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Economic Impacts of Increased Corporate Average Fuel Economy (CAFE) Standards

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ECONOMIC IMPACTS OF INCREASED CORPORATE AVERAGE FUEL ECONOMY (CAFE) STANDARDS

by

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ECONOMIC IMPACTS OF INCREASED CORPORATE AVERAGE FUEL ECONOMY (CAFE) STANDARDS

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The Renewable Fuel Standard (RFS) mandates that U.S. transportation fuel producers blend specific volumes of ethanol and other biofuels with fossil fuels to spur U.S. biofuel production and to minimize foreign oil imports. Ethanol is more corrosive to auto engines than gasoline, and although vehicles manufactured since 2001 are approved to use up to a 15% ethanol blend (E15) (Naylor & Falcon, 2011), E10 is much more widely available. Ethanol producers therefore face a so-called blend wall at 10 percent—a maximum amount of ethanol that is usable domestically based on the demand for gasoline.

Meanwhile, gasoline demand in the U.S. has declined since 2008, when high gas prices and the onset of the recession abruptly led Americans to drive less and to buy more fuel-efficient vehicles. The Environmental Protection Agency (EPA) has since updated Federal Corporate Average Fuel Economy (CAFE) standards to double fuel efficiency in cars and light duty trucks by 2025 to 54.5 miles per gallon (mpg) on average, further diminishing gasoline demand.

Until now, RFS and CAFE have mostly been examined separately or compared to hypothetical carbon cap and trade policies. Analyzing how the RFS and CAFE interact is important because unlike cap and trade, these two policies exist in the U.S. already, and they affect each other in ways unanticipated when each was created. This research uses a comparative statics model to examine the interactions between RFS and CAFE, first in 2013, then in 2025, when updated CAFE standards have been fully implemented and average gas mileage for model year 2025 is 54.5 mpg.

This analysis finds that if both policies are implemented simultaneously in 2025, the outcome is incompatible with even an E15 blend wall. While motor fuel consumers' gains are 50 percent of their 2013 expenditures, gasoline producers lose surplus equivalent to 20 percent of their 2013 receipts.

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Dr. Fulginiti and Dr. Perrin are the reason I started working on environmental issues. They opened my eyes to the economics of global warming as an undergraduate, recruited me into the agricultural economics masters program, and motivated me to complete the degree. They have been supportive of my unconventional path since starting graduate school, encouraging me to take internships and then jobs in Washington, D.C. They went far beyond the call of duty to offer the flexibility and financial support to complete the degree—taking my last-minute decision to return to the program in stride and sacrificing weekends and sleep to provide essential comments on this thesis.

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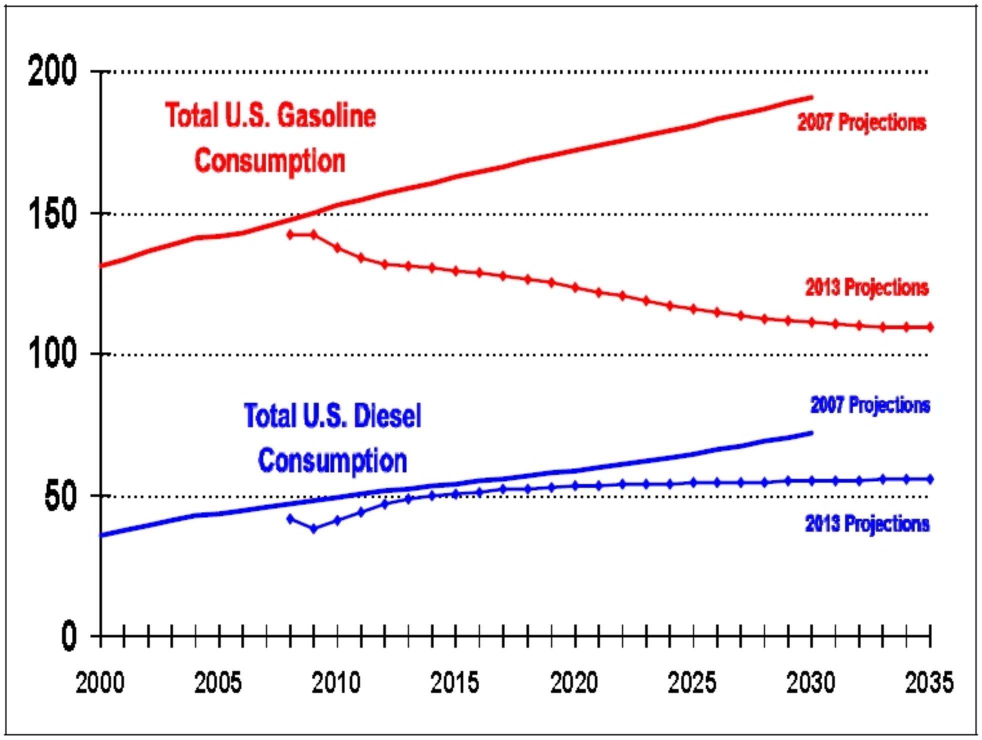
CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

The Renewable Fuel Standard (RFS), created in 2005 and expanded in 2007, mandates that U.S. transportation fuel producers blend specific volumes of ethanol and other biofuels with fossil fuels to spur U.S. biofuel production and minimize foreign oil imports. Ethanol is more corrosive to auto engines than gasoline, and although vehicles manufactured since 2001 are approved to use up to a 15% ethanol blend (E15) (Naylor & Falcon, 2011), E10 is much more widely available. Ethanol producers therefore face a so-called blend wall at 10 percent—a maximum amount of ethanol that is usable domestically based on the demand for gasoline.

