Administration for Defense Districts (PADD) over time.[7] PADDs are regions of the country represented in Figure 4. The average

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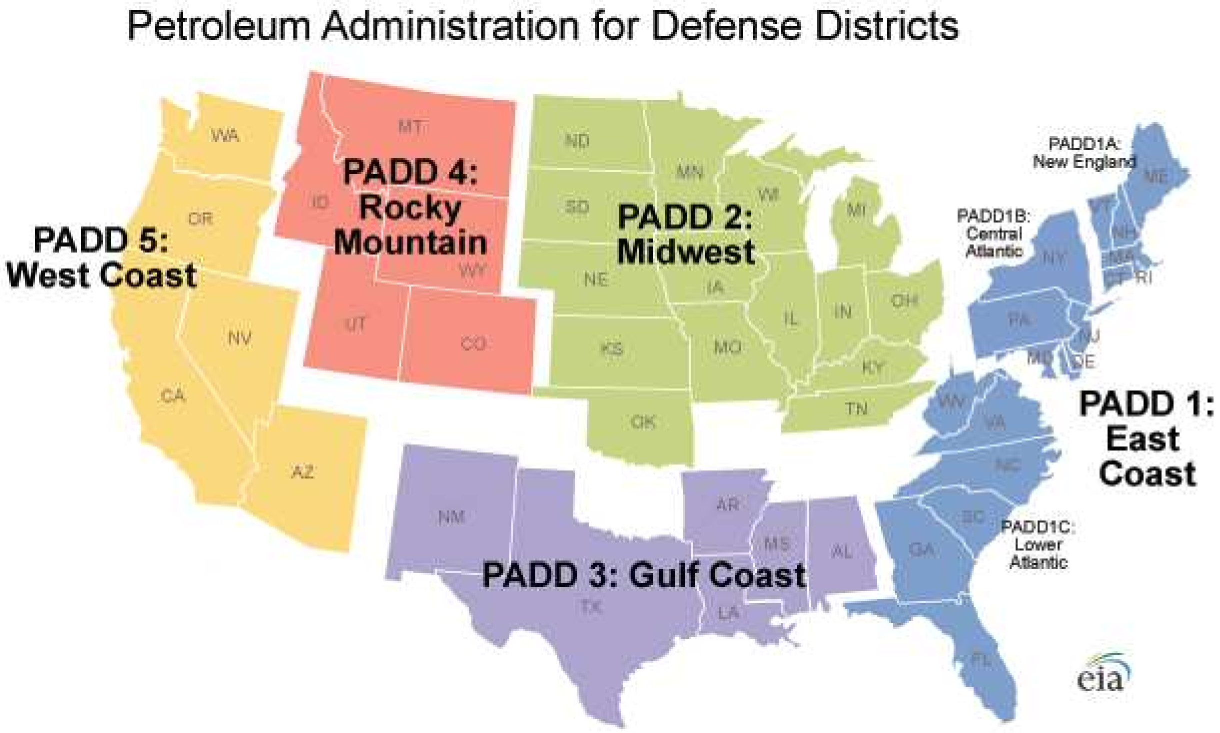
[4] These quantities are based on data from the Energy Information Administration. Specifically, we use the Refinery Yield (`http://www.eia.gov/dnav/pet/pet_pnp_pct_dc_nus_pct_m.htm`) and Fuel Consumed (`http://www.eia.gov/dnav/pet/pet_pnp_capfuel_dcu_nus_a.htm`) tables.

[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

Figure 4: Map of Petroleum Administration for Defense Districts (PADDs)



crack spread from 1995 to 2011 was 41 cents per gallon, in 2011 dollars; the crack spread was 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. These ranges make it seem implausible that removing ethanol production in 2010 or 2011 would have caused the crack spread to expand by $0.89 or $1.09 for a whole year.

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

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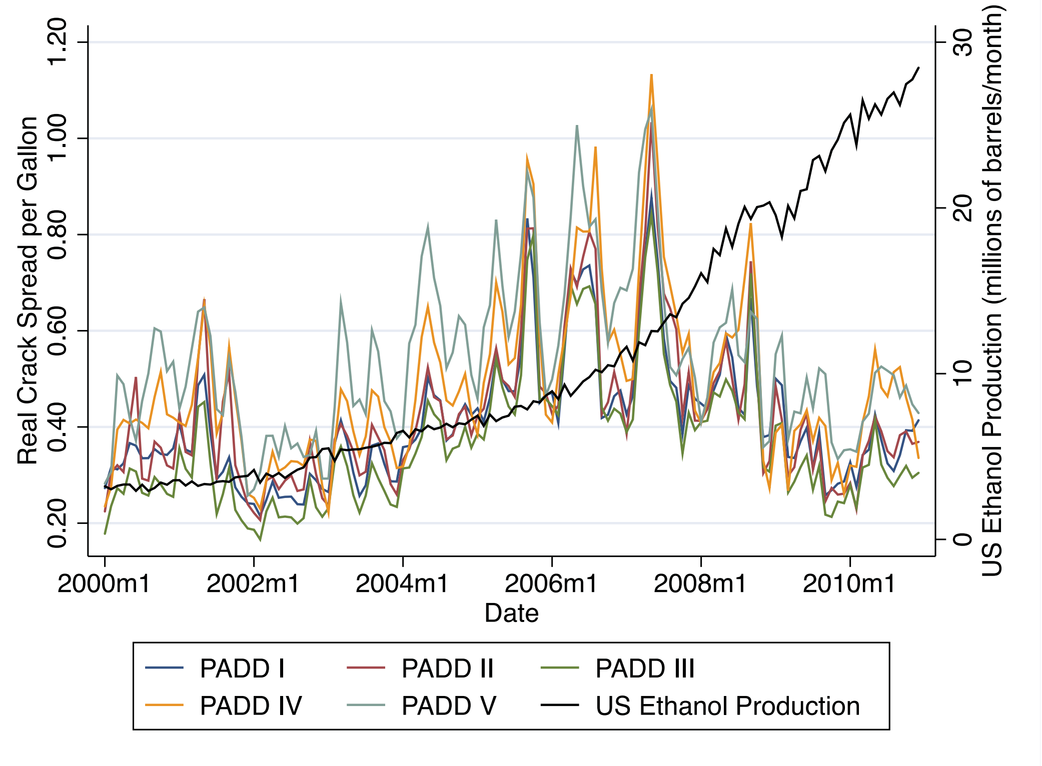
cost of crude oil. PADD-specific crude oil acquisition costs exist only back to 2004, which is why we use the national series. The gasoline prices exclude taxes. According to their description, these are the same series used by Du and Hayes. We deflate by the urban consumer price index (CPI).