Gasoline demand in the U.S. has declined since 2008, when high gas prices and the onset of the recession abruptly led Americans to drive less and to buy more fuel-efficient cars (Pentland). The Environmental Protection Agency (EPA) has since updated Federal Corporate Average Fuel Economy (CAFE) standards to double fuel efficiency in cars and light duty trucks by 2025 to 54.5 miles per gallon (mpg), further diminishing gasoline demand (US EPA). Figure 1.1 shows the disparity between the 2007 and 2013 projections for future gasoline and diesel use (data from EIA, graphic from Forbes).



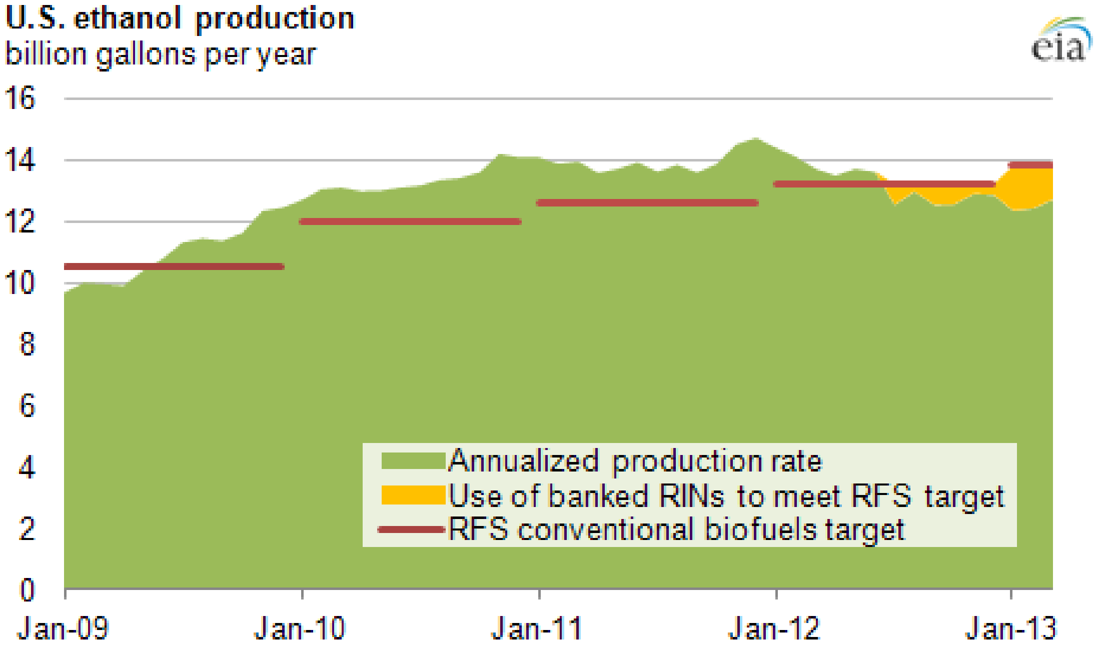
EIA Long-Term Projections of U.S. National Transportation Fuel Use

Billion gallons

Source: DOE, EIA, *Annual Energy Review 2007* and *Annual Energy Review 2013*,

Figure 1.1

Because projected gasoline consumption from recent years is lower than 2007 expectations, EPA has proposed amending the RFS to require less biofuel than originally called for in the statute (15.21 billion gallons in 2014, down from 18.15 billion gallons). The change has alarmed some corn growers and ethanol producers, who relied on the levels in the RFS to make long-term infrastructure investments, and some of whom fear the ethanol market could collapse if the RFS is lowered in subsequent years. Figure 1.2 shows the existing surplus of ethanol in the U.S., which would grow larger were the RFS not amended.



Source: U.S. Energy Information Administration, U.S. Environmental Protection Agency

Note: RFS line represents the implied annual conventional biofuels portion of the RFS target, which primarily includes corn ethanol.