[8] In the 12 years leading up to the period shown in Figure 5, 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.

Figure 5: Real crack spread over time (per gallon)



operating costs and recuperate their investments in capital, but low enough not to encourage entry. Figure 5 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 5 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 and ratios 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 affect the refining margin in the short run if it arrives when refineries are 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. Without ethanol, gasoline prices would still have declined in the longer run as more refining capacity was built or gasoline imports increased. 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 in the short run.

Du and Hayes appear to ignore the short- and long-run distinction. Their regression models control for some factors that may affect refinery profitability in the short-run, such as inventories and capacity utilization, but they make no mention of the length of run in their discussion of the effects of ethanol production. As an example, suppose the Du and Hayes regression results are true—ethanol production decreased gasoline prices by 89 cents per gallon in 2010. Eliminating all ethanol would have increased the *average* crack spread from 39 cents to $1.28 cents in 2010; the May average across PADDs would have been $1.37. This is 20 cents higher than the highest crack spread *ever* observed in the data. For this to be a long-run effect—which is the implicit assumption in the RFA's claims—we would have to expect that these historic high crack spreads would not increase capacity utilization. According to the EIA, refinery capacity utilization averaged 86.4% in 2010, 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 would quickly be attracted by such massive profit margins.

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

The empirical models in Du and Hayes use monthly PADD-level data on either the crack ratio or the crack spread and include several covariates. The key covariate is the monthly production of ethanol in the US. The other covariates are: the PADD-level stock of oil

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

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.[10]

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 5 shows that ethanol production increased smoothly during the 11-year sample period, with the exception of a downward blip following 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.

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. Du and Hayes do not use such controls. Moreover, they focus their analysis on the crack *ratio* rather than the crack *spread*. Figure 6 plots the crack ratio in each PADD over time, along with US 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.

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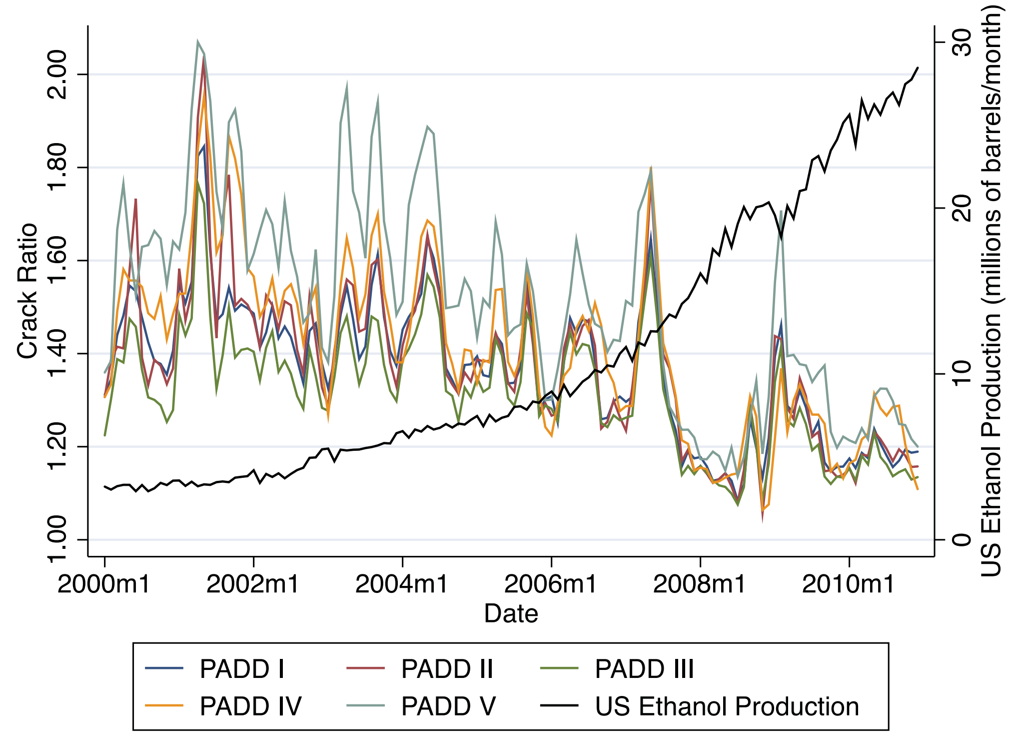
[10] Du and Hayes (2009) uses an instrumental variables approach for gasoline imports. However, the numbers cited by the RFA and Secretary Vilsack are based on Du and Hayes (2011) and Du and Hayes (2012) which explicitly say the authors estimate the model using ordinary least squares (page 3 in both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