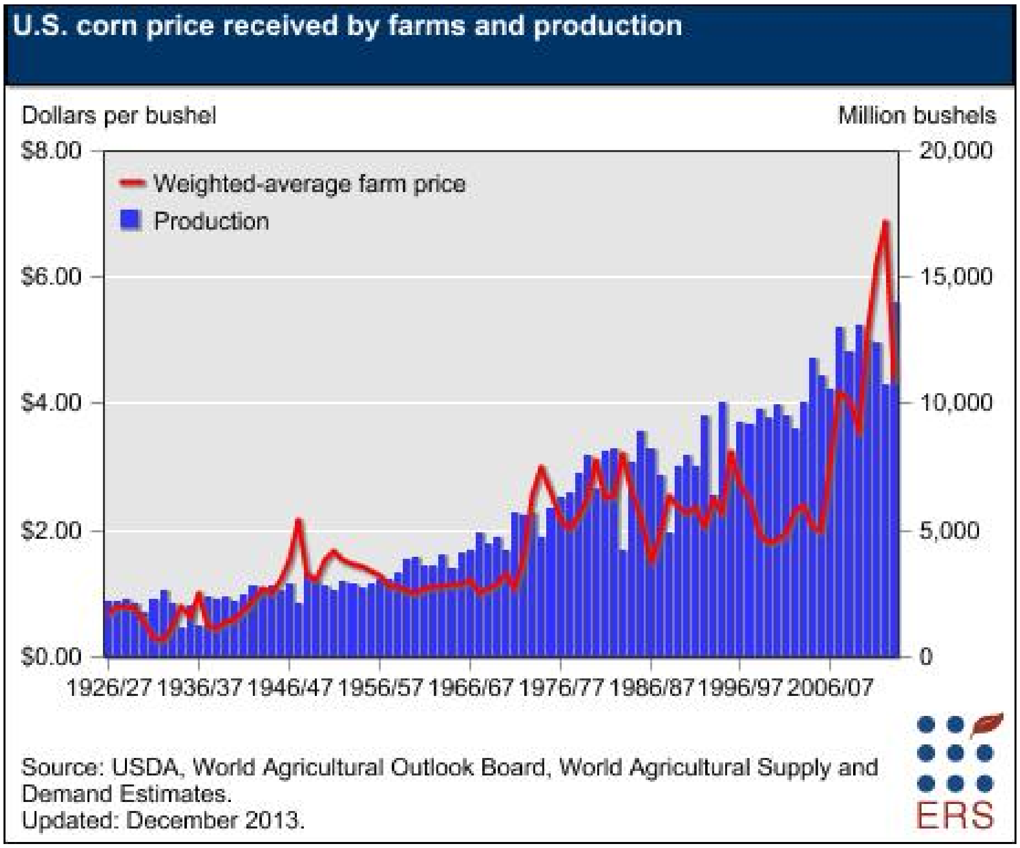
Figure 1.2

The Energy Independence and Security Act (EISA) of 2007, which created the RFS II, had two main goals in promoting biofuels: making transportation fuel more environmentally friendly, and increasing U.S. energy security by minimizing foreign oil imports. Ethanol in the U.S. is made primarily from corn, which is controversial for its impacts on water quality, food prices, and climate change.

Corn is a water- and energy-intensive crop. In many regions, reaching maximum yield requires the use of irrigation systems that typically run on diesel fuel, as well as the use of nitrogen fertilizer, which is produced with natural gas and which can run off soil and cause water pollution.

Water pollution from land use change is also a concern—USDA notes that ethanol production has dramatically increased demand for U.S. corn since 2006, pushing corn and farmland prices to all-time highs in 2013. Producers have since had a strong incentive to remove land from conservation to grow corn, as well as to use existing working lands to plant corn continuously for multiple years rather than to rotate between corn and soybeans, which help naturally replenish nitrogen in the soil.

Figure 1.3 shows average annual corn prices since 1926, demonstrating that recent price spikes made corn highly profitable in the short run.



Source: USDA, World Agricultural Outlook Board, World Agricultural Supply and Demand Estimates.
Updated: December 2013.

Figure 1.3

Economists also debate whether and how much ethanol impacts food prices. The United Nations Food and Agriculture Organization (FAO 2013) argues that ethanol drives up global food prices by increasing the price of corn and other food staples, though Gilbert (2010) and others have disputed that finding. In addition, since corn is used as livestock feed in the U.S., increased corn demand from ethanol also drives up meat prices. Thus, groups as diverse as the American Petroleum Institute, U.S. livestock producers, FAO, and some environmental organizations oppose the RFS.

The climate impacts of corn ethanol remain the subject of debate. Among other provisions, EISA requires that EPA analyze the life cycle emissions of greenhouse gases (GHGs) from biofuels to ensure that each category of renewable fuel emits fewer GHGs than the fossil fuel it replaces. Life cycle analysis of CO2 from ethanol and other biofuels has proved difficult because researchers disagree on whether soil carbon emissions from planting and harvesting should be included in biofuels' carbon footprints, and whether the impacts of land use change should be considered (Schnepf and Yacobucci 2013, Liska 2009, Searchinger 2008).

Ethanol proponents point to national security as a reason to support a robust RFS. The Renewable Fuels Association claims that ethanol reduces the amount of oil the U.S. imports from the Middle East, from 60% to 41% of the U.S. fuel supply. Liska and Perrin have estimated the cost to the U.S. military of securing oil transportation routes at roughly $100 billion annually, or roughly 20 percent of the Department of Defense budget. Ethanol could play a role in reducing those costs, and DOD seems to agree: in late 2013, the Navy announced a “Farm to Fleet” program with USDA to in which the Navy will purchase billions of gallons of domestic biofuels to help fuel its fleet.

Numerous studies have addressed the desirability of the Renewable Fuel Standard compared to other policy options for limiting greenhouse gas (GHG) emissions. DeGorter and Just (2010) contend that the combination of an ethanol production mandate and a tax credit for blending ethanol into the fuel supply actually encourages gasoline consumption—since gasoline producers received a tax credit through 2011 for blending ethanol into the gasoline supply, increased tax incentives encouraged greater gasoline use.