Figure 6: Crack ratio and ethanol production over time

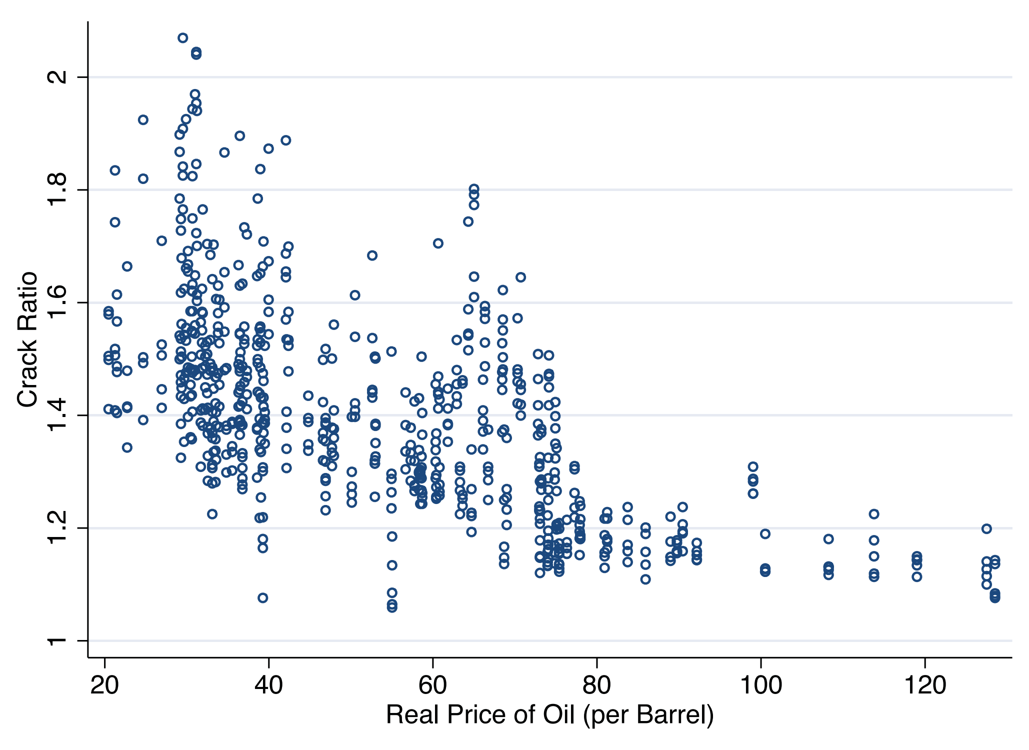


3.2 Choice of Dependent Variable

Du and Hayes calculate the change in gasoline prices from eliminating ethanol using their results from the crack ratio regression; they do not show the calculation for their crack spread results. This is a curious choice. 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 the 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

Figure 7: Crack ratio versus the real price of oil (per barrel)



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 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. Du and Hayes make the implicit assumption that the crack 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.[11]

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.

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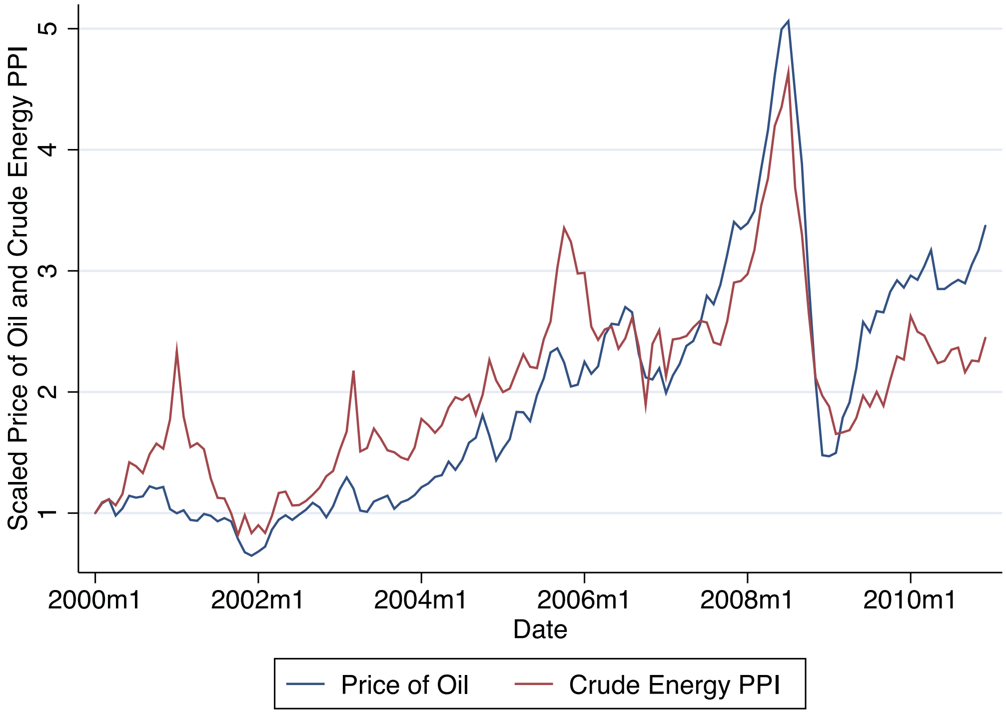
[11] The simple correlation is -0.67.

Figure 8: The price of oil and the Energy Sector PPI over time



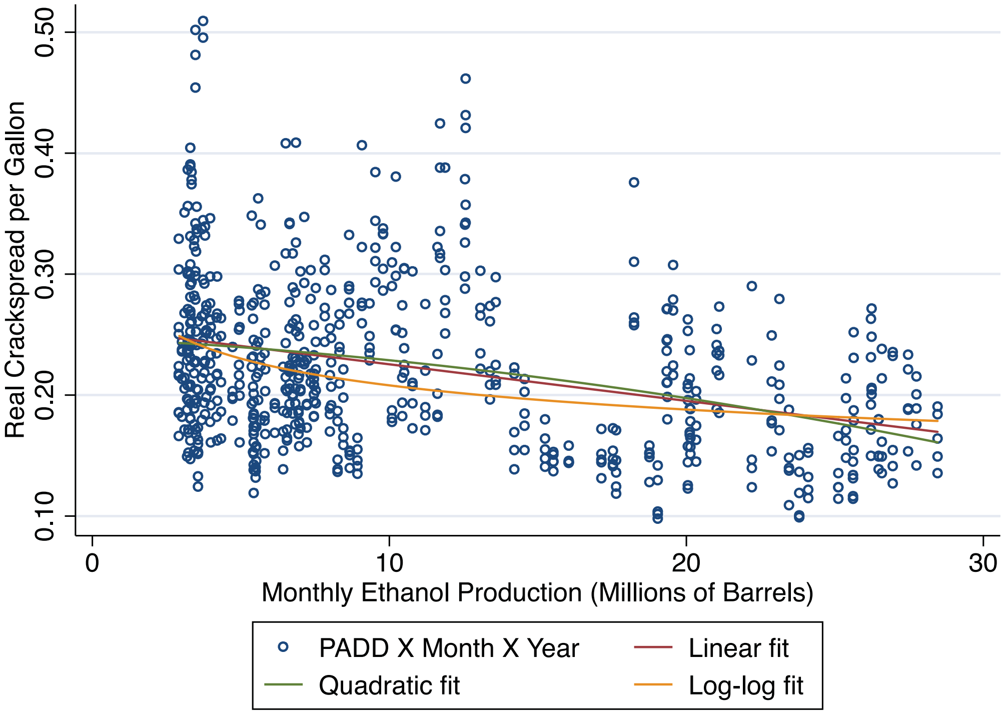
3.3 Controlling for Inflation

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 choose to deflate prices by the producer price index (PPI) for crude energy material, which measures changes in energy prices over time. The authors do not discuss their choice, but refer to their deflated crack spread as the "real crack spread", suggesting that their goal is to account for inflation—again, the overall change in prices over time. Deflating by the PPI for crude energy material does not do this and makes their 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:

$$\frac{price_{gas} - price_{oil}}{Energy\ PPI} \approx \frac{price_{gas} - price_{oil}}{price_{oil}} = \frac{price_{gas}}{price_{oil}} - 1 = crack\ ratio - 1 \tag{2}$$

Figure 9: Scatterplot of the monthly crack spread versus monthly ethanol production deflating by the Energy Sector PPI