Holland et al. (2013) examine how the RFS compares to a cap-and-trade (CAT) proposal, finding CAT to be more efficient. But others are more optimistic that the RFS is effective. Cui et al. (2011) use a tractable computational model to compare welfare under several alternate fuel taxation and subsidy policies. Interestingly, they find “the second best instruments of a fuel tax and an ethanol subsidy come close to replicating the outcomes under the first best policy combination of oil import tariffs, corn export tariffs, and a carbon tax.”

Perrin (2013) notes that the so-called blend wall is really more of a “blend curtain”—the wall could be overcome if just 20 percent of the 15 million flex fuel vehicle drivers already on the road used E85. However, Perrin notes, E85—and by extension, even E15—have been unattractive options because ethanol has been “overpriced relative to its energy content” in recent years. Ethanol is roughly 65 percent as efficient as gasoline—so a flex-fuel vehicle (FFV) running on E85 typically gets 15-25% fewer miles per gallon compared to E10 (EPA, DOE). With high ethanol prices, the switch is uneconomical.

Crago and Khanna (2014) compare second-best taxes on fuels. Assuming no other distortionary taxes are in place, a Pigouvian tax would equal the marginal external damage (MED) from economic activity, in this case, GHG emissions from driving. They note, however, that "in the presence of labor taxes and other market distortions, a Pigouvian first-best is unattainable. [. . .] The second best optimal carbon tax is higher than the MED for carbon emissions," (p. 99), and that biofuel subsidies "erode welfare gains from carbon taxation" by increasing biofuel demand.

Other researchers have compared a biofuel subsidy to carbon cap and trade (CAT), finding CAT preferable. Holland et al. (2011) examine the distributional impacts of the RFS and the Waxman-Markey carbon CAT bill that failed in the House of Representatives in 2009. They find that RFS and CAT are policy substitutes, and "the greater a district's gain from the RFS, the more money the district's House Member received from organizations opposing Waxman-Markey," (p. 2). Further, they find that although the national economic benefits from CAT outweighed those from RFS, the RFS benefits were more concentrated per capita in ethanol-producing counties, giving House members in those districts greater incentive to vote against Waxman-Markey than other members had to vote for it.

A separate literature has dealt with the impact of increased gas mileage standards (CAFE) on the fuel supply and driving behavior. Karplus et al. (2013) explore the effects of fuel economy standards (FES) alone and in combination with CAT policies proposed in the 2009 Waxman-Markey bill. They show that a "FES policy is at least six to fourteen times as costly to the economy as a gasoline tax that achieves the same cumulative reduction" (p. 331). Further, "The cost and availability of vehicle efficiency technology, alternative fuel vehicles, and advanced low carbon fuels relative to other economy-wide GHG emissions abatement opportunities will determine whether a fuel economy standard binds when combined with a cap-and-trade policy, and the magnitude of its incremental economic cost" (p. 332).

Lee and Wagner (2012) explore the so-called rebound effect from increased fuel efficiency. When drivers need to fuel up less often, the income effect of spending less on fuel may induce them to drive more—"Buy a more fuel efficient car, visit Grandma more often." They note that studies in various parts of the world have found heterogeneous rebound effects, but that rebound effects typically decrease as real income increases. Built into CAFE standards, based on the literature, is an assumed 10 percent rebound effect.

Until now, the renewable fuel standard and gas mileage standards (CAFE) have mostly been examined separately or compared to carbon cap and trade policies. Analyzing how the RFS and CAFE interact is important because unlike cap and trade, these two policies exist in the U.S. already, and they affect each other in ways that were unanticipated when each was created.

CHAPTER 2: COMPARATIVE STATICS ANALYSIS

The present research uses a comparative statics model to examine the interactions between RFS and CAFE, first in 2013, then in 2025, when updated CAFE standards have been fully implemented and average gas mileage for model year 2025 is 54.5 mpg.

2.1 Theoretical Model:

This analysis examines the markets for ethanol, gasoline, and corn and treats CAFE as a technological shock that induces a decrease in demand for fuels, to compare the states of each market in 2013 and 2025. Ethanol is made from corn, and gasoline, which are used in fixed proportions, assumed at 90 percent gasoline to 10 percent ethanol in U.S. motor fuel. Each of the 3 markets consists of a supply equation and a demand equation, yielding six equations in total in the simple case. Perrin (2011) explains that these equations determine the six endogenous variables G (quantity of gasoline), Pg (price of gasoline), E (quantity of ethanol), Pe (price of ethanol), C (quantity of corn), and Pc (price of corn).

“The general approach of comparative statics is to take the total differential of each equation, then solve the system for the changes in endogenous variables (prices and quantities) caused by the exogenous ‘shock’ variable(s)” (Perrin). This approach allows one to calculate changes in prices and quantities, as well as changes in producer and consumer welfare due to exogenous shocks in the markets for the three goods. .

“The log-linear version of comparative statics replaces absolute changes such as dG with relative changes dlnG=dG/G, and replaces slopes such as fc with elasticities such as η=dlnG/dlnPg, yielding the solution for the effect of the shock on the equilibrium system" (Perrin). Converting the supply and demand equations to logs allows one to determine percentage changes in each variable from one time period to the next.