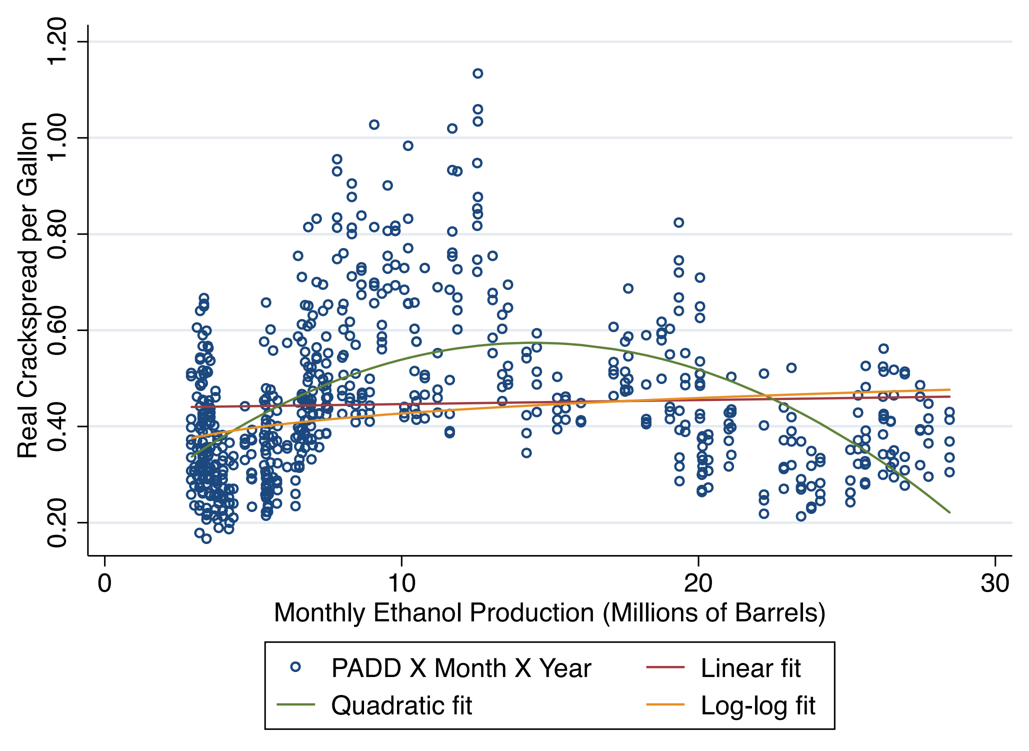


We show in Section 6 that this assumption increases the estimated effect of ethanol on gasoline prices. The foundation underlying this result can be seen in two simple scatter plots. Figure 9 is a scatterplot of the PADD-level monthly crack spread, deflated by the PPI for crude energy material, and US 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, 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

The Du and Hayes empirical specification assumes 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.

Figure 10: Scatterplot of the monthly deflated crack spread versus monthly ethanol production deflating by the Urban CPI



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 we may 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

Du and Hayes estimate some models using a panel that includes monthly time series data for each of the five PADDs. They 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 5 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. Unit-root test resuls for 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.[12] Each of these steps reduces the standard error by about half. 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 by estimating 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 believe 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).

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[12] 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.

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.
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.

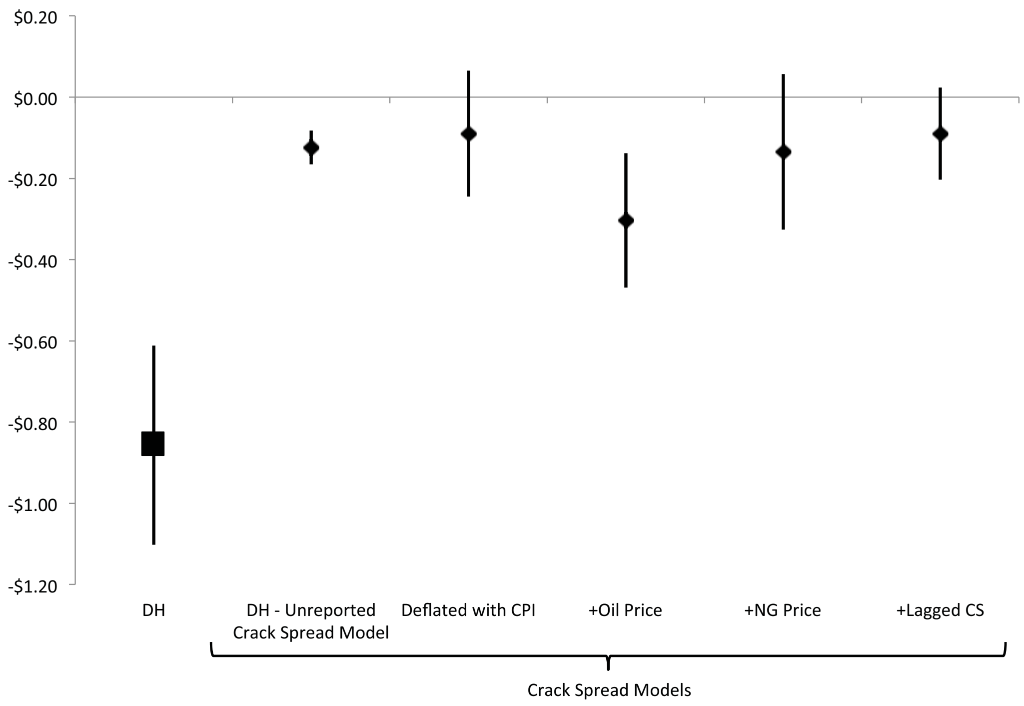
The gasoline price variable is the total gasoline wholesale/resale price by refiners, which excludes taxes and is mostly reflects gasoline prior to blending with ethanol. The crude oil price is the national average refiner acquisition cost of crude oil. PADD-specific crude oil acquisition costs exist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

As in Du and Hayes (2011), our sample begins in January 2000 and goes 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 and empirical specifications that consider the basic economics of the industry yield much smaller effects than those cited by the RFA and Secretary Vilsack.

6 Results

Figure 11 presents the estimated effects from eliminating ethanol for 2010 using the method of Du and Hayes and the pooled-sample estimates, which we also show in Table 1. We

Figure 11: Implied gasoline price effects from elimination of ethanol for 2010



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.

discuss the PADD-level results in Section 6.2. 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.[13]

Du and Hayes never present the estimated effect of ethanol production on gasoline prices from their crack spread models. We calculate the ethanol effect from the crack spread models as the implied increase in the crack spread from eliminating all ethanol production.[14]

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[13] The results for the expanded set of crack ratio models are presented in Table 1 and reported graphically in Figure 15 in the Appendix. The underlying regression results are shown in Appendix Tables 3 and 4. 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.

[14] Specifically, we take average 2010 ethanol production of 26.38 million barrels per month and multiply it by the relevant regression coefficient on ethanol production, which we show in Table 3. This calculation is the direct analog to those made by Du and Hayes for the crack ratio.

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

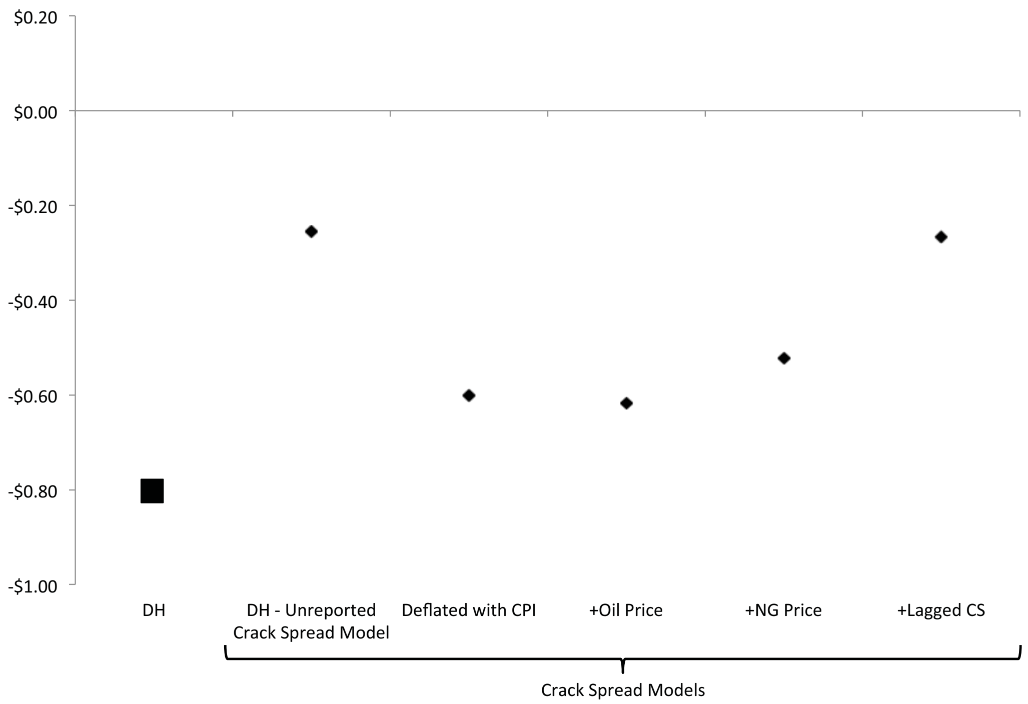
Note: Statistical significance at 5%.

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 ethanol effect of just $0.12 per gallon, a small fraction of the $0.89 estimate trumpeted by the RFA. 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 $0.13 and statistically insignificant. Finally, the model that includes a lagged dependent variable produces the smallest estimated impact is also statistically insignificant.

We hesitate to endorse any of these models. We only claim that the number reported by the RFA and Secretary Vilsack is (a) inconsistent with the basic economics of the industry, (b) at the high end of the distribution of possible estimates, and (c) outside of the distribution of estimates one obtains when taking the economics of the industry seriously. 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 statistically insignificant amounts 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

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.

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.[15] 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.

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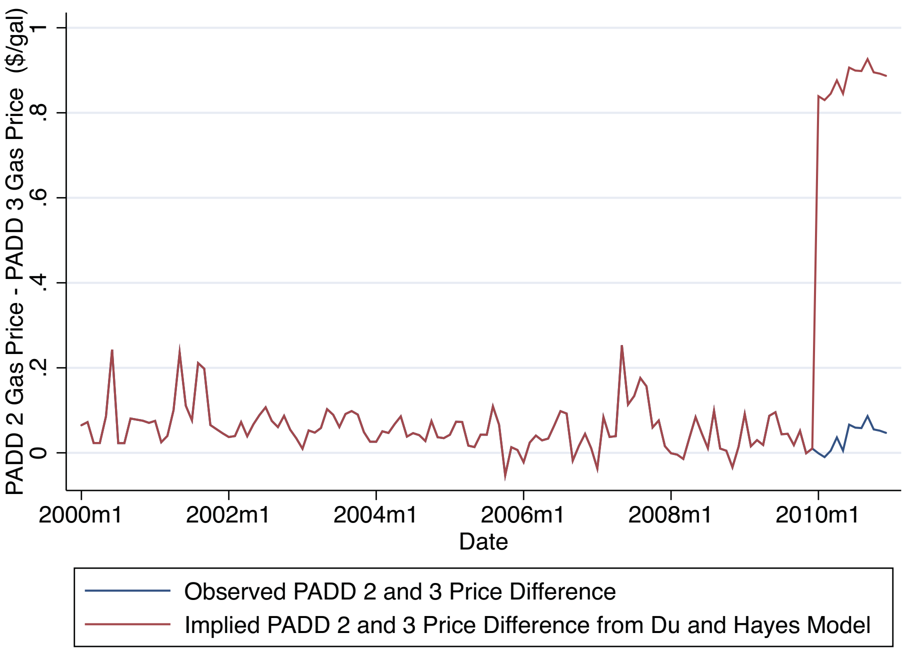
[15] For the underlying regression estimates, see Appendix Tables 5 through 14.