Initially, the consumer expenditure function is used with arguments of utility level (U), price of ethanol (P_e), price of gasoline (P_g), price of other consumer goods (P_{oc}), and CAFE, an exogenous shifter that reflects technological updates (improved fuel efficiency) that alter demand for gasoline and ethanol.

$$Ex = f(U, P_e, P_g, P_{oc}, CAFE) \tag{1}$$

Demands for ethanol and gasoline are obtained using Shepard's lemma from their respective price derivatives. The log linear total differentials are expressed below each supply and demand equation.

Ethanol demand:

$$\partial Ex/\partial P_e = E^d \left(U, P_e, P_g, P_{oc}, CAFE\right) \tag{2}$$

$$dlnE^d = \eta_{ee} dlnP_e + \ \eta_{eg} dlnP_g + \eta_{eo} dlnP_{oc} + dlnCAFE \tag{3}$$

where etas are Hicksian demand elasticities.

Gasoline demand:

$$\partial Ex/\partial P_g = G \left(U, P_e, P_g, P_{oc}, CAFE\right) \tag{4}$$

The log differential is

$$dlnG^d = \eta_{ge} dlnP_e + \eta_{gg} dlnP_g + n_{go} dlnP_{oc} + dlnCAFE \tag{5}$$

where etas are Hicksian demand elasticities.

Gasoline supply is assumed to be an exogenous function of the price of oil.

$$G = f(P_g) \tag{6}$$

$$dlnG = \sigma_{gg} dlnPg \tag{7}$$

where sigma is the supply elasticity.

The ethanol industry is described with a cost function including arguments quantity of ethanol produced (E), price of corn (P_c), price of other ethanol inputs (P_{oc}), and capital (K).

$$Cost = f(E, P_c, P_{oc}, K) \tag{8}$$

By Shepard's lemma the ethanol inverse supply is:

$$\partial Cost/\partial E = P_e(E, P_c, P_{oc}, K) \tag{9}$$

The total differential in log linear form is:

$$dlnP_e = \sigma_{ee} dlnE + \sigma_{ec} dlnP_c + \sigma_{eo} dlnP_{oc} + \sigma_{ek} dlnK \tag{10}$$

where the sigmas are marginal cost elasticities.

The Hicksian corn demand (for use in ethanol) is obtained by differentiating the ethanol industry cost function with respect to its price:

$$\partial C/\partial P_c = C^{\,d}(E, P_c, P_{oc}, K) \tag{11}$$

and its log differential is

$$dlnC^d = \eta_{ec}dlnE + \eta_{cc}dlnP_c + \eta_{oc}dlnP_{oc} + \eta_{ck}dlnK \tag{12}$$

where the etas are Hicksian derived demand elasticities.

Corn supply to the ethanol industry is assumed to be an exogenous function of its own price.

$$C^s = f(Pc) \tag{13}$$

with log differential

$$dlnC = \sigma_{cc}dlnPc \tag{14}$$

where sigma is a supply elasticity.

Rearranging the above equations so that the dependent variables are on the left-hand side and the shock variables are on the right-hand side yields the following system of six equations with six unknowns (where η represents price elasticities of demand and σ represents price elasticities of supply).

$$dlnE^d = \eta_{ee}dlnP_e + \eta_{eg}dlnP_g + \eta_{eo}dlnP_{oc} + dlnCAFE \tag{15}$$

$$dlnG^d = \eta_{ge}dlnP_e + \eta_{gg}dlnP_g + n_{go}dlnP_{oc} + dlnCAFE \tag{16}$$

$$dlnG = \sigma_{gg}dlnPg \tag{17}$$

$$dlnP_e = \sigma_{ee}dlnE + \sigma_{ec}dlnP_c + \sigma_{eo}dlnP_{oc} + \sigma_{ek}dlnK \tag{18}$$

$$dlnC^d = \eta_{ec}dlnE + \eta_{cc}dlnP_c + \eta_{oc}dlnP_{oc} + \eta_{ck}dlnK \tag{19}$$

$$dlnC = \sigma_{cc}dlnPc \tag{20}$$

Assuming no changes in the price of other crops or in the quantity of capital, $dlnP_{oc}$ and $dlnK$ are set to 0. $dlnCAFE$ represents the exogenous shift in demand due to the increased efficiency of vehicles after CAFE standards are introduced. In addition, ethanol is produced from corn in fixed proportions, so the change in the derived demand of corn is equal to the change in the quantity of ethanol produced and does not respond to any other variables.