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 that are 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%

Figure 13: Implied gasoline price difference between PADDs 2 and 3 from the Du and Hayes model following the elimination of ethanol in 2010



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 4 maps the five PADDs. While gasoline pipeline capacity constraints sometimes generate price differences across PADDs, certain PADDs are well integrated. This integration 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 refined product in PADD 2 is currently being piped to PADD 3. To illustrate that these price-effect differences are implausible, Figure 13 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 largest observed price difference between the two PADDs is 26 cents, yet the predicted Du and Hayes price difference exceeds 80 cents in every month.

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 both the US and Europe. This analysis forms a "placebo test" because we know natural gas prices and unemployment are unaffected by US ethanol production.

We first present results for three placebo variables: US wellhead natural gas prices, US unemployment, and unemployment in Europe. Appendix Table 15 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 US 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. These results are robust to the alternative specifications we suggest above.

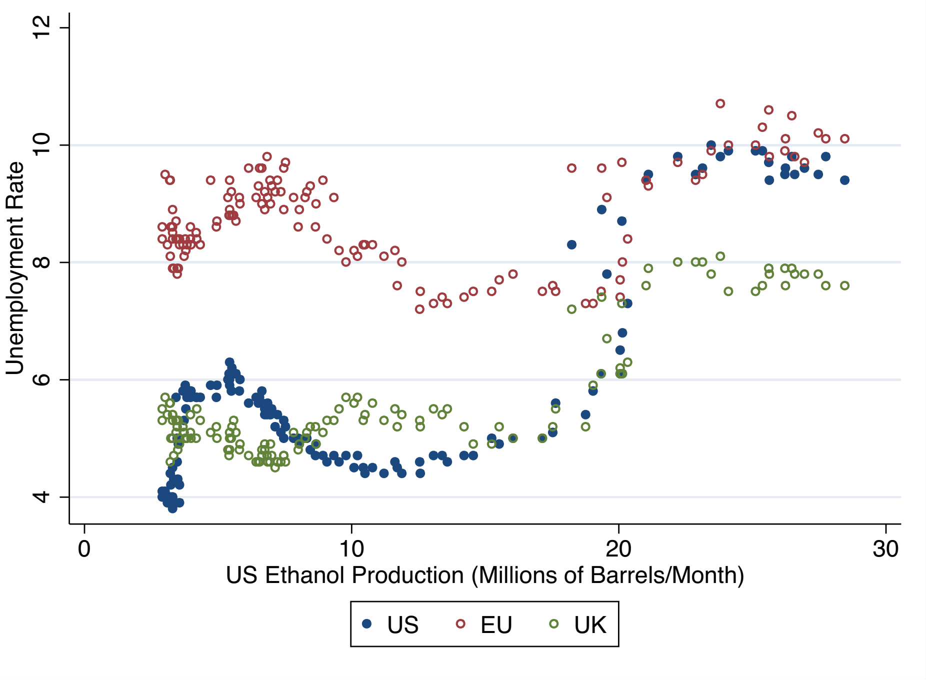
Appendix Table 16 replaces the crack ratio with US national unemployment. These results suggest that US ethanol production "causes" increases in unemployment. Again the implied effect is large; eliminating ethanol production in 2010 would have decreased US unemployment by 65 percent. These results are 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?

Appendix Table 17 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 14 illustrates this correlation for unemployment and ethanol production.

Finally, in case there are any doubts that ethanol production does not impact unemployment in the US and Europe, we offer a whimsical example. Appendix Table 18 replaces the crack ratio with the age of our eldest 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 affect on Hayley's age, with every million barrels increasing her

Figure 14: Scatterplot of US, EU, and UK National Unemployment and US Ethanol Production



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 covariates. 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 5 and 6. Taken together, our results suggest strongly that results reported in Du and Hayes (2011) and Du and Hayes (2012) are spurious.

7 Conclusions

Understanding the relationship between ethanol production and gasoline prices is important. The US has historically subsidized ethanol production and capacity expansion explicitly 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 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 economic assumptions and spurious statistical correlations. 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, US unemployment, and European unemployment. We find that ethanol production "causes" lower natural gas prices and higher unemployment rates in both the US 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 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 US might raise gasoline prices for a short time period, one cannot assume these instantaneous effects would persist for more than a few weeks. This is precisely what Du, Hayes, the RFA, and Secretary Vilsack have done.

References

Borenstein, S. and R. Kellogg (2012): "The Incidence of an Oil Glut: Who Benefits from Cheap Crude Oil in the Midwest?" Tech. rep., Energy Institute at Haas, UC Berkeley.

Borenstein, S. and A. Shepard (2002): "Sticky Prices, Inventories, and Market Power in Wholesale Gasoline Markets," *RAND Journal of Economics*, 33, 116–139.

Carter, C., G. Rausser, and A. Smith (2012): "The Effect of the U.S. Ethanol Mandate on Corn Prices," Working paper, UC Davis.

DeGorter, H. and D. Just (2009): "The Economics of a Blend Mandate for Biofuels," *American Journal of Agricultural and Resource Economics*, 91, 738–750.

Du, X. and D. Hayes (2009): "The Impact of Ethanol Production on U.S. and Regional Gasoline Markets," *Energy Policy*, 37, 3227–3234.

——— (2011): "The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to May 2009," Working Paper 11-WP 523, Center for Agricultural and Rural Development, Iowa State University.

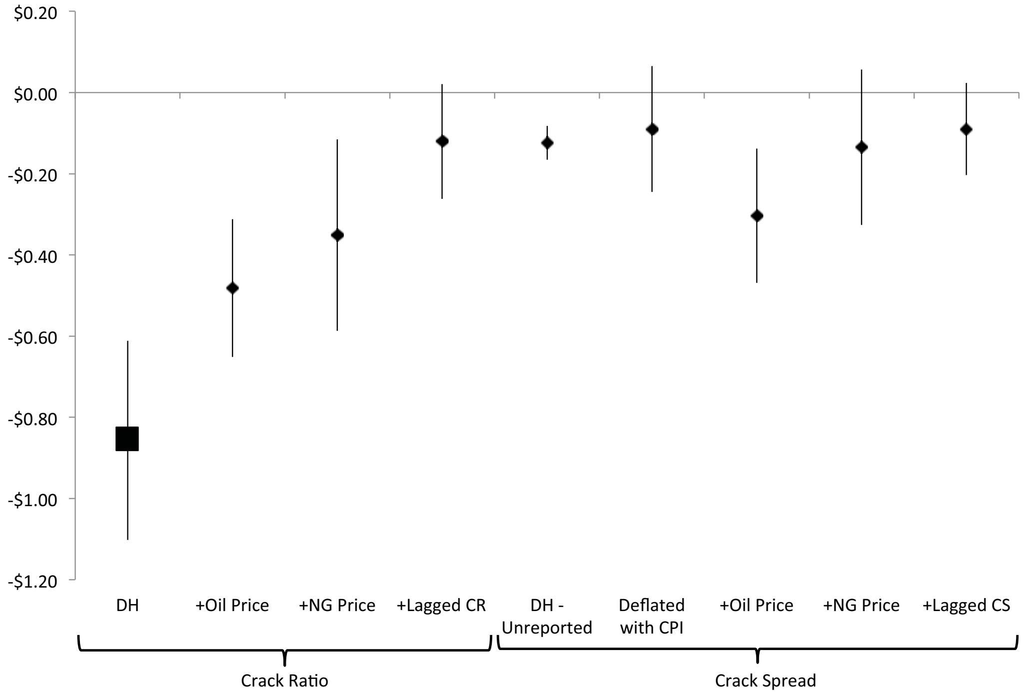
——— (2012): "The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to 2012," Working Paper 12-WP 528, Center for Agricultural and Rural Development, Iowa State University.

Moulton, B. (1990): "An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables on Micro Units," *The Review of Economics and Statistics*, 72, 334–338.

Rajagopal, D., S. E. Sexton, D. Roland-Holst, and D. Zilberman (2007): "Challenge of biofuel: filling the tank without emptying the stomach?" *Environmental Research Letters*, 2, 1–9.

A Appendix — Full Empirical Results

Figure 15: 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 3: Deflated Crack Spread Results

	(1)	(2)	(3)	(4)	(5)
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	-0.0047***	-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 4: 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 5: 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 6: 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	-0.0109**	-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 7: Crack Ratio Results PADD III

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 8: Crack Ratio Results PADD IV

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 9: Crack Ratio Results PADD V

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 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 11: Crack Spread Results PADD II

	(1)	(2)	(3)	(4)	(5)
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	-0.0067***	-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 12: Crack Spread Results PADD III

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 13: Crack Spread Results PADD IV

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 14: Crack Spread Results PADD V

	(1)	(2)	(3)	(4)	(5)
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	-0.0067***	-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: 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 16: Replacing the Crack Spread and Crack Ratio with the US 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 17: 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

Table 18: Replacing the Crack Spread and Crack Ratio with the Age of our Eldest 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

From: Tyner, Wallace E. <wtyner@purdue.edu>
Sent: Wednesday, September 12, 2012 3:19 PM
To: 'William Roenigk'; Kushner, Gary Jay; Eyink, Brian D.; Knapp, Veronica S.
Subject: RE: 10:15 am Telephone Conference Call
Attachments: 20120912150854505.pdf

Bill,
This message is to confirm our phone conversation from this morning. In our paper, "Potential Impacts of a Partial Waiver of the Ethanol Blending Rules," we simulated three sizes of the corn crop: 10.5, 11.0, and 11.5 billion bushels. Today, USDA released the latest update of their crop production estimate. It is 10.73 billion bushels. It is appropriate to use values half way between our 10:5 and 11.0 billion bushel cases we ran to get values for this crop size. The expected prices for the four levels of corn ethanol usage are as follows:
13.8 BG corn 8.19
11.8 BG corn 7.52
10.4 BG corn 7.06
7.75 BG corn 6.19 (all $/bu)
The corn price difference between the first and second cases (use of RINs only – no waiver) is $0.67, just as reported in the paper. The difference between that case and the low waiver is another $0.46, and the difference between that case and the larger waiver is $1.33/bu. The combined effect of the use of prior year RINs and the large waiver is $2/bu.
Also, attached is a paper that provides more documentation for the model. The model has been modified somewhat and updated for this work. In particular, we had to convert in from ex ante to ex post, since drought impacts occur after planting occurs.
Wally

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