The below matrix represents elasticities relating the supplies and demands for the three commodities to one another. The left-hand side sets up the market equilibria while the right side introduces the shock of CAFE.

$$\begin{bmatrix} 1 & 0 & -\eta_{eg} & -\eta_{ee} & 0 & 0 \\ -\sigma_{ec} & 1 & 0 & 0 & -\sigma_{ec}^{-1} & 0 \\ 0 & 0 & -\sigma_{gg}^{-1} & -\sigma_{gg}^{-1} & 0 & 0 \\ 0 & -\eta_{ge} & -\eta_{gg} & 1 & 0 & 0 \\ -\eta_{ec}^{-1} & 0 & 0 & 0 & -\eta_{ec}^{-1} & 1 \\ 0 & 0 & 0 & 0 & -\sigma_{cc} & -\sigma_{cc} \end{bmatrix} \begin{bmatrix} dlnEd \\ dlnGd \\ dlnG \\ dlnPe \\ dlnCd \\ dlnC \end{bmatrix} = \begin{bmatrix} dlnCAFE \\ dlnCAFE \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{21}$$

The RFS is a mandate that induces production of ethanol above the equilibrium quantity in that market. To model RFS the system of equations is modified to represent this policy. The mandate implied by RFS is represented as a change in the quantity supplied of ethanol by the following equation:

$$dlnE = dlnRFS \tag{22}$$

where $dlnRFS$ represents the increase in quantity supplied of ethanol due to the mandate.

The RFS implies a wedge in the ethanol market with marginal cost above the price of ethanol that demanders are willing to pay. This loss is passed to motor fuel consumers as higher prices. Consumers of gasoline pay a price high enough to cover the loss induced in the ethanol market by the RFS regulation. Another equation is necessary to represent the relationship between the loss in the ethanol market induced by the mandate and the compensating revenue in the gasoline market required for motor fuel suppliers to survive in the industry. This is:

$$[dlnP_e^d \; - \; dlnP_e^s \;] \; = \; (\frac{P_g \, G}{P_e \, E}) \, (dlnP_g s - dlnP_g d)$$

(23)

where the expenditures are average of initial and final equilibrium expenditures on gasoline and ethanol, and the superscripts *d* refers to demand and *s* to supply. The system of equations used to capture the impact on the markets for ethanol, gasoline and corn under the RFS mandate is:

$$dlnE = dlnRFS$$

(24)

$$dlnE^d = \eta_{ee} dlnP_e + \; \eta_{eg} dlnP_g$$

(25)

$$dlnG^d = \eta_{ge} dlnP_e + \eta_{gg} dlnP_g$$

(26)

$$dlnG = \sigma_{gg} dlnPg$$

(27)

$$dlnP_e = \sigma_{ee} dlnE + \; \sigma_{ec} dlnP_c$$

(28)

$$dlnC^d = \eta_{ec} dlnE + \eta_{cc} dlnP_c$$

(29)

$$dlnC = \sigma_{cc} dlnPc$$

(30)

$$dlnP_e^d - dlnP_e^s = dlnP_g^s - dlnP_g^d$$

(31)

$$dlnP_e^d - dlnP_e^s = (\frac{P_g G}{P_e\, E})\ (dlnP_g^s - dlnP_g^d)$$

(32)

When both policies—CAFE standards and the RFS mandate—are introduced simultaneously, the system of equations that allows analysis of positive and normative impacts in the markets for ethanol, gasoline, and corn is:

$$dlnE = dlnRFS$$

(33)

$$dlnE^d = \eta_{ee} dlnP_e + \eta_{eg} dlnP_g + dlnCAFE$$

(34)

$$dlnG^d = \eta_{ge} dlnP_e + \eta_{gg} dlnP_g + dlnCAFE$$

(35)

$$dlnG = \sigma_{gg} dlnPg$$

(36)

$$dlnP_e = \sigma_{ee} dlnE + \sigma_{ec} dlnP_c$$

(37)

$$dlnC^d = \eta_{ec} dlnE + \eta_{cc} dlnP_c$$

(38)

$$dlnC = \sigma_{cc} dlnPc$$

(39)

$$dlnP_e^d - dlnP_e^s = dlnP_g^s - dlnP_g^d$$

(40)

$$dlnP_e^d - dlnP_e^s = (\frac{P_g\, G}{P_e\, E})\ (dlnP_g^s - dlnP_g^d)$$

(41)

2.2 Implementation

CAFE

Wanner (2012) uses DOE projections on the makeup of the U.S. vehicle fleet to estimate the impact of CAFE in future years. Assuming that 1/13th of the U.S. vehicle fleet turns over annually based on average lifetime mileage, Wanner identifies expected fuel efficiency for different types of vehicles and their respective shares of the fleet. By aggregating the vehicle data, Wanner projects annual U.S. gasoline and ethanol consumption.

Comparing expected consumption in 2013 and 2025, the technology shift from CAFE is represented as a 50 percent decline in both gasoline and ethanol demand. This amount is likely to decrease further after 2025 as more vehicles turn over and a larger portion of the total fleet is subject to 2025-level fuel mileage standards. The displacement model matrix used to simulate this situation uses elasticity estimates from Cui et al. (2011) and Hossiso (2012) and can be seen below:

	dlnE	dlnG	dlnPe	dlnPg	dlnC	dlnPc		
ethanol demand	1	0	3	-2.3	0	0		-50%
gasoline demand	0	1	-0.26	0.96	0	0		-50%
ethanol supply	0	0	1	0	0	-0.5	=	0%
gasoline supply	0	-1	0	1.61	0	0		0%
corn demand	1	0	0	0	-1	0		0%
corn supply	0	0	0	0	-1	2.75		0%

Table 2.1

RFS

Since this analysis is restricted to corn ethanol—considered a "conventional biofuel" under the RFS—the RFS as currently implemented mandates only an 8.7% increase in the quantity used beyond current levels. That shock is represented in the matrix below, in this case imagining that CAFE does not exist in 2025. Further volumetric increases of ethanol called for in the RFS are in the advanced, biodiesel, and cellulosic categories (Schnepf, 2012) and are outside the purview of this study.

Additionally, this study ignores the blend wall to examine how the RFS would impact ethanol markets if infrastructure barriers did not exist, both alone and in combination with CAFE. The elasticities below are from the same source: Cui et al. (2011) and Hossiso (2012). The share coefficient of 8.36 in the last equation is the average ratio of expenditures in gasoline and ethanol in the initial and final equilibria.

	dlnE	dlnG	dlnPes	dlnPed	dlnPgd	dlnPgs	dlnC	dlnPc		
ethanol mandate	1	0	0	0	0	0	0	0		8.7%
gasoline demand	0	1	0	-0.26	0.96	0	0	0		0%
ethanol demand	1	0	0	3	-2.3	0	0	0		0%
ethanol supply	0	0	1	0	0	0	0	-0.5		0%
gasoline supply	0	1	0	0	0	-1.61	0	0	=	0%
corn demand	-1	0	0	0	0	0	1	0		0%
corn supply	0	0	0	0	0	0	1	-2.75		0%
Motor fuel distributors' equilibrium condition	0	0	-1.00	1.00	8.36	-8.36	0	0		0%

Table 2.2

RFS and CAFE

The matrices in table 2.3 represent the joint implementation of two shocks—the decrease in demand for gasoline and ethanol induced by increased efficiency from CAFE standards and the increase in the quantity of ethanol supplied as a result of the RFS mandate.

	dlnE	dlnG	dlnPes	dlnPed	dlnPgd	dlnPgs	dlnC	dlnPc		
ethanol mandate	1	0	0	0	0	0	0	0		8.7%
gasoline demand	0	1	0	-0.26	0.96	0	0	0		-50%
ethanol demand	1	0	0	3	-2.3	0	0	0		-50%
ethanol supply	0	0	1	0	0	0	0	-0.5	=	0%
gasoline supply	0	1	0	0	0	-1.61	0	0		0%
corn demand	-1	0	0	0	0	0	1	0		0%
corn supply	0	0	0	0	0	0	1	-2.75		0%
Motor fuel distributors' equilibrium condition	0	0	-1.00	1.00	8.36	-8.36	0	0		0%

Table 2.3

2.3 Results and Implications:

Market Effects of Alternative Scenarios				
	Initial (2013)	2025		
		CAFE alone	**RFS alone**	**CAFE + RFS**
Ethanol supply price	$2.50	$2.21	$2.54	$2.54
Ethanol demand price	$2.50	$2.21	$2.42	$1.62
Ethanol quantity	13.8 B gal	5.1 B gal	15.0 B gal	15.0 B gal
Gasoline demand price	$3.50	$2.78	$3.50	$2.79
Gasoline supply price	$3.50	$2.78	$3.48	$2.64
Gasoline quantity	120 B gal	80 B gal	119 B gal	72.4 B gal
Corn price	$4.00	$3.08	$4.12	$4.13
Corn quantity	4.6 B bu	1.7 B bu	5.1 B bu	5.1 B bu
Ratio of ethanol to gasoline quantities	10 %	6 %	11 %	17%

Table 2.4

Table 2.4 shows supply and demand prices and compares quantities demanded for the three commodities under the three policy scenarios. Where supply and demand prices for a commodity are the same, the scenario includes just one market price. For cases where supply and demand prices differ, buyers and sellers face different prices.

Removing the RFS entirely, as in the CAFE alone scenario, would cause a substantial drop in the quantity of ethanol demanded—and would also significantly decrease corn demand. In addition, the ratio of ethanol to gasoline quantities in the CAFE alone scenario decreases From 10 percent (E10) in 2013 to 6 percent (E6)—so the country uses comparatively less ethanol relative to gasoline in 2025 than it does today and nowhere near the amount required by the RFS mandate. Meanwhile, CAFE technology, alone or in combination with RFS, can be expected to decrease gasoline consumption at least 25% implying a slight change in motor fuel mix from E10 to E11.

Under the CAFE + RFS scenario—the status quo in the U.S.—demand prices for ethanol drop precipitously. The RFS requires the ethanol industry to continue producing large quantities at subsidized prices even though demand for motor fuel declines 50 percent, so the result is a substantial change in the mix of ethanol to gasoline in the nation's motor fuel, from an E10 to an E17 blend and a major gap between the supply price and the demand price. Welfare analysis will show who benefits and who loses from the above effects.

Welfare Effects of Alternative Scenarios in 2025

	CAFE alone		**RFS alone**		**CAFE + RFS**	
	(Dollars)	(% of initial expenditure)	(Dollars)	(% of initial expenditure)	(Dollars)	(% of initial expenditure)
Δ Ethanol CS	$23,198,978,792.04	67.29%	-$1,925,595,797.31	-5.59%	$10,145,905,843.25	29.43%
Δ Gasoline CS	$197,375,145,974.19	46.99%	$3,063,714,843.11	0.73%	$217,748,989,250.19	51.84%
Δ Gasoline PS	-$43,477,720,924.90	-10.35%	$2,020,624,054.72	0.48%	-$82,900,828,884.05	-19.74%
Δ Corn PS	-$230,845,310.14	-1.24%	$613,449,733.63	3.30%	$613,449,733.63	3.30%
Δ Motor fuel CS	$220,574,124,766.24	48.53%	$1,138,119,045.80	0.25%	$227,894,895,093.44	50.14%

A Hicksian-type measure is used here as a metric for consumer welfare. It shows the change in consumer expenditures due to technological change given utility levels—such as new technology from CAFE standards that increases vehicle efficiency. This is modeled as a change in consumer expenditures given prices and utility levels (equation 1 in this section) due to this technological change.

Using this measure of consumer surplus (CS) and traditional measures of producer surplus (PS) as welfare measures, the above table shows welfare changes between 2013 and 2025 under each of the 3 scenarios. Changes are shown both in dollars and as a percentage of the economy-wide initial expenditure on the commodity being examined. (For reference, 2013 expenditures are $420 billion/year for gasoline, $34.4 billion/year for ethanol, and $18.6 billion/year for corn. Motor fuel expenditures are the sum of gasoline and ethanol expenditures.)

Consumers do not buy ethanol directly; they buy it as a component of motor fuel. So the change in motor fuel consumer surplus captures the benefits of a policy to both ethanol and gasoline consumers.

Ethanol is made from fixed ratios of corn to other ingredients. Because corn demand in this study is perfectly inelastic, benefits to ethanol producers eventually accrue to corn producers—just as benefits to land-renting farmers ultimately accrue to landowners, because land is a fixed resource. So changes in ethanol PS are not shown because they are captured in the corn market.

Gasoline producer surplus is distributed among all participants up the gasoline supply chain—so it captures benefits not only to gas stations but also to refiners, blenders, and distributors. Thus, all of the welfare changes in the model are displayed above.

Motor fuel consumers benefit greatly under CAFE in 2025, gaining back nearly 50 percent of their 2013 expenditures. More expensive new cars due to technological improvements from CAFE are not included in this analysis, but these results show that the significant increase in consumer surplus would allow for their purchase. Gasoline producers are 10 percent worse off under CAFE alone than in 2013, while corn producers are affected only modestly. If the RFS existed in a vacuum in 2025, motor fuel consumers and gasoline producers would be relatively unaffected, while corn producers would be 3% better off.

If both policies are implemented simultaneously in 2025, the effects on gasoline producers in particular are dramatic. Gasoline producers are nearly 20 percent worse off than in 2013—twice as badly hurt as they are under CAFE alone. This is because the wedge between the supply price and the demand price for ethanol widens considerably. In the long run, the gap is passed on to consumers as higher gasoline prices—but if both policies are implemented simultaneously, gasoline producers will suffer a larger loss in welfare.

Corn producers are equally well off under the RFS with or without CAFE, while motor fuel consumers benefit slightly from both policies together, edging their gains to just above 50 percent from 48 percent under CAFE alone.

CHAPTER 3: CONCLUSION

This study examines the market only for corn ethanol and ignores cellulosic ethanol. Fully implementing the cellulosic provisions of the RFS would significantly impact these results, but thus far, cellulosic technology has not been commercialized nearly as fast as anticipated under the EISA in 2007.

This analysis demonstrates that CAFE standards offer significant benefits to consumers by 2025 and beyond, while the effects of the RFS between now and 2025 are more modest. The increased cost of buying new, more efficient cars under CAFE is not included in the analysis; consumers would use some of the increased consumer surplus to purchase them.

The present research also ignores the blend wall to show that if there were no infrastructure barriers to increasing the ethanol blend, staying on the current path of implementing CAFE and RFS simultaneously—with no changes—would result in a substantial increase in motor fuel blend to E17. If the quantities mandated are fixed by the RFS, the declining demand for ethanol and gasoline in the motor fuel supply will result in lower prices—hurting gasoline producers. This study shows that the current blend wall is incompatible with current RFS and CAFE mandates. Further, when RFS and CAFE are combined in 2025, gasoline producers lose 20 percent of their 2013 receipts.

With slight changes in market realities or in policy, the RFS and CAFE standards could better coexist. Policymakers could encourage the purchase of flex-fuel vehicles that can use up to 85% ethanol (E85)—or simply educate owners of existing FFVs that their cars can handle higher ethanol blends. States could also be incented to offer more E15 fueling stations.

However, policymakers cannot expect those measures to succeed until ethanol prices better align with its energy content. Lower corn prices would help bring ethanol's price back in line with its mileage value—and at least in the short run, that change seems likely. USDA projects 2015-16 corn prices at $3.30 per bushel, 27% below 2013-14 prices (Westcott 2014). Lower corn prices would make higher ethanol blends more economical alternatives to gasoline.

In summary, motor fuel consumers benefit greatly from CAFE standards, while welfare changes from the RFS alone between now and 2025 will be relatively modest. CAFE and RFS, implemented together, have a minimal impact on ethanol producers in 2025. This analysis suggests that the fears of many in the corn and ethanol industries are unfounded—that EPA slightly downshifting RFS targets this year would not cause the ethanol market to collapse, but could help avoid an untenable gap between the supply price and the demand price of ethanol several years in the future.

